PERKINS+WILL

Research Journal

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2013 / VOL 05.02

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Acknowledgements: **With much APPRECIATION** *to everyone who contributed in many ways to the research work and articles published in this journal.*

We would like to extend our **VERY SPECIAL THANKS** *to: Hannah Palmer.*

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+7 2013 / VOL 05.02

TABLE OF CONTENTS

JOURNAL OVERVIEW

The Perkins+Will Research Journal documents research relating to architectural and design practice. Architectural design requires immense amounts of information for inspiration, creation and construction of buildings. Considerations for sustainability, innovation and high-performance designs lead the way of our practice where research is an integral part of the process. The themes included in this journal illustrate types of projects and inquiries undertaken at Perkins+Will and capture research questions, methodologies and results of these inquiries.

The Perkins+Will Research Journal is a peer-reviewed research journal dedicated to documenting and presenting practice-related research associated with buildings and their environments. Original research articles, case studies and guidelines have been incorporated into this publication. The unique aspect of this journal is that it conveys practice-oriented research aimed at supporting our teams.

This is the tenth issue of the Perkins+Will Research Journal. We welcome contributions for future issues.

RESEARCH AT PERKINS+WILL

Research is systematic investigation into existing knowledge in order to discover or revise facts or add to knowledge about a certain topic. In architectural design, we take an existing condition and improve upon it with our design solutions. During the design process we constantly gather and evaluate information from different sources and apply it in novel ways to solve our design problems, thus creating new information and knowledge.

An important part of the research process is documentation and communication. We are sharing combined efforts and findings of Perkins+Will researchers and project teams within this journal.

Perkins+Will engages in the following areas of research:

- Market-sector related research
- Sustainable design
- Strategies for operational efficiency
- Advanced building technology and performance
- Design process benchmarking
- Carbon and energy analysis
- Organizational behavior

EDITORIAL

This issue of Perkins+Will Research Journal includes five articles focusing on different research topics.

"Using a Lean Perspective to Explore the Impact of the Built Environment and Operations on the Retention of Patients in an Outpatient Care Delivery Setting" discusses how lean design principles have been used to improve operations of an outpatient clinic for treatment of HIV and AIDS. Observational studies, value stream mapping and utilization analyses were used to assess patient flow and services within the clinic, and findings were used to identify how the built environment can be modified to improve patient care and operations of this facility.

"Holding the Sun at Bay: A Study in the Development of the Double-Skin Façade for the Case Western Reserve University Tinkham Veale University Center" presents research that was conducted during the design of this academic building, focusing on innovative facade technologies. During the early stages of the design, the team investigated several different options for the west facade. The findings indicated that the double skin facade was the best solution, and series of subsequent studies were performed to determine its functionality.

"Achieving Energy Independence: Methods and Case Studies in Healthcare for Use of Waste to Energy Technologies" reviews different waste-to-energy technologies, and how healthcare facilities can employ these technologies. The article is a literature review, environmental aspects, financing concepts, as well as case studies. The conclusion indicates that there is a potential to implement these technologies in healthcare facilities, and that there are environmental and economic benefits for their integration.

"Interdisciplinary Training in Medical Simulation: A Comparison of Team Training Courses in Simulation Programs in Hospital Healthcare Systems, Medical Schools, and Nursing Schools" discusses medical simulation training and identifies how this learning style can impact the design of simulation centers. The article reviews existing research regarding team-based simulations in medical and educational facilities. Also, several case studies are reviewed that illustrate how the built environment should be designed to support this type of training. Conclusions indicate that simulation centers are evolving at a rapid pace, and that flexibility of use is a key aspect for architectural design.

"A Zero Net Energy Building Pilot Study: Low Energy Strategies for Weygand Residence Hall at Bridgewater State University" presents research that was conducted during the design of this residence hall. The article reviews the design process and analyses that were conducted to investigate different design strategies, building systems, renewable energy sources, as well as operational and maintenance factors. Conclusions suggest that high occupancy and significant energy demand in residence halls require consideration of new ideas about energy consumption, as well as changes in operation to drastically improve building performance.

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01.
USING A LEAN PERSPECTIVE TO EXPLORE THE IMPACT OF THE BUILT ENVIRONMENT AND OPERATIONS ON THE RETENTION OF PATIENTS IN AN OUTPATIENT CARE DELIVERY SETTING: *Improving Efficiency as a Strategy to Increase Capacity*

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ABSTRACT
The Grady Health System Ponce de Leon Center is a comprehensive outpatient clinic for treatment of HIV and AIDS. The Center sought to improve operations and the built environment to retain and attract more patients in ongoing care at the Center. The project employed a Lean perspective to identify opportunities and improve efficiency within the clinic. Lean tools such as observational studies, spaghetti diagrams, value stream maps, and utilization analyses were used to assess the current patient flow and service within the clinic. Findings were utilized to develop conceptual diagrams reflecting a modified built environment to facilitate greater efficiency in providing care.

KEYWORDS: patient-centered medical home, clinic redesign, efficiency, primary care, HIV/AIDS

1.0 INTRODUCTION

1.1 Client Background
The Ponce de Leon Center is one of the largest, most comprehensive facilities dedicated to the treatment of advanced Human Immunodeficiency Virus (HIV) and Acquired Immunodeficiency Syndrome (AIDS) in the United States. Founded in 1986, the Ponce de Leon Center provides health care and support services to approximately 5,000 eligible men, women, adolescents/young adults, and children living with HIV/AIDS.

The Ponce de Leon Center integrates primary internal medicine and infectious disease subspecialty care in three clinics. Staffed by doctors, nurse practitioners, physician assistants, nurses, and more than 100 staff, the care teams seamlessly provide medical, support, and community services.

To qualify for care in the Ponce de Leon Center, adult referrals must have a previous AIDS diagnosis or a Nadir CD4 count below 200 (a clinical indicator of the severity of the disease). Pediatric and adolescent patients have no referral restrictions.

Services Offered at the Ponce de Leon Center include:
- Laboratory
- Pharmacy
- X-Ray
- Translation services
- Social services
- Financial counseling
- Behavioral health
- Non-Emergency clinic
- Specialty clinics
- Oral health

The Ponce de Leon Center operates from the former Presbyterian Headquarters in Atlanta, Georgia. Atlanta is considered to be one of the epicenters of the HIV/AIDS epidemic in the United States. The biggest problem associated with care of these patients is getting them into the care system and retaining them. Only approximately 66 percent of the people living with HIV or AIDS are linked to care and only 37 percent are retained in care and treatment. Many do not seek treatment or drop out of treatment due to challenges such as homelessness, mental illness, substance abuse, and/or stigma associated with the disease. Because of the stigma, many patients fear other people seeing them while they receive care, as that would reveal their diagnosis. Large waiting areas that lack privacy, coupled with long waits, increase the chances of patients being seen while at the Center.

1.2 Research Interest

The primary research interest was to explore the impact of the physical environment on care process efficiency and patient satisfaction. Specifically, current operations were analyzed, including identification of opportunities to gain efficiencies in providing care to patients. Then, a few redesign options were considered for enhancing the patient flow and experience. Overall, the purpose was to enhance the care process to retain patients in the care delivery system.

2.0 PROJECT DETAILS

2.1 Project Goals

The project had three main goals:
Goal 1: Increase the percentage of people with HIV/AIDS who receive care at the clinic. The two main barriers to people with these diagnoses receiving care are stigma and the possibility of seeing people they know while receiving care. The project goal was to provide-patient privacy and efficiency in receiving care at the Center.

Goal 2: Improve patient flow to ensure patients do not feel herded or confined in the building.

Goal 3: Maximize the use of the existing space in the building, and explore the potential to use the existing shell space on the fifth and sixth floors.

While not a stated goal, the cost of the project needed to be kept to a minimum. Being a subsidiary of a large public, academic hospital, there is limited funding for improvements or changes to the building. Therefore, when identifying potential changes, high priority was given to solutions with minimal cost.

2.2 Project Objectives

Based on the three goals, the project team identified four objectives to drive the work in alignment with the stated goals:

1. Increase privacy to reduce the likelihood of patients seeing other patients.
2. Improve flow to reduce the feeling of being confined or herded through the care process.
3. Improve efficiency to decrease the total time a patient spends in clinic (throughput time).
4. Increase capacity to optimize the use of resources (space and people) to achieve maximum results.

All solutions were also checked against an organizational strategy to become a patient-centered medical home.

2.3 Project Approach

The project approach could be summarized in three steps:

1. Understand the current flow of patients and staff.
2. Identify opportunities to enhance efficiency and efficacy of clinic operations.
3. Define potential changes to improve flow and reduce turnaround (throughput) times.

These three steps were completed using Lean approach and tools. Lean is a method that is based on continuous improvement, and focuses on increasing value delivered to the customer while minimizing waste. In this project, the customer was defined as the patient. Value to the patient includes tasks that the patient would be willing to pay for and tasks that advance the care process. Waste includes tasks that the patient would not be willing to pay for, tasks that are not done correctly the first time, or tasks that do not advance the patient's care process.

In Lean, there are eight types of waste that can be found in processes[1]. The eight wastes include defects, overproduction, waiting, non-utilized talent, transportation, inventory, motion, and excess processing[2]:

- Defects include errors, and examples in healthcare include medication errors and surgical errors[3].
- Redundant work is covered by the waste of overproduction. In healthcare, an example of overproduction is completion of many forms with the same information[3].
- Waiting is a waste that is difficult to be avoided in healthcare. After all, in healthcare, rooms are designated for the function of waiting.
- Non-utilized talent includes lack of engagement of employees[1]. Examples of non-utilized talent in healthcare include unmonitored suggestion boxes and assigning tasks that do not require licensure to licensed employees.
- The waste of transportation includes movement of the patient or supplies to complete a task[3]. An example of transportation in healthcare is staff leaving their assigned work area to go to central supply to pick up supplies[3].
- Inventory includes any materials that are available, yet not needed to do the work at hand[3]. Examples of inventory include overstocked medications and supplies at the point of use[3].

- The waste of motion is movement or double-handling that is not necessary. The waste of motion is often described as "hunting and gathering." An example is a nurse looking for supplies needed to do a task[3].
- The eighth waste of excess processing, includes activities that do not align with the patient's needs[1]. An example of excess processing in healthcare is the collection of data that is never used[1].

In this project, the team analyzed processes, identifying the eight wastes, and considering processes to eliminate the wastes.

2.4 Project Deliverables

The project entailed conducting several observational studies. An observational study, in Lean speak, refers to "going to the gemba." Gemba is a Japanese word meaning "the real place."[4] Going to the gemba means going to the location where the work is done. In this project, the team toured the existing environment, spoke with employees and patients, and gathered their feedback and ideas for improvement. During an observational study, current workflow and processes were observed. Further, the observational study allowed the team to understand the myriad of roles of workers in the environment, what the scope of each role was, and how the various roles interacted. From a built environment perspective, the workspace was visualized, and issues identified.

After the observational study, floor plans were updated to reflect the current use of each space on five floors of the building (patio level through fourth floor level). This exercise was imperative to understand the space allocation of each function, as well as the relationship between each function. Figure 1 displays the updated floor plan for the patio level. Many areas were being utilized for purposes different than what was labeled on the floor plan drawings. For example, the area labeled as "break room" was actually being used as office space. Another example was the room labeled "trash/soiled linen," which was being used as a maintenance shop.

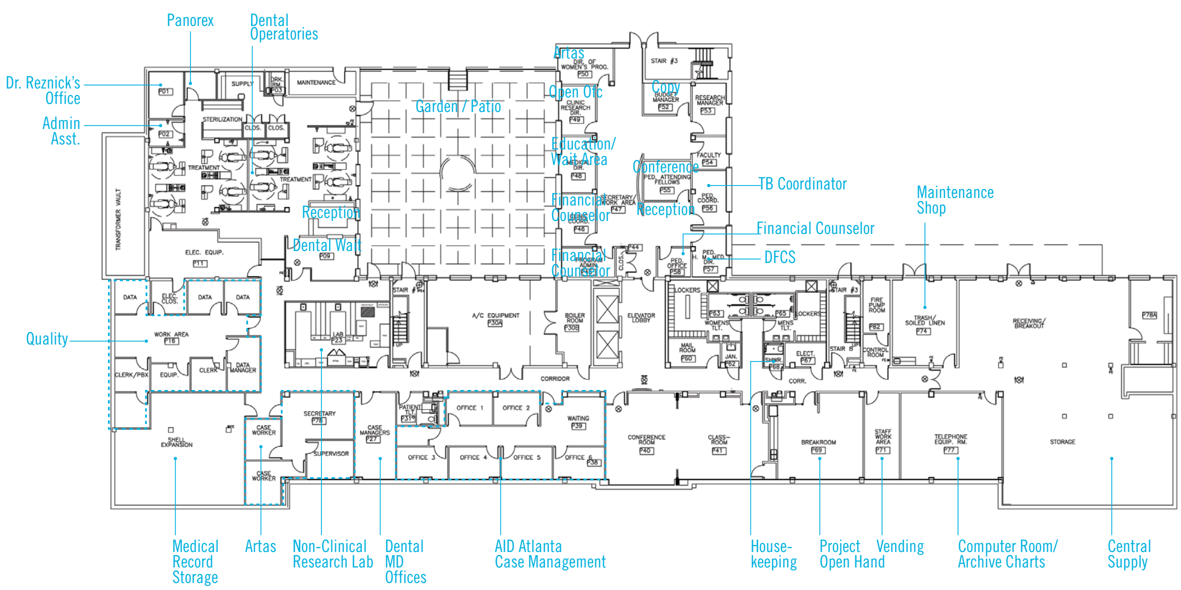

Figure 1: Updated floor plan for the patio level of the Ponce de Leon Center.

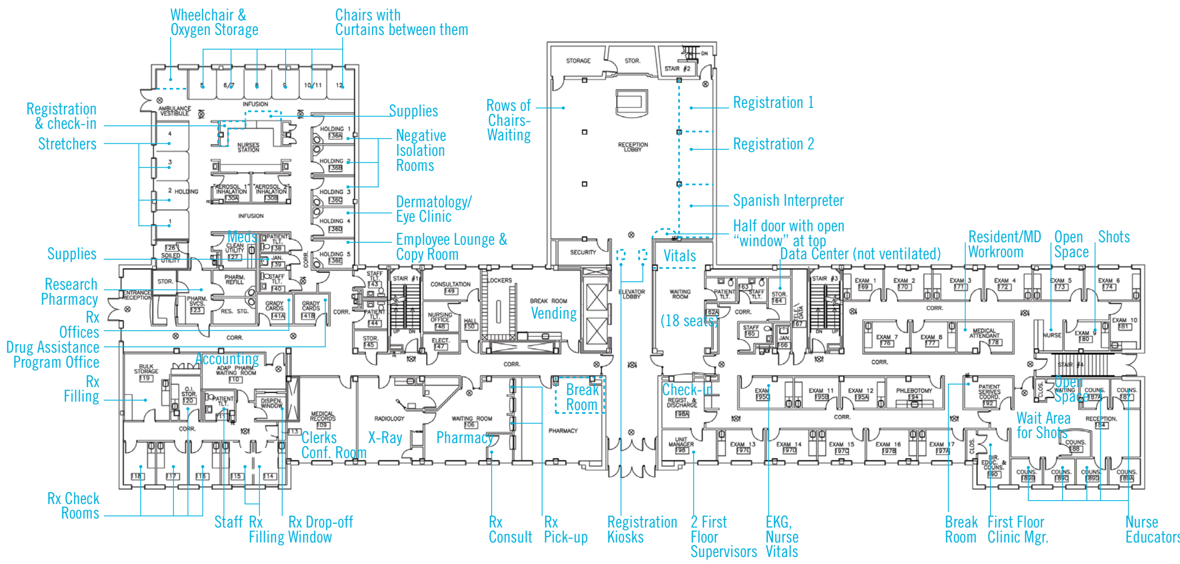

Figure 2: Updated floor plan for the first level of the Ponce de Leon Center.

Figure 2 displays the first level floor plan with updated room labels. Some of the discrepancies on this floor included the omission of the registration and interpreter cubicles located in the reception/lobby area. This area was previously used as a chapel, and it has high ceilings and acoustics to facilitate sound travel. This acoustical property is undesirable for functions requiring privacy, such as registration.

The next step was to develop spaghetti diagrams to outline the flow of patients in each clinical service area. According to the American Society for Quality, "A spaghetti diagram is a visual representation using a continuous flow line tracing the path of an an item or activity through a process. The continuous flow line enables process teams to identify redudancies in the work flow and opportunities to expedite process flow."[5] In the example of the Ponce de Leon Center, spaghetti diagrams were utilized to identify opportunities to streamline patient flow through each clinical area. Figure 3 and Figure 4 demonstrate examples of spaghetti diagrams of patient flow in two of the clinics at the Ponce de Leon Center.

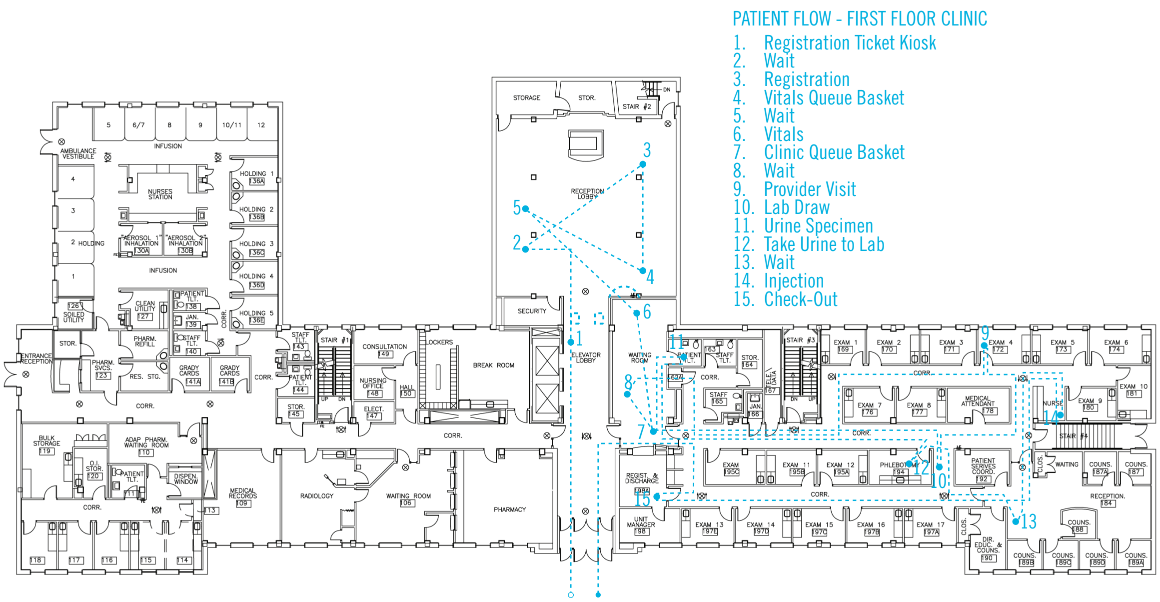

Figure 3: Spaghetti diagram of patient flow in the First Floor Clinic.

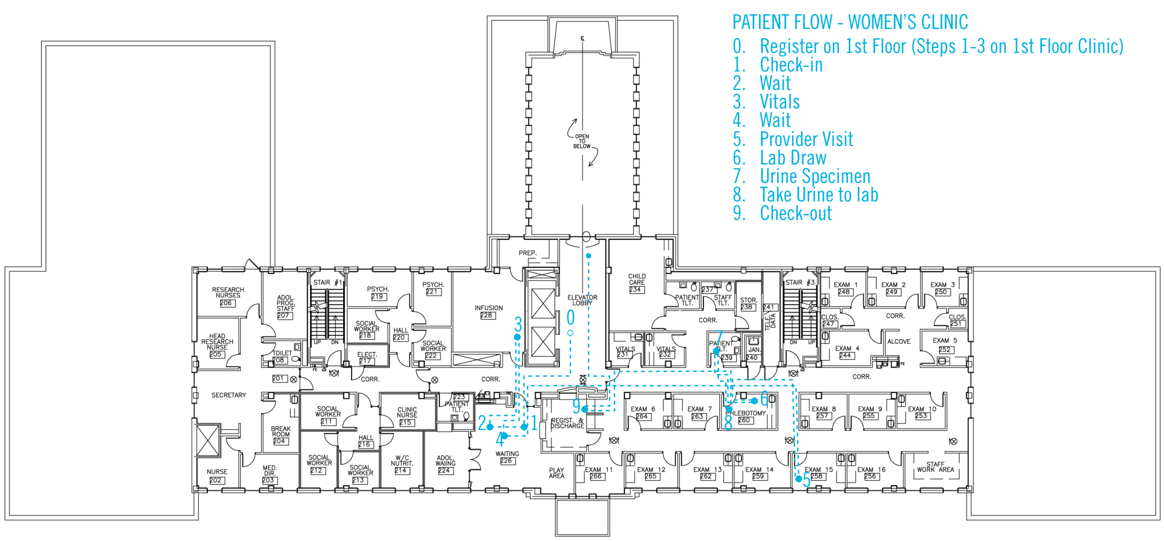

Figure 4: Spaghetti diagram of patient flow in the Women's Clinic.

After conducting the observational study, updating the floor plans based on current utilization, and development of spaghetti diagrams, a report of opportunities with potential actions was developed. The report focused on opportunities to achieve greater efficiency with patient flow and throughput. The report identified dozens of opportunities, of assorted varieties. For example, some of the opportunities included redundant pharmacies, lack of access to food for staff, inability for wheelchairs and walkers to navigate through waiting area, and exam rooms being used for multiple functions such as offices and patient exam space.

The project chose to focus on two main opportunities that would drive the most improvement in value to the patient.

One opportunity was the way that the exam rooms were utilized. Exam rooms served as a place for patient consultation, patient exam, and as clinical provider offices. This varied utilization of the rooms resulted in an area of focus for several reasons:

- Exam rooms were not utilized fully. Many exam rooms were idle while the waiting area was full. Patients in exam rooms have more privacy than in large waiting spaces where they can be seen by other patients. This visibility between patients was a main objective to be addressed by the project.
- All clinical providers are not working simultaneously. Therefore, the exam rooms that are used as provider offices could not be used when the provider was not present. This resulted in idle rooms.
- Flow of patients was hindered due to the artificial lack of exam rooms caused by the first two points.
- Further, provider's belongings could not be secured in the exam rooms. If the provider must leave a patient in the exam room alone, the provider's belongings are at risk.
- With no central work area for collaboration between providers, many providers felt isolated and lacked opportunities to collaborate.

To address the utilization of exam rooms, the team proposed utilization of exam rooms exclusively for patient consultation and exam. Additionally, a centralized staff work area would be provided for providers to complete documentation and store valuables.

The second opportunity of focus was the patient experience. Patient satisfaction surveys revealed a desire for patients to spend less time in the clinic, receive more communication throughout their clinic visit, and provide access to providers via telephone. In analyzing the process, it was found that the current average patient throughput time was 185 minutes, or just over three hours.

To address this opportunity, the team created a hybrid value stream map/swim lane diagram of the clinic visit. Value steam mapping is a tool to visualize information and material flow through processes[6]. The value stream map provides a way to identify value-added steps in processes, from the customer's perspective[6]. Aligning all stakeholders in an understanding of the current process and the vision for the future process is another benefit of the value stream map[6]. Swim lane diagrams provide a visual way to identify the responsible party for each process step. The hybrid of value stream mapping and swim lane diagramming was used to reap the benefits of both types of flow charting.

The current state value stream map/swim lane diagram created for the first floor clinic is illustrated in Figure 5. The map was created in a swim-lane format, with each lane indicating a role or responsible party for the step. Each step of the process is indicated by a shape, with the task, time, and location indicated in the shape. The various shapes represented the areas within the clinic, such as the lobby, phlebotomy, and injection. Each shape or task was then color-coded. Red shapes indicated tasks or steps that were non-value-added, meaning that the step did not add value to the process. Yellow shapes indicated tasks or steps that were non-value-added but necessary. These tasks do not add value to the process, but are required, for regulatory purposes, as an example. Green shapes indicated value-added tasks or steps. These shapes illustrate the core of the process.

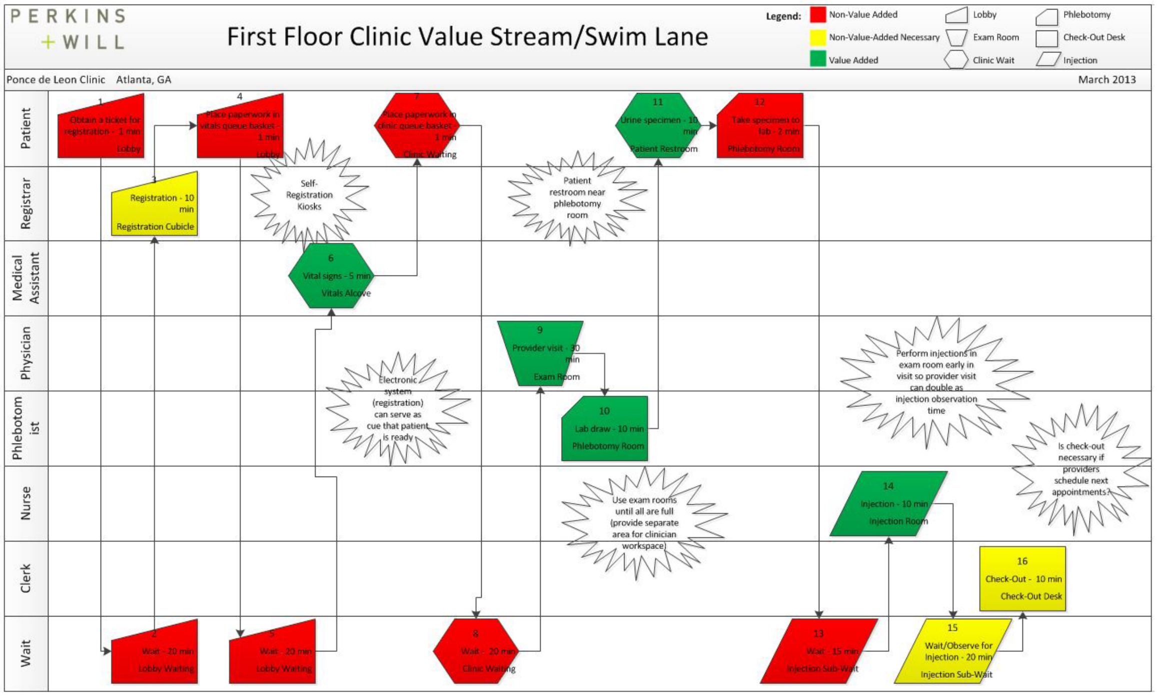

Figure 5: Current state hybrid value stream map/swim lane diagram for the Ponce de Leon Center's First Floor Clinic.

By analyzing the red and yellow shapes, waste in the process can be eliminated. As waste is eliminated, the total throughput time for patients in the clinic is reduced. One of the wastes identified on the value stream map and in the spaghetti diagram was the travel distance for patients. Patients repeatedly travel throughout the clinic and back again.

The team then analyzed the design of the built environment, to identify opportunities to modify the environment and operations to provide smoother flow. Conceptual diagrams were created to illustrate the future clinic structure.

Figure 6 illustrates the conceptual diagram of the patio level of the Ponce de Leon Center. Modified areas are highlighted in blue. The changes in this floor plan include the addition of a cafeteria, as well as four dental operatories, and the expansion of several support spaces.

In Figure 7, modifications to the first floor of the Ponce de Leon Center are outlined. The modifications on this floor are expected to have the biggest impact on the patient experience. Two pharmacies are reduced to one pharmacy, with a U-shaped flow (another lean principle). An odd entry to the infusion center is corrected with a clean, obvious entry. The waiting area for the first floor clinic is moved from the old Presbyterian chapel, with high ceilings that echo and conflict with patient privacy goals. Instead, this area is moved to an area just inside the front entry, with dividers, low ceilings, and furnishings to promote patient privacy. Registration, also formerly located in the chapel, is also moved and placed just inside the front door. This helps with privacy as well as serves the function of greeting the patient. The issues of idle exam rooms and lack of opportunities to collaborate are addressed by moving provider work areas out of exam rooms and into the center of the clinic.

In Figure 8, the fifth floor conceptual diagram displays an option for finishing this currently shelled floor. The building boasts beautiful views of the city of Atlanta from the fifth and sixth floors, which are currently used for storage. Finishing the fifth floor as an area for patient and staff education makes great use of this area. The large classroom provides a space for staff meetings, an area that is currently not available to the employees of the clinic. Further, the education area and offices could be more accessible to patients. Additional space is also needed to support the significant research projects that take place at the facility by Emory University researchers.

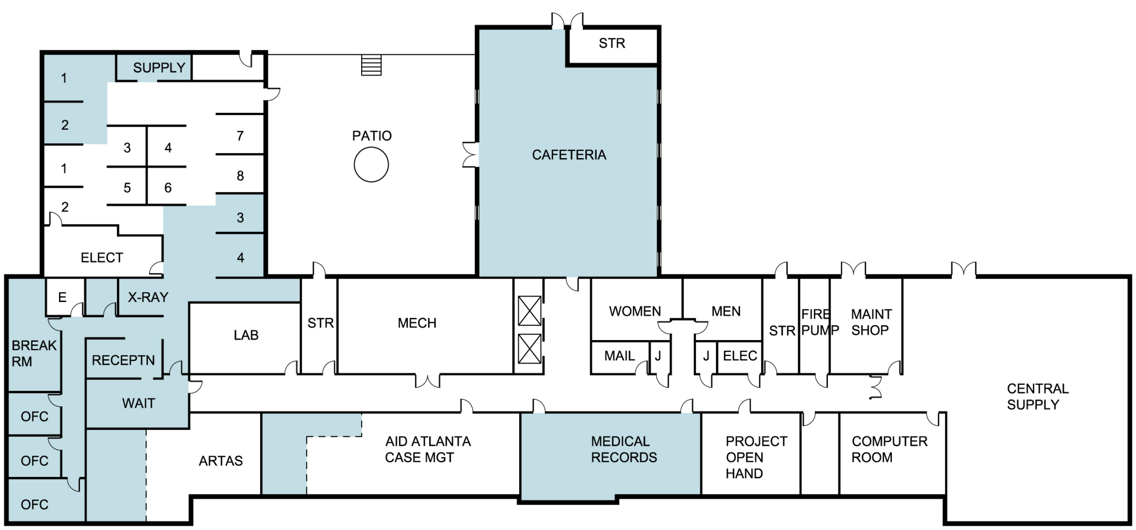

Figure 6: Conceptual diagram of the patio level of the Ponce de Leon Center.

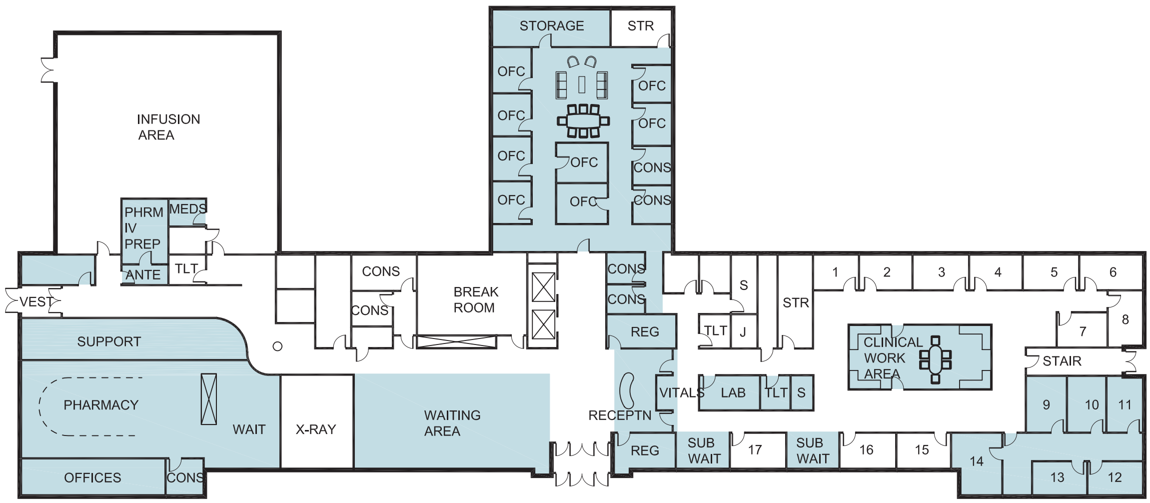

Figure 7: Conceptual diagram of the first floor of the Ponce de Leon Center.

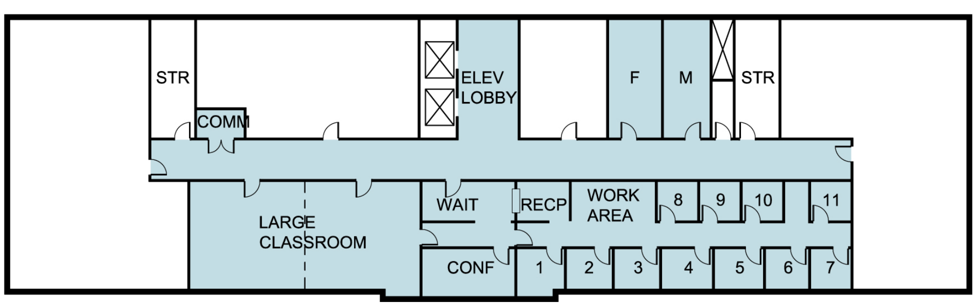

Figure 8: Conceptual diagram of the fifth floor of the Ponce de Leon Center.

The final aspect of the project was to ensure that the conceptual diagrams outline enough exam rooms and provider work areas to support the patient load and clinicians working simultaneously. First, provider schedules were analyzed to assess workload. Room utilization rates were reviewed based on the assumption that providers are fully booked. Room utilization was calculated as the number of rooms with a provider scheduled plus one room for the doctor-of-the-day and walk-in patients. Then, a review of the number of providers present at any given time was completed, to ensure the conceptual diagrams had enough workstations to accommodate all providers. Providers present was calculated as the number of providers scheduled plus one team nurse plus one registered nurse plus one medical assistant. Table 1 shows a snapshot of the analysis for the first floor clinic.

The analysis demonstrated that there are enough workstations and exam rooms in the conceptual diagrams to support clinic operations.

Table 1: Room utilization and provider workstation analysis for first floor clinic.

Shift	Rooms Utilized	Rooms Available	Room Utilization Rate	Providers Present (not including residents)	Rooms in Conceptual Drawing	Workstations in Conceptual Drawing
Monday am	14	16	88%	17	16	19
Monday pm	12	16	75%	15	16	19
Tuesday am	13	16	81%	16	16	19
Tuesday pm	11	16	69%	14	16	19
Wednesday am	15	16	94%	18	16	19
Wednesday pm	11	16	69%	14	16	19
Thursday am	15	16	94%	18	16	19
Thursday pm	12	16	75%	15	16	19
Friday am	11	16	69%	14	16	19
Friday pm	11	16	69%	14	16	19

3.0 CONCLUSION

The team learned the value of Lean tools in the assessment of healthcare operations and the built environment. Specifically, use of gemba, or visiting the place where work happens, assisted with understanding the use of the space, as well as current operations. Spaghetti diagrams were utilized as a visual way to understand the flow of patients through the clinical environment. Both gemba and spaghetti diagrams facilitated the identification of opportunities that would help the Ponce de Leon Center in achieving its goals. Digging into the details further with value stream maps helped to understand the value delivered to the patient, from the patient's perspective. This refined the team's focus further, exploring turn-around-times and privacy issues in more detail. Finally, conceptual diagrams were created to resolve many of the issues that resulted from the current built environment. Using Lean principles in analyzing the operations and built environment proved to be an intuitive way to approach design. Lean tools provided a common language for communicating between planners, designers, and client representatives. Further, Lean tools helped to ensure that the most important stake-holder in healthcare, the patient, remained as the focal point of all improvement efforts. Next steps in the project include prioritization of the solutions, identification of funding for implementation, and then implementation of the solutions. Several of the proposed changes have already been implemented, resulting in a reduction in the total turn-around-time of patients in the clinics.

Acknowledgements

The authors would like to acknowledge and extend their gratitude to the following individuals: Lisa Roland (Administrator, Ponce de Leon Clinic), George Smith (Architectural Project Manager, Grady Health System), Dr. Wendy Armstrong (Medical Director, Ponce de Leon Clinic), Dr. Vincent Marconi (Assistant Medical Director, Ponce de Leon Clinic), Marie Todd-Turner (Clinical Manager, Ponce de Leon Clinic), Jason Nevoit (Charge Nurse at the Main Clinic, Ponce de Leon Clinic), Deborah Hammett-Harris (Charge Nurse for Women's/Pediatrics, Ponce de Leon Clinic), Samuel Williams (Vice President of Facilities, Grady Health System), Dr. Karen Duncan (Senior Vice President of Ambulatory/Community Medicine, Grady Health System).

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02.
HOLDING THE SUN AT BAY:
A Study in the Development of the Double-skin Façade for the Case Western Reserve University Tinkham Veale University Center

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ABSTRACT
Early in the development of the design for the Tinkham Veale University Center, the team determined that the west-facing glass wall of the Commons space presented challenges to the usability and conditioning of that space. The team proceeded to explore several options to control solar heat and light gain, including electrochromic glass, internal sun shading, fixed external sun shades and a double-skin wall with operable shading. Once the team determined that the double-skin wall was the best solution, they proceeded to perform a series of studies to validate that choice and determine overall functionality.

The configuration of the glazing for each plane of the double-skin was studied to optimize performance. Multiple types and configurations of integral shading were studied for cost-effectiveness, durability and function. The team engaged in extensive study and exploration of the airflow through the double-skin cavity to guide the configuration of ventilation components. This work helped the team determine that passive ventilation was not a workable option and ultimately guided the team's selection of ventilation fan locations, quantities and capacity as well as the locations and sizes of intake. Finally, the design team addressed issues of maintenance access and interface with the adjacent underground parking garage and completed the architectural detailing.

The final combination of design elements for the double-skin façade (monolithic glass exterior plane; insulated glass interior plane; mechanical ventilation; 3'-0" wide cavity; and sun-controlled operable roller shades) met all of the project's functional, aesthetic and energy goals and was deemed to be the best solution.

KEYWORDS: double-skin; curtain wall; solar control; computational fluid dynamics

1.0 INTRODUCTION
The 2005 Case Western Reserve University master plan identified the need for a strong physical and functional campus center to deemphasize the physical and psychological boundaries that exist between the historical Case Institute of Technology and Western Reserve University campuses. Openness, light and transparency emerged as primary design directions to achieve these goals and drove much of the design of the Tinkham Veale University Center. The new student center was envisioned to serve as the figurative heart of the unified campus and to be a beacon to students, staff and visitors. Thus, the site identified for the project occupies a prime open space at the center of the campus and is easily accessible from all corners of the University.

The central campus location, shown in Figure 1, proved to be challenging due to the proximity of numerous buildings, including a two-story below-grade parking

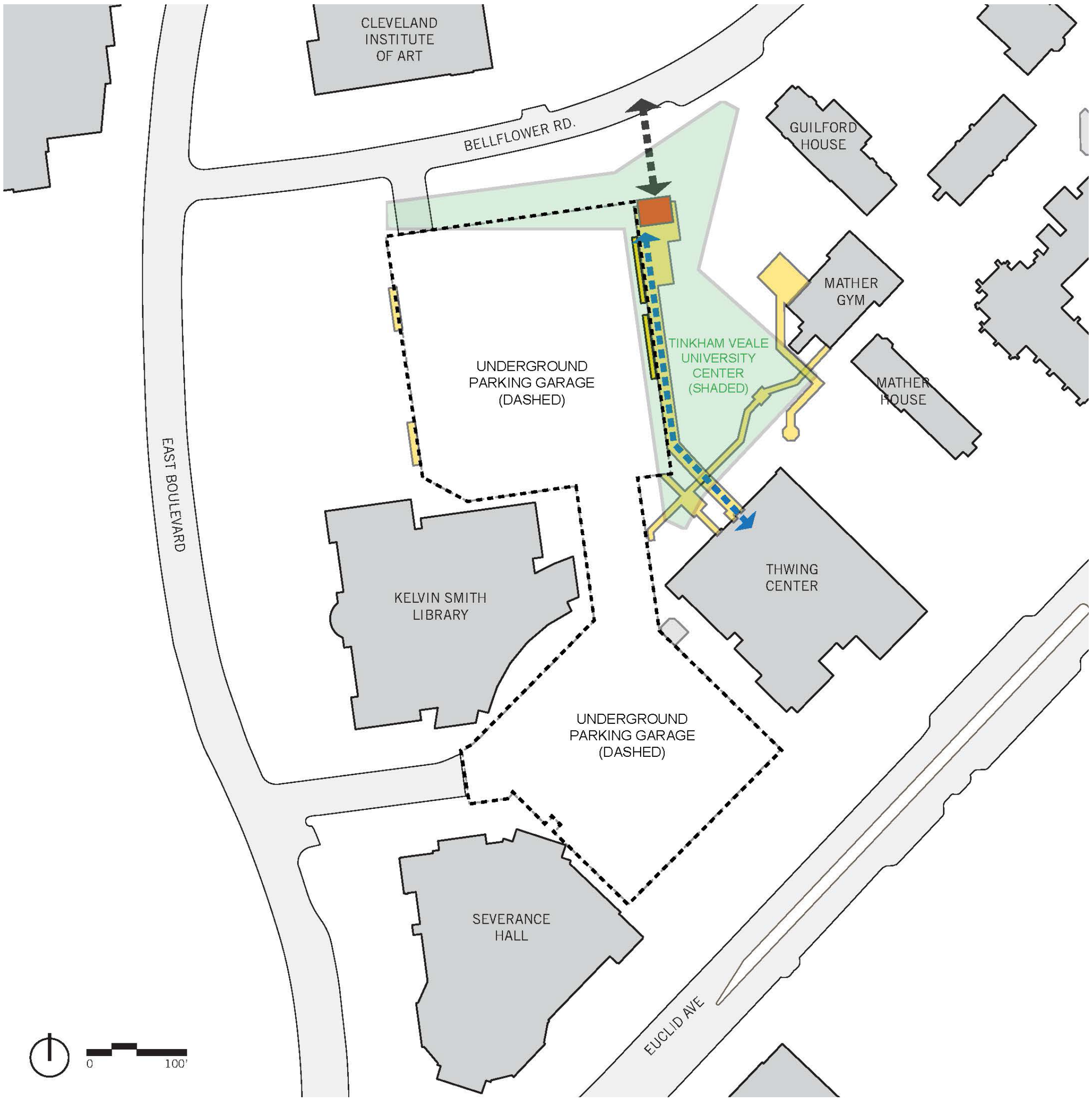


Figure 1: Site plan.

structure; a crossing network of infrastructure; and important pedestrian paths leaving limited space to build.

These challenges drove the building form, massing and layout that resulted in the placement of the large central Commons space along the west building orientation and overlooking the open field above the parking garage.

Case Western Reserve University's desire for transparency drove the decision to use an ultra-clear glass curtain wall for the entire west wall of the Commons space; sustainability, occupant comfort and functionality dictated that the design team then develop a means to control solar heat and light gain.

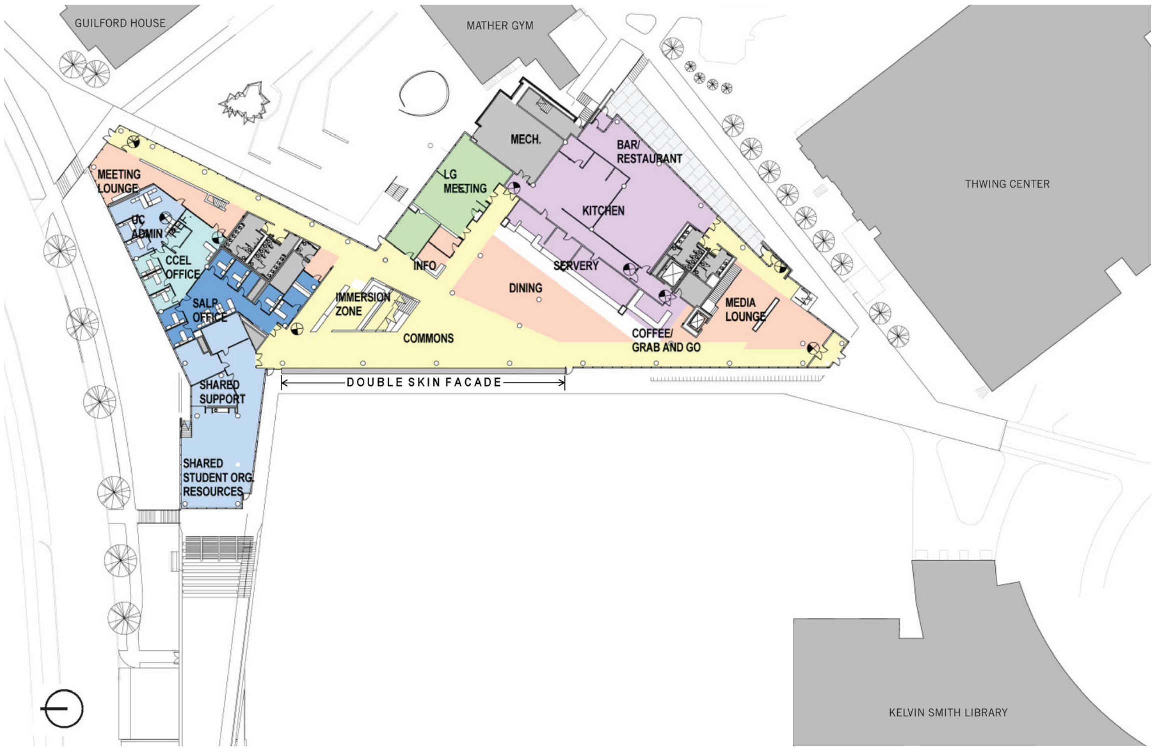


Figure 2: Level 1 plan.

1.1 Identifying the Issue

The Tinkham Veale University Center is intended to be open and occupied 24 hours a day, 7 days a week and the Commons space is anticipated to be a major hub of activity. The double-height space is not programmed for a specific function, but is rather designed for gathering, studying, lounging and all manner of activity, both sedentary and active; some occupants will simply pass through, some will stay for hours. The Commons' western exposure means that there will be numerous hours of the day, throughout the year, when the space is bathed in direct sunlight. While this serves the goal of using daylighting in lieu of electric lighting and of creating an energizing space, it also has the potential to create significant heat gain and glare and adversely affect occupant comfort. The design team's concern about these issues was supported by a study by Hendricksen, et al that identified high lighting contrast in open plan areas and glare as major negative issues associated with large, glazed facades[1]. Thus two primary design challenges arose: controlling solar heat gain; and controlling solar light gain, glare and high lighting contrast; while maintaining transparency and views (both outside looking in, and inside looking out).

Occupants in a space such as this can be expected to want to take in the expansive views of the surroundings, but they can also be expected to work on computers, read, converse and linger for hours. These activities benefit from sunlight, but too much of it becomes detrimental and diminishes functionality. Infiltration of direct sunlight can create glare on computer screens, discomfort from sun in occupant's eyes and strong visual contrasts created by bold shadows. The building design needed to deal with these issues or risk significant occupant dissatisfaction.

As sustainability was a major project goal, the heating and cooling system for the space was designed to be as energy efficient as possible. The resulting system provides both heating and cooling through radiation from the floor. All of the air supplied to this space is used for ventilation only and does not appreciably contribute to heating or cooling the space. While this is an extremely efficient system, both in terms of energy use and equipment space required, it does have its limitations. In this case, the limitation is in the capacity of the system to cool the space under very high heat loading conditions.

Unobstructed views to the west, and ultra-clear glass allow significantly more heat gain than the radiant cooling system can counteract and required some form of solar control.

1.2 Literature Review

While this paper is primarily a case study on the selection and design of the double-skin façade for the Case Western Reserve University Tinkham Veale University Center, the authors believed that it was important to understand the state of current research and writings related to double-skin façades. Several recent articles were reviewed and are summarized below.

Ole J. Hendriksen, Henrik Sorensen, Anders Svensson and Pontus Aaqvist – *Double-Skin Façades-Fashion or a Step Towards Sustainable Buildings* – This undated paper explores the general concepts of configuration and typology of double-skin façades[1]. The authors discuss some of the environmental factors that should be considered when designing double-skin façades including: daylight, glare, view and transparency; heat loss; venting and natural ventilation; solar shading; noise; and fire. They conclude that double-skin façades can have beneficial effects in each of these areas if designed for the building's specific climate and environmental conditions.

Terri Meyer Boake – *The Tectonics of the Double Skin: Green Building or Just more Hi-Tech Hi-Jinx?* – This undated paper endeavors to explain the basic concepts behind double-skin façades and how these affect the façade's performance[2]. One of the more important conclusions of this work is the classification of double-skin façades into four major categories: buffer system; extract air system; twin face system; and hybrid system. Major elements and aspects of double-skin façades are briefly explained: division of the cavity; cleaning the cavity; ventilation strategies; and solar heat gain. The author discusses environmental claims of designers of double-skin façades and economic considerations related to the design and construction of double-skin façades. The author concludes that double-skin façades can mitigate the high energy use endemic to highly glazed buildings, particularly high rises.

Matthias Hasse and Alex Amato – *Simulation of Double-Skin Facades for Hot and Humid Climate* – This paper focuses on the efficacy of double-skin façades in the Hong Kong area in reducing peak cooling loads during the summer[3]. Simulations of the double-skin façade take several factors into account, including the building HVAC control strategy and the urban context. The authors conclude that a double-skin façade can reduce peak cooling load on the interior of a building by up to 30 percent over a baseline single glazed curtain wall.

Brett Pollard and Mary Beatty – *Double-Skin Façades More is Less?* – This paper was produced for the 3rd International Solar Energy Society Conference-Asia Pacific Region (2008)[4]. It begins as an inquiry into the proclaimed benefits of double-skin façades. The authors then summarize recent trends in the design and categorization of double-skin façades, explain some proposed design considerations and briefly discuss the application of double-skin façades in hot climates. The paper includes brief descriptions of several buildings in North America and Australia that include double-skin façades.

Harris Poirazis – *Single and Double Skin Glazed Office Buildings, Analysis of Energy Use and Indoor Climate* – This extensive report was published under the auspices of Lund University Department of Architecture and Built Environment[7]. The main focus of the report is to explain how highly glazed facades affect the energy use and occupant comfort in office buildings. The author also makes the case for needed improvement in building energy simulation tools to assist in designing energy-efficient buildings. The paper includes a description of a baseline single skin building model and proceeds to explore numerous options for single- and double-skin façades and their energy performance. The author's conclusion is that double-skin façades can be very effective in reducing energy use in highly glazed buildings.

Mauricio Torres, Pere Alavedra, Amado Guzman, Eva Cuerva, Carla Planas, Raquel Clemente and Vanessa Escalona – *Double-Skin Façades-Cavity and Exterior Openings Dimensions for Saving Energy on Mediterranean Climate* – This paper explores three primary aspects of double-skin façades: cavity depth; external opening area; and single-story vs. multi-story cavity configurations, with the goal of determining the best performance in a Mediterranean climate[8]. The study ultimately concludes that the depth of the cavity and the single/multi-story configuration were less important to the efficacy of reducing cooling loads than the influence of the exterior opening area. The authors note, however, that the simulation tools used were not particularly sensitive and the models were somewhat specific to the simplified double-skin façade configurations and the particular climatic conditions that were used, limiting transferability of the results.

2.0 EXPLORATION OF POTENTIAL SOLUTIONS

After the team identified the need to control both solar heat and light gain, we began to explore potential systems, both active and passive, that could be employed.

Exterior Solar Shading

One of the first systems we explored was fixed, exterior solar shades. The western exposure and the potential for 24/7 use of the space suggested that vertical shading elements would be most effective. Our initial idea for this system had airfoil-shaped aluminum fins generously spaced along the entire west building façade as seen in Figure 3.

We performed solar studies on the preferred layout and determined that this spacing would not provide effective shading. In order to adequately shade the interior spaces and meet the occupant comfort and conditioning needs, the shade spacing would had to have been reduced significantly. The dense spacing and the required depth of the shade elements would have compromised the desired transparency of this façade and could have created maintenance issues, so this approach was abandoned.

Interior Solar Shading

The team investigated the use of interior solar shading, specifically fabric roller shades, to control the solar heat and light gain. Physically, this solution presented a challenge because the ceiling in the Commons area follows the sloping roof line and created difficulties in mounting shades, which must be installed horizontally. Beyond that, there were functional issues that made this solution unworkable. While internal shades would provide sufficient protection from light gain, they would actually compound the solar heat gain. By locating the shades on the building interior, they would act as a heat sink; collecting and redistributing the solar heat inside the building, overloading the mechanical system on the hottest and sunniest days. Since this approach was unable to satisfy all of the functional requirements, it was also abandoned.

Electrochromic Glass

Electrochromic glass is a glazing product that has a coating that changes from transparent to tinted state when electric current is applied, integrating the shad-

Figure 3: Southwest aerial view – vertical solar shades.

ing into the glazing units. This solution offered much promise, as it satisfied the need to control heat and light gain; was variable and controllable based on weather conditions; and would not require separate shading devices. The efficacy of the product was investigated from both architectural and mechanical perspectives and it appeared to perform well in both areas. The difficulties in using this product that emerged were primarily aesthetic. First, the electrochromic coating that was on the market during the design phase was only available in blue. While the color palette of the building does rely heavily on the use of blue, as the official color of Case Western Reserve University, blue-tinted glass did not fit the design vision of the project. Further, and more importantly, the electrochromic coating had size limitations that were not compatible with the building design. The effective width of the electrochromic coating, the distance that an electric current could travel through the film to activate it, was 60 inches. As a result, any glazing panel that exceeded this width would need an additional electrical conductor located no more than 60 inches from one vertical edge. The building module is 6ft-3in, meaning that each glazing panel would require a conductor. These conductors are clear, so they are not readily visible when the electrochromic coating is not energized; however, they remain clear even when energized, so when the electrochromic coating is tinted for shading, the conductor is easily visible. These added vertical elements in the curtain wall would disrupt the carefully implemented building module in a way that seriously compromised the design. So, in the end, while electrochromic glass was an excellent functional choice, the aesthetic compromises it required were unacceptable.

Double-Skin Curtain Wall

The final option that was investigated was a double-skin curtain wall. By carefully designing the support structure to be as unobtrusive as possible and by selecting ultra-clear, low-iron glass, the wall achieved the desired transparency. The wall cavity provided an opportunity for solar shading that was outside the conditioned space and an ability to create a buffer between the indoor and outdoor temperatures. Having dismissed the other potential solutions, the design team began to investigate the configuration of the double-skin wall and validate its performance.

Supporting Energy Analysis

Energy modeling was conducted to provide answers to many of the concerns related to each of the potential façade choices. EnergyPlus modeling allowed the design team to understand the energy impact of each design and the potential number of hours of occupant discomfort. EnergyPlus was chosen for its high level of accuracy, its ability to simulate multiple façade schemes and the capability of including variables like electrochromic glazing controls and double skin façade ventilation effects. EnergyPlus allowed the design team to estimate the summer cooling savings associated with the shading effects of each façade as well as any winter heating savings. It should be noted that only the double skin façade demonstrated winter heating savings as it was the only façade type capable of providing a thermal buffer space to trap heat in the winter. Estimates of the change in peak thermal load for each option were also generated, allowing the design team to understand the mechanical system capacities needed to serve the Commons.

Figure 4 shows the modeled energy use in the Commons space for some of the strategies that were investigated. Electrochromic glazing and double-skin façades provide superior energy use reduction over fins, with the thermal buffering properties of a double-skin façade providing additional savings beyond electrochromic glass. Energy modeling estimated that the double-skin façade will yield a nearly 50 percent reduction in cooling energy and a 53 percent reduction in heating energy for the Commons space when compared to a conventional curtain wall with insulated glazing. While the electrochromic glazing offers greater cooling savings (74 percent) this is achieved with a small increase in heating energy as the electrochromic glass must tint in order to minimize glare, thereby cutting out beneficial solar heat gains during the colder months. The objective data generated by the energy modeling meshed well with the aesthetic goals and reinforced the decision to provide a double-skin façade.

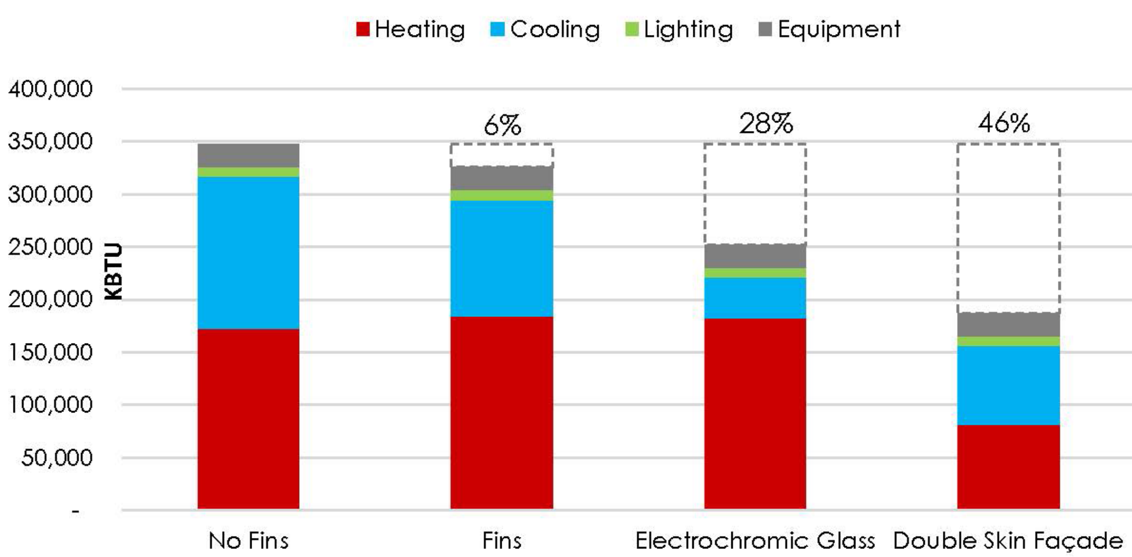


Figure 4: Energy use and savings in commons space for different façades.

2.1 Double-Skin Curtain Wall Development

General Operational Concept

As the double-skin façade provides an interface between the interior and exterior environment for a large, public space, special care was given to the understanding and design of the façade. Chief among the duties of the double-skin façade is to limit solar heat gain, particularly in the summer evening hours when the direct sunlight passing through the façade can lead to a spike in air conditioning loads and energy use. Operable shades provide much of the protection from solar infiltration, but heat gains to the occupant space are also minimized by flushing the cavity with outside air. Figures 5 and 6 illustrate the general operational concept.

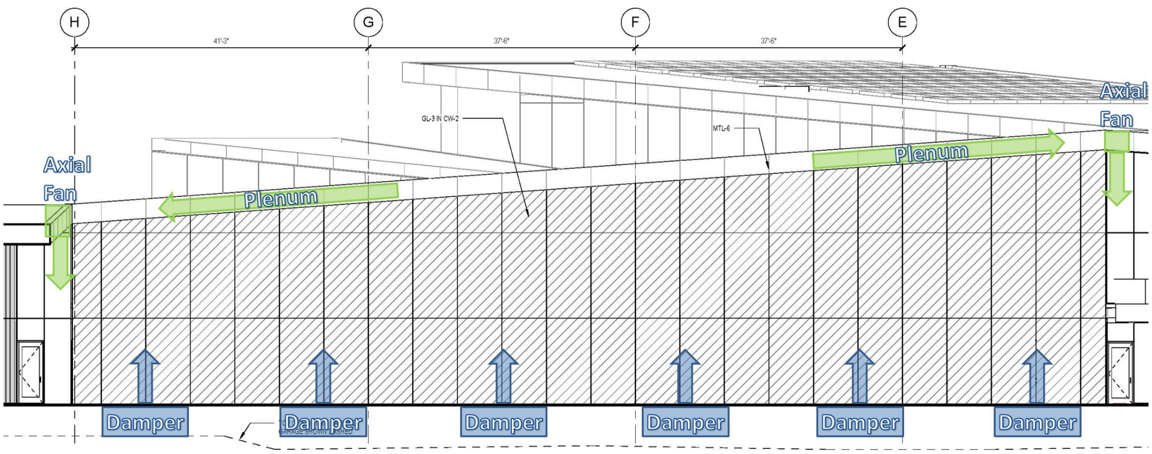


Figure 5: General operational concept-elevation.

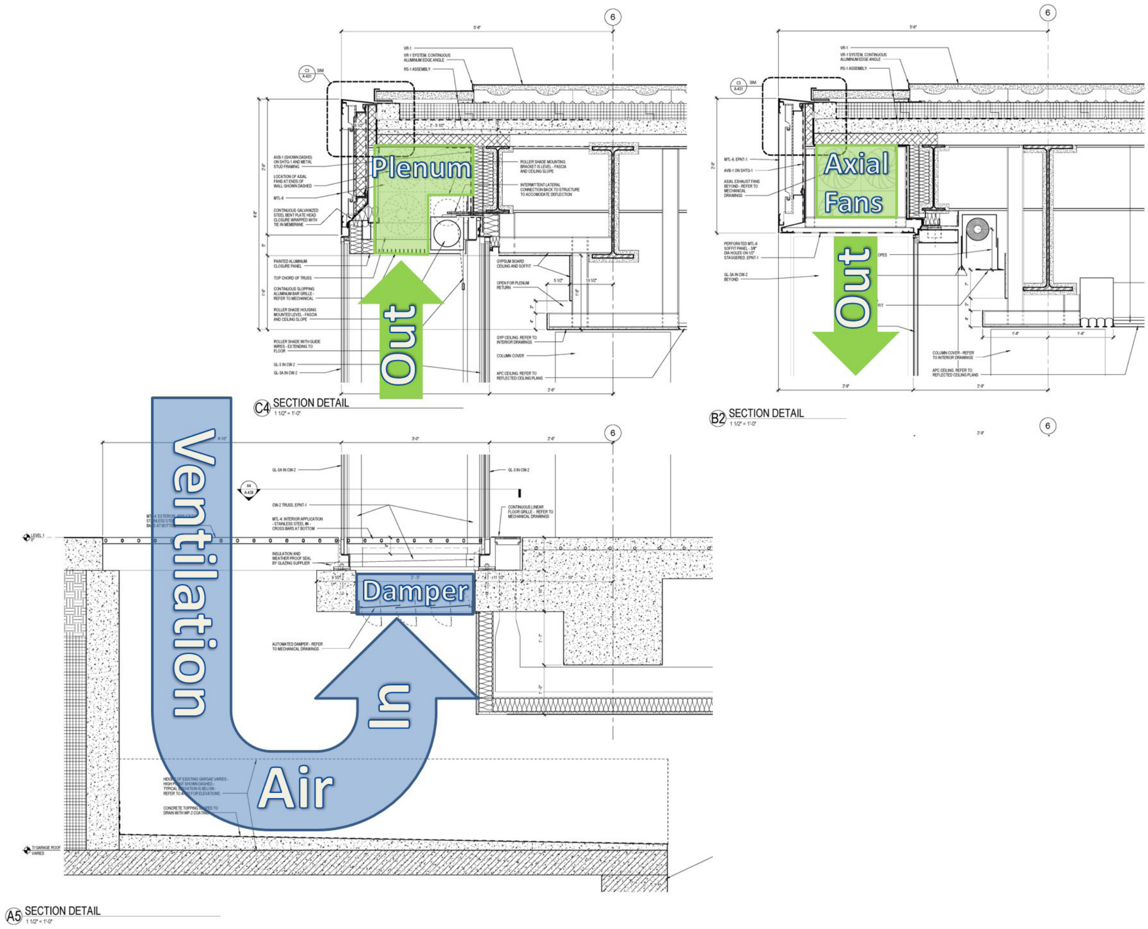


Figure 6: General operational concept-sections.

The general configuration of the double-skin façade used here can be categorized as a “buffer system” as identified by Boake[2]. Variations of this configurations have been used for over 100 years and have proven to be an effective means of controlling both visual discomfort (glare) and thermal gains/losses. In fact, Haase and Amato, and Pollard and Beatty suggest that this configuration is the most effective means of controlling external heat loads for buildings with active HVAC systems in cooling-intensive climates[3,4]. Given these established opinions on the efficacy of the configuration, the operational scheme was developed to optimize efficiency, respond to outside air conditions and control direct solar gains.

Summer/Warm Weather Operation

When the temperature at the top of the double-skin cavity reaches 95 degrees F, as measured by three equally-spaced sensors, all of the dampers at the bottom of the cavity open and fans begin pulling air through the space, preventing the buildup of excessively warm air within the cavity. When the cavity temperature drops below 95 degrees F, the dampers close and the fans stop. This sequence of operations prevents the cavity from becoming a heat source for the adjacent interior space and minimizes the energy used by the fans. When the roof-mounted radiometers detect that the sun has moved into the western sky, particularly in the evening hours when direct sunlight begins to create glare in the Commons, the roller shades within the cavity are lowered.

Winter/Cool Weather Operation:
When the temperature at the top of the double-skin cavity is below 95 degrees F, as measured by three equally-spaced sensors, the dampers at the bottom of the cavity remain shut and the fans do not operate. The resulting closed cavity is allowed to trap heat from the sun and serve as a thermal buffer between the cold exterior and warmer interior. The shades operate in the same manner as described above for the summer/ warm weather operation.

CFD Ventilation Studies
Opening and closing the double-skin façade cavity is a primary means of controlling heat gain through the façade. When the cavity begins to overheat, air must be flushed from the cavity, either through natural convection and buoyancy, or forced air movement with fans. Understanding the nature of the airflow needed to remove this trapped heat was a crucial part of developing the doubling skin façade design.

One of the unifying architectural elements of the building is an aluminum-clad band that is employed throughout the building envelope and is used to “wrap” areas of curtain wall and define volumes. In the area of the double-skin façade, the band occurs at the roof line and caps the curtain wall below. The nature of this architectural relationship meant that a traditional, passive buoyancy driven approach to ventilating the cavity would not work. It was not possible for the design team to place openings at the top of the façade (interrupting the expanse of curtain wall) or above the roof (breaking the continuity of the aluminum “wrapper”), the traditional approaches to cavity ventilation, so a large number of possible design alternatives were investigated in order to determine what other designs would provide a level of performance similar to a buoyancy-driven design.

Thirteen design alternatives were investigated using computational fluid dynamics (CFD) analysis. CFD is an analysis approach that uses numerical methods to solve the equations governing fluid dynamics and heat transfer in order to simulate the effects of different conditions and parameters. Simulation results provide the temperature, velocity, and direction of flow for the fluid being simulated given geometric and thermal information provided by the analyst, and this information allowed the design team to select the alternative capable of providing the best heat removal from the cavity.

The design alternatives analyzed using CFD techniques include:
1. Natural Ventilation w/ 2 sided exhaust
2. Fan Assisted w/ 1 sided exhaust at 6,000 cfm
3. Fan Assisted w/ 2 sided exhaust at 6,000 cfm
4. Fan Assisted w/ 2 sided exhaust at 9,000 cfm
5. Natural Ventilation w/ lower and upper face openings
6. Fan Assisted w/ 2 sided exhaust at 6,000 cfm (3+2 Fans)
7. Fan Assisted w/ 2 sided exhaust at 6,000 cfm (5 + 2 Fans)
8. Fan Assisted w/ 2 sided exhaust and in-cavity fans (6,000 cfm)
9. Fan Assisted w/ 2 sided exhaust and in-cavity fans (9,000 cfm)
10. Fan Assisted w/ 2 sided exhaust and in-cavity fans (8x 6,300 cfm)
11. Fan Assisted w/ 2 sided exhaust and in-cavity fans (10x 6,300 cfm; in series)
12. Fan Assisted w/ 2 sided exhaust and in-cavity fans (10x 6,300 cfm; in parallel)
13. Fan Assisted w/ 2 sided exhaust, in-cavity fans and adjusted bottom intake (8x 6,300 cfm).

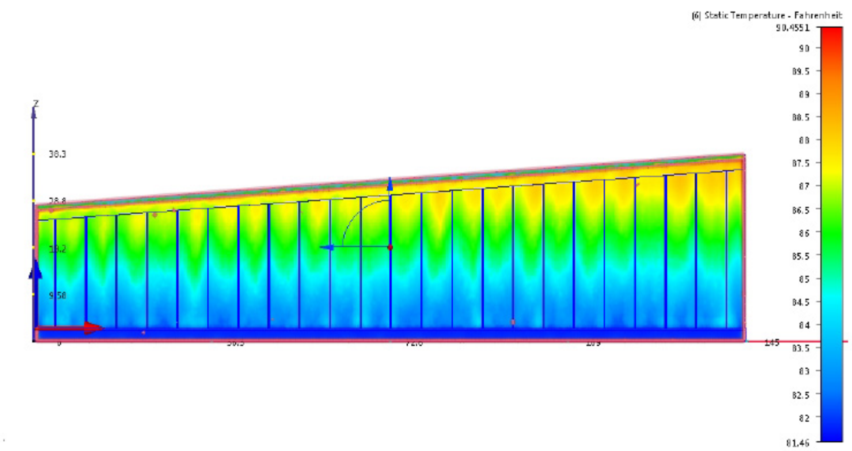
The methodology for the CFD modeling involved modeling a worst case scenario representing the highest summer heat gain hour for the façade. The conditions at this hour were determined using an annual energy simulation model created in EnergyPlus from which hourly results were extracted to determine the conditions external to the façade responsible for creating the highest thermal flux through the double-skin. This approach was chosen as it would estimate the moment requiring the highest airflow through the double skin to avoid excessive heat gain in the summer months. Steady-state analysis was chosen over transient for the sake of analysis time and because the use of worst case conditions limited the design team’s need to understand the transient nature of the heat gains within the façade.

The Launder-Sharma formulation of the K-epsilon model (also called the “Standard” model) was chosen for this analysis as an industry best practice for situations without large adverse pressure gradients[5]. K-epsilon, as a two equation model, allows for the CFD analysis to account for certain effects such as convection and turbulent energy diffusion where other turbulence models would ignore these effects[6].

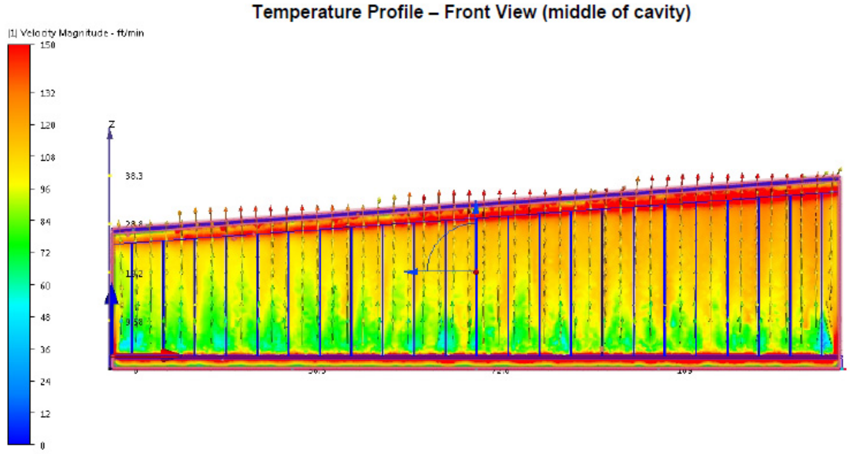
General physical and thermal conditions of the analysis were as follows:

Model Type:	Simple; airflow driven
Heat Gain through glazing surfaces:	Q_{ext_window} = 90,097 Btu/hr Q_{int_window} = 201,614 Btu/hr
Peak Outdoor Air Temperature:	81.5 degrees F
Cavity Ventilation:	Fan-assisted
Type of Analysis:	At equilibrium with peak conditions
Turbulence Model & Iterations:	k-ɛ, 100 iterations

As a baseline case, the team modeled an idealized version of a naturally ventilated double-skin façade with intake and exhaust openings running continuously along the bottom and top of the cavity, respectively. Poizaris has pointed out that a naturally ventilated strategy for double-skin façades can be problematic and somewhat unpredictable, particularly in an urban context such as this one[7]. This consideration, in addition to functional, technical and aesthetic issues (identified above) precluded the use of this configuration, but it was useful in determining the temperatures and airflows possible without the use of ventilation fans. Figure 7 shows the temperature and airflow profiles within the cavity during peak design conditions for this condition. Even with an outside air temperature of 81.5 degrees F, the cavity air temperature does not exceed 90 degrees F, minimizing any additional heat gains through the façade without the need for fans. Had this configuration been achievable, this would have been the best solution.



Temperature Profile – Front View (middle of cavity)



Airflow Profile – Front View (middle of cavity)

Figure 7: Temperature and airflow profiles in the façade cavity (natural ventilation option).

With information in hand on the baseline case, the team began the exploration of configurations that were compatible with the building design, all of them involving mechanical ventilation. In the course of trying multiple fan-based ventilation schemes, problematic design options were encountered. Figure 8 is the same temperature profile as the baseline case, but for a system with two large fans (9000 CFM), one exhausting from either side of the cavity. The upper portion of the cavity reaches a temperature of 140 degrees F, which is not excessively hot for such a small portion of the façade, but additional velocity analysis indicated extremely fast and turbulent airflow. This high velocity and turbulence brought up concerns about fluttering and damage to the roller shades when they are deployed.

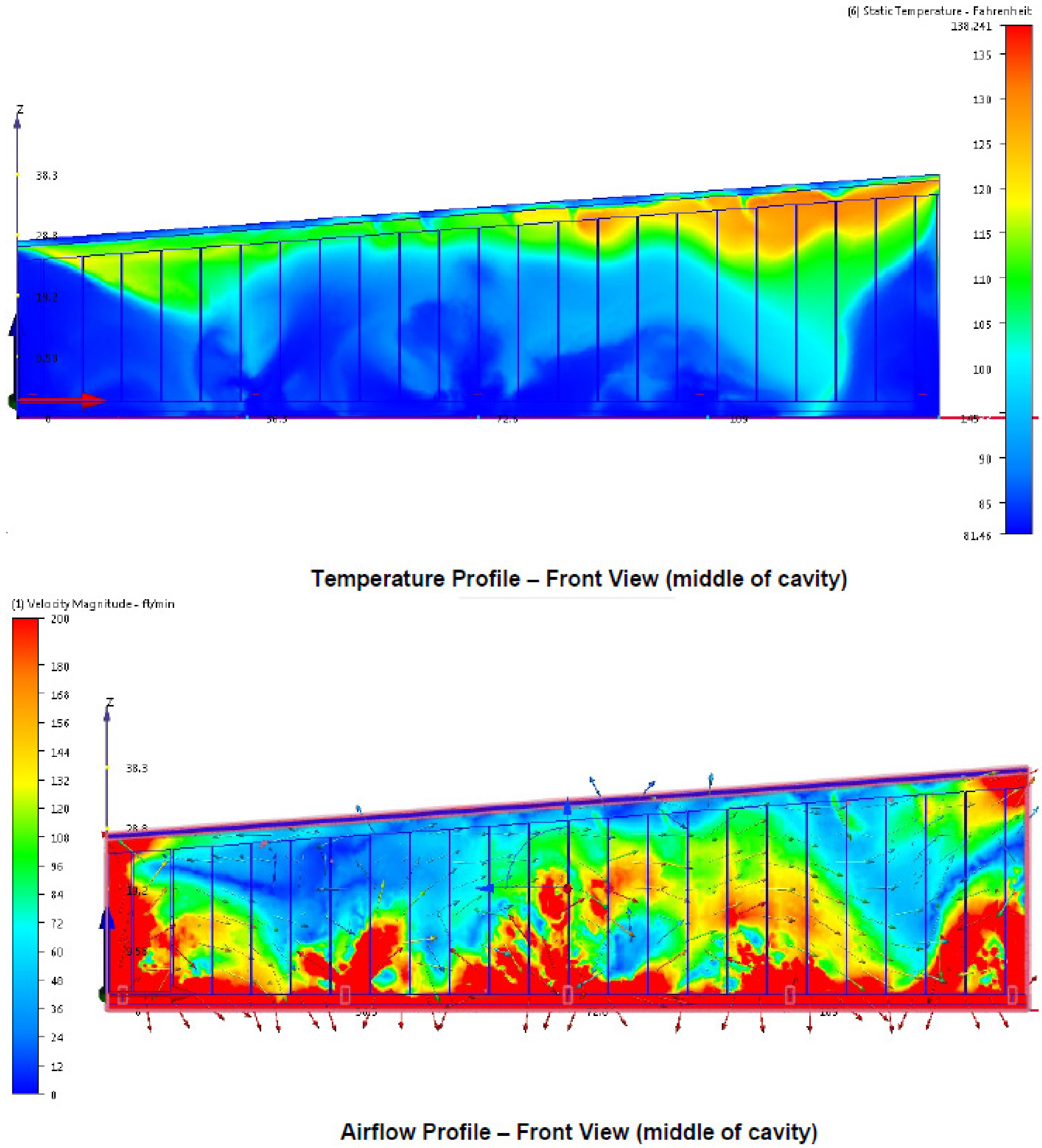
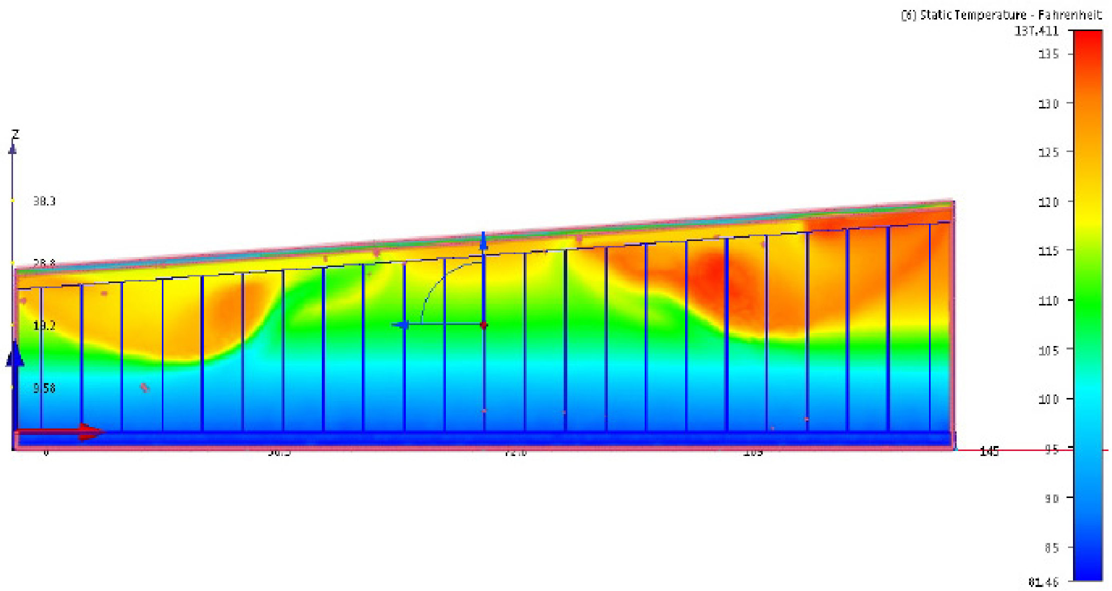
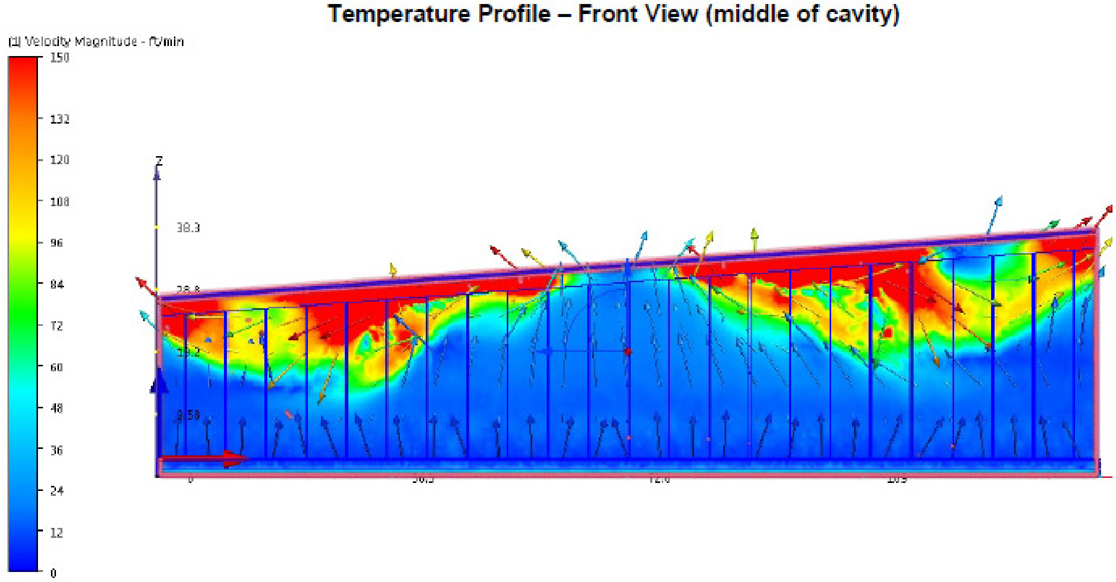


Figure 8: Temperature and airflow profiles in the façade cavity (fan assisted,two-sided exhaust, 9,000 CFM).

The team developed more options until finally settling upon a design using 8 fans at the top of the cavity, three on each side and two in the center. The temperature and airflow profiles for this design are shown in Figure 9. This design provided a good temperature profile, while minimizing turbulence and providing lower air velocities in the cavity. Overall, the CFD analysis helped the team to develop the input and fan configuration that optimizes thermal and airflow performance of the double-skin façade.



Temperature Profile – Front View (middle of cavity)



Airflow Profile – Front View (middle of cavity)

Figure 9: Temperature and Airflow Profiles in the Façade Cavity (Fan Assisted, 2 sided exhaust, 8x 6300 CFM).

Cavity Depth

The team studied several different options to determine the optimal depth of the double-skin façade cavity. The simulations done by Torres et al. generally indicated that deeper cavities yielded better results in reducing the cooling load in hot climates[9]. Further, Aksamija's study on different configurations of double skin facades and their effects on energy consumption, concluded that a 28 in (0.7 m) to 38 in (1.0 m) width was optimal in cold climate conditions. Cavities narrower than 28 in (0.7 m) were determined to be too difficult to access and maintain. Cavities wider than 38 in (1.0 m) add the expense of additional material and increase summertime energy use in mechanical ventilation of the large cavity space. Thus, the design team selected 3ft-0in (0.9 m) outside face of glass to face of glass as the ideal double wall width.

Glazing Configuration

The choice of the glass type for the interior and exterior panes depends largely on the façade ventilation strategy. In case of a facade ventilated with outdoor air, an insulating pane (sealed double-glazed unit) is usually placed at the inner plane of the cavity as a thermal break and a monolithic pane is placed at the outer plane to serve as the primary weather barrier. The design team studied this configuration relative to a single plane of insulated glass and to a configuration with the insulated plane to the exterior. Figure 10 shows that the results of this study validated the initial conclusion. Consequently, the final design of the double-skin façade is configured with monolithic glass at the exterior plane and low-e coated, insulated glazing units at the interior plane.

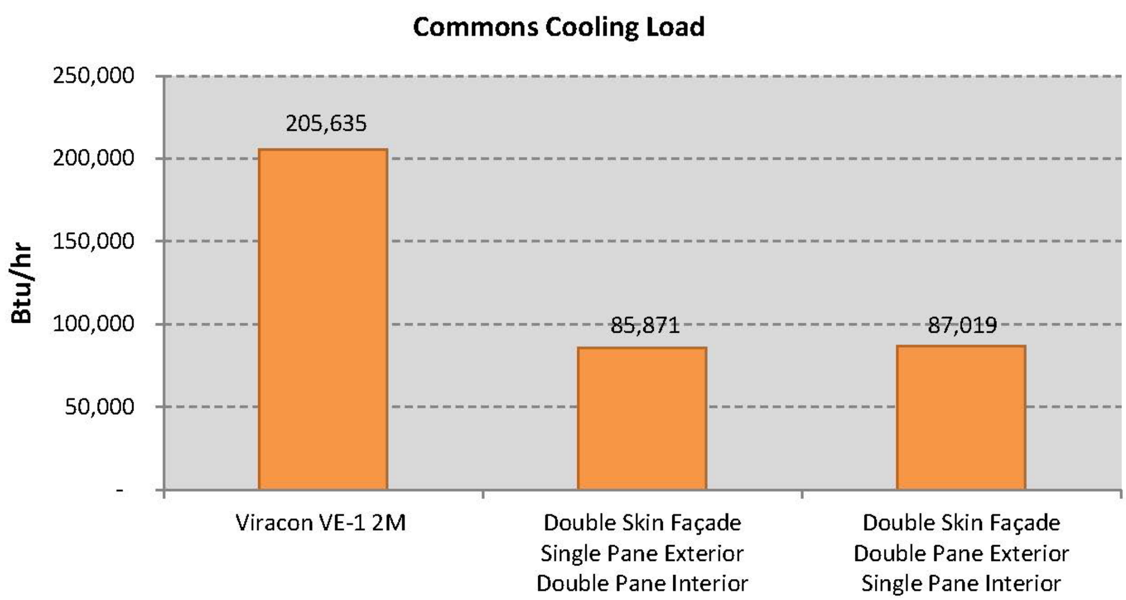


Figure 10: Cooling load comparison of glazing configurations.

Solar Shading Options

It has been suggested that operable solar shading devices are the most effective means of controlling solar heat gain in large glazed facades[2]. With this in mind, the design team explored two primary options for the solar shading devices that would be installed within the double-skin curtain wall cavity: horizontal blinds and roller shades.

Early in the process the horizontal blinds were the favored solution for a number of reasons. Aesthetically, they worked well with the horizontal nature of the building design and they could be finished to match the other curtain wall elements. Furthermore, horizontal blinds offer a nearly endless degree of adjustability as they can be raised or lowered and the slats can be tilted to vary the overall openness of the system. This level of variability did, however, come with prices in both cost and complexity. The systems that were investigated had, by their very nature, very complex control and activation equipment that included numerous sensors, motors and actuators. The complexity is reflected in the system first-cost and creates ongoing maintenance and operational costs for the life of the building.

There were also physical constraints that worked against this type of system. As previously mentioned, the roof in the area of the double-skin wall slopes and, thus, creates difficulties when the shading system needs to be mounted horizontally. As we will explain later, the design team was able to effectively conceal roller shade housings that were not parallel to the roof structure in the ceiling of the cavity; but the physical size of the horizontal blind systems proved to be nearly impossible to conceal. Additionally, the height of the curtain wall, and the required drop of the shading system, exceeded the total length that a horizontal blind system could accommodate. This type of system would, then, require that an intermediate shade housing be located somewhere in the height of the wall cavity and would seriously compromise the transparency of the wall.

In the end, first cost, operating cost and the sheer physical size and complexity of this type of system combined to make it unworkable.

Roller shades, the solution that was initially less favored, ultimately proved to be the better choice. The height of the cavity and concealing the shade housings in the ceiling were challenging, but were issues that could be solved without compromising the building design intent. For roller shades, the overall drop determines the total fabric length and the resulting size of the housing that conceals the fabric, roller and motor. In this case the long fabric drop required that the housing be 9 inches deep, a dimension that the team was able to conceal in the cavity ceiling. The roof and cavity ceiling in this area slopes up from north to south and the shades must be installed level to operate, so fitting the housing into the ceiling became something of a challenge at the south end of each shade. The shades are designed to fit between the double-skin wall trusses and are, thus, slightly less than 6 feet long. By splitting the shades up in this way, we were able to work with the building geometry to conceal the shades in the ceiling as shown in Figure 11.

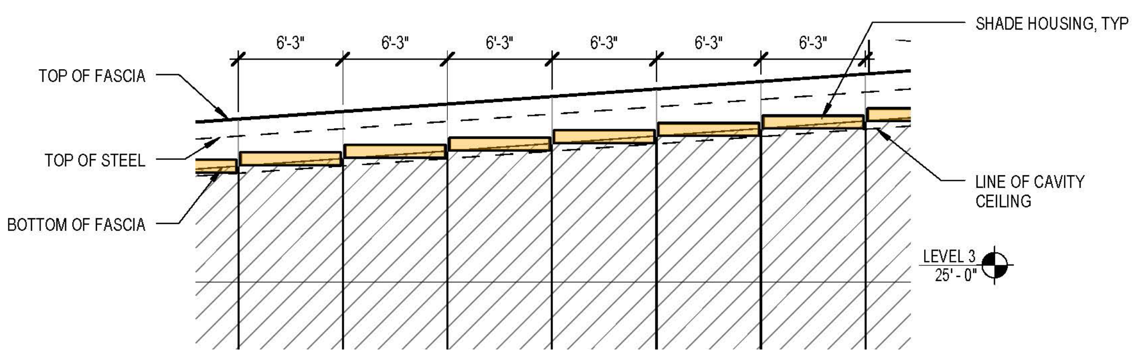


Figure 11: Roller shade geometry.

Given the length of the shade drop, and the fact that there would be airflow within the cavity at some times of the year, it was necessary to provide guides to stabilize the shades and to keep them from curling at the edges. In keeping with the minimal aesthetic of the double-skin wall, the team included guide cables that run from the top of the cavity to the bottom and are anchored to the concrete floor below the bar grate floor. This solution provides the necessary stabilization and is as unobtrusive as possible.

As the shading will only be required when there is direct sunlight on the west façade, it was important to include a control system that would minimize the amount of time that the shades were deployed (and thus hindering the views into and out of the building). The decision made on this is twofold. First the shades are programmed so that they never drop below 7 feet above the floor, insuring that Level 1 occupants and those outside will always have an unobstructed view through the double-skin wall. Secondly, the shade position was specified to be controlled by a radiometer mounted on the roof. The radiometer tracks the position and intensity of the sunlight and sends that information to a controller that then drops shades only when necessary and only to the level required to block solar infiltration into the Commons space. In order to preserve visual consistency, all shades in the double-skin wall will move in unison. The design team worked closely with the shade manufacturer to insure that the motors and controls system could achieve the desired operation. The system that was ultimately chosen was provided by Mechoshade and includes the following key components: IQ2 Electronic Drive Unit; I-Con Intelligent Motor; and SunDialer WindowManagement System.

Implications of the Adjacent, Underground Parking Garage

The addition of the double-skin façade required demolition of existing ground level air intake grilles that previously occupied this area. These grilles provided makeup air for the adjacent underground parking garage exhaust system through a large vertical shaft that extended down to the garage lower level.

Locating the building, and particularly the west façade, over this intake required that it be re-configured and integrated into the new construction. Figure 12 presents for a schematic section showing the final configuration. The challenge was to create a new air intake system that would maintain the required air intake for the existing garage exhaust system and supply the double-skin façade ventilation system.

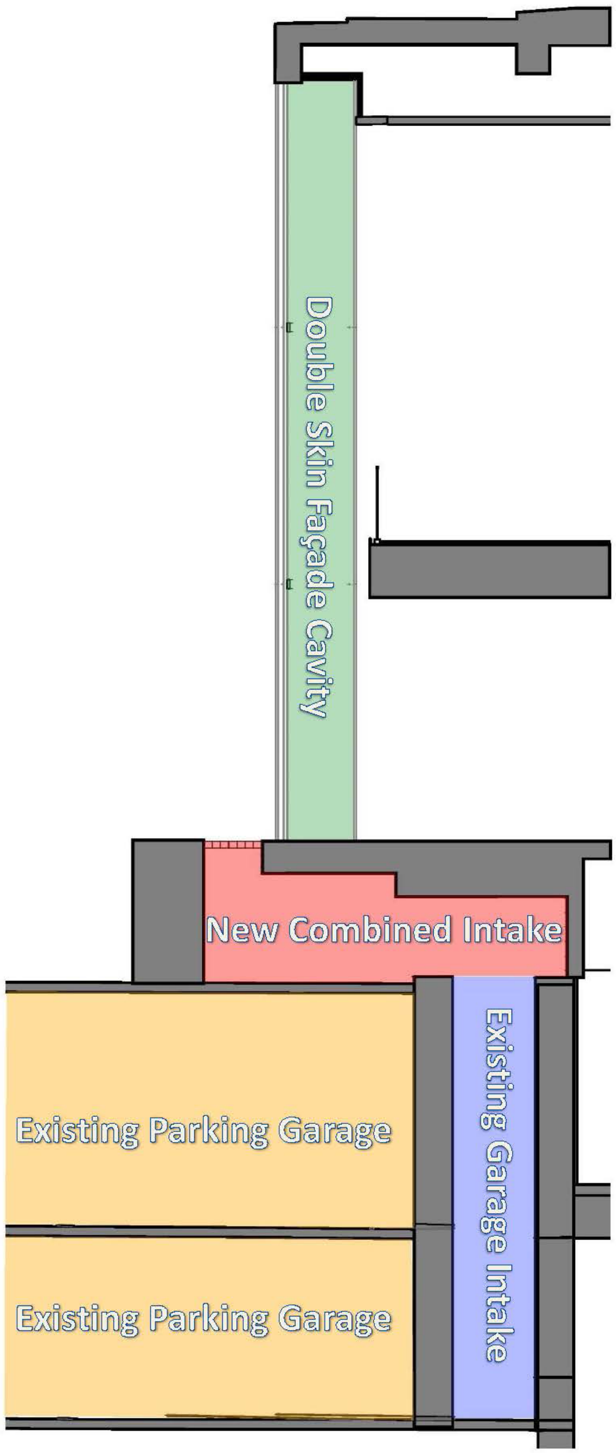


Figure 12: Schematic section showing new construction at garage intake.

The team first investigated two options that tied the garage and double-skin façade systems together. The first option was to use the double-skin façade as the intake for the parking garage fans by pulling air down through the cavity, into the garage intake and then through the garage. We discovered that the garage fan system is run continuously and the garage is, therefore, constantly at a negative pressure to the air intake cavity. The second option was to reverse the airflow through the garage, route the exhaust through the double-skin facade and use the double-skin fans to expel air from the cavity. The probability of entraining polluted garage air inside the double wall cavity was deemed to be an inherent, and insurmountable problem with this solution. Beyond this specific issue with the latter idea, there were additional challenges that were common to both combined-airflow options. The implementation of either solution would mean that air would constantly be pulled through the cavity, which is counterproductive to the effectiveness of the double-skin façade in the cooler seasons of the year when it is beneficial to trap warm air in the cavity. Further, determination of the operational efficacy of either option would have been difficult and would have required that the entire parking garage be modeled and included in the CFD analysis. Precise modeling of the existing garage building and determining the performance characteristics of existing fans would have been an enormous undertaking that was well outside the scope of the project. In the end, the design team concluded that it was best for the two systems to act independently of one another.

With the goal of allowing separate operation of the double-skin façade and existing garage air systems; a new intake grating was sized with enough cross-sectional free area to accommodate adequate makeup airflow for both garage exhaust and double wall exhaust. Since the garage exhaust system operates all year long, an unobstructed air path was created down to existing wall openings at the east end of each of the two garage levels. Existing louvers in these wall openings were removed, and replaced with 2-hour fire dampers of equal airflow capacity. The intent was to keep air flow to the double-skin wall completely separate from the flow into the garage, as shown in Figure 13. In the event of a fire within either space, the new garage fire dampers act to isolate the garage from the double-skin wall.

As explained above, motorized dampers were provided at the bottom of the double-skin wall and were interlocked with the exhaust fans at the top of the cavity through the building automation system (BAS). The fans and motorized dampers are controlled via temperature sensors inside the cavity, and the fans operate to relieve heat from the cavity to maintain a maximum allowable summer temperature setpoint, as determined by the CFD analysis. When the building is in heating mode, the BAS commands the double-skin wall fans to shut off and motorized dampers to close. The design goal was to trap heat in the space (largely gained from solar radiation) and use the double-skin wall an insulated heating mechanism, reducing the load on the building's heating system.

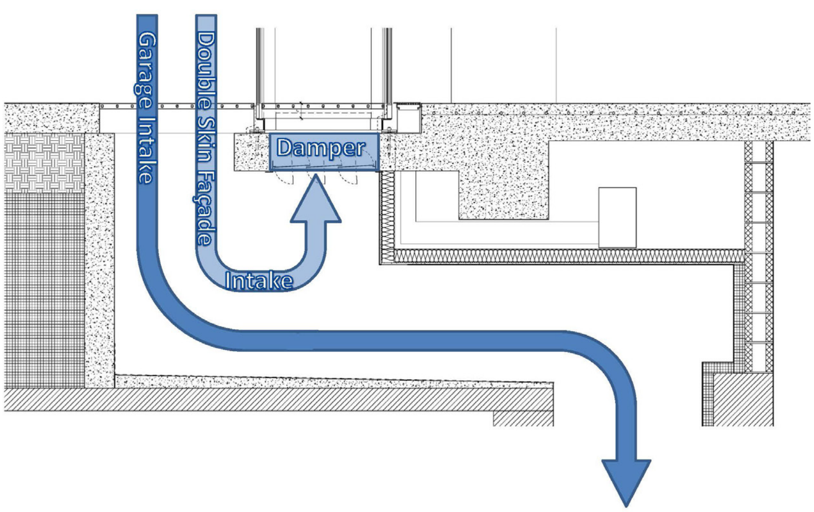


Figure 13: Intake airflow diagram.

Maintenance Access
Once the double-skin wall aesthetics and functions were determined, the final issue to contend with was maintenance access. Introducing exterior air into the cavity will, inevitably, result in the deposit of dirt, dust and other contaminants on its surfaces. The glass and metal surfaces inside the cavity will have to be cleaned periodically and the shades and ventilation fans will have to be maintained and serviced. The limited space between the planes of the double-skin wall, the cavity height, the frequency of the support trusses, the inclusion of shades at the ceiling and the sloping roof plane all have an impact on the means chosen for maintenance access.

The very first issue to tackle was accessing the cavity. The building configuration precluded access at Level 2 or the roof, leaving only the ground floor as the entry level. To preserve the minimalist aesthetic of the curtain wall construction, doors were located on the narrow ends of the cavity and the final design includes only the hardware necessary for periodic access. This approach maintains the uncluttered appearance the design team strove for. Figure 14 shows for shop drawings of the final details.

For vertical access within the cavity, the design team explored a number of solutions that included suspended cradles or baskets with both manual and powered lateral and vertical operation. These all, necessarily, in-

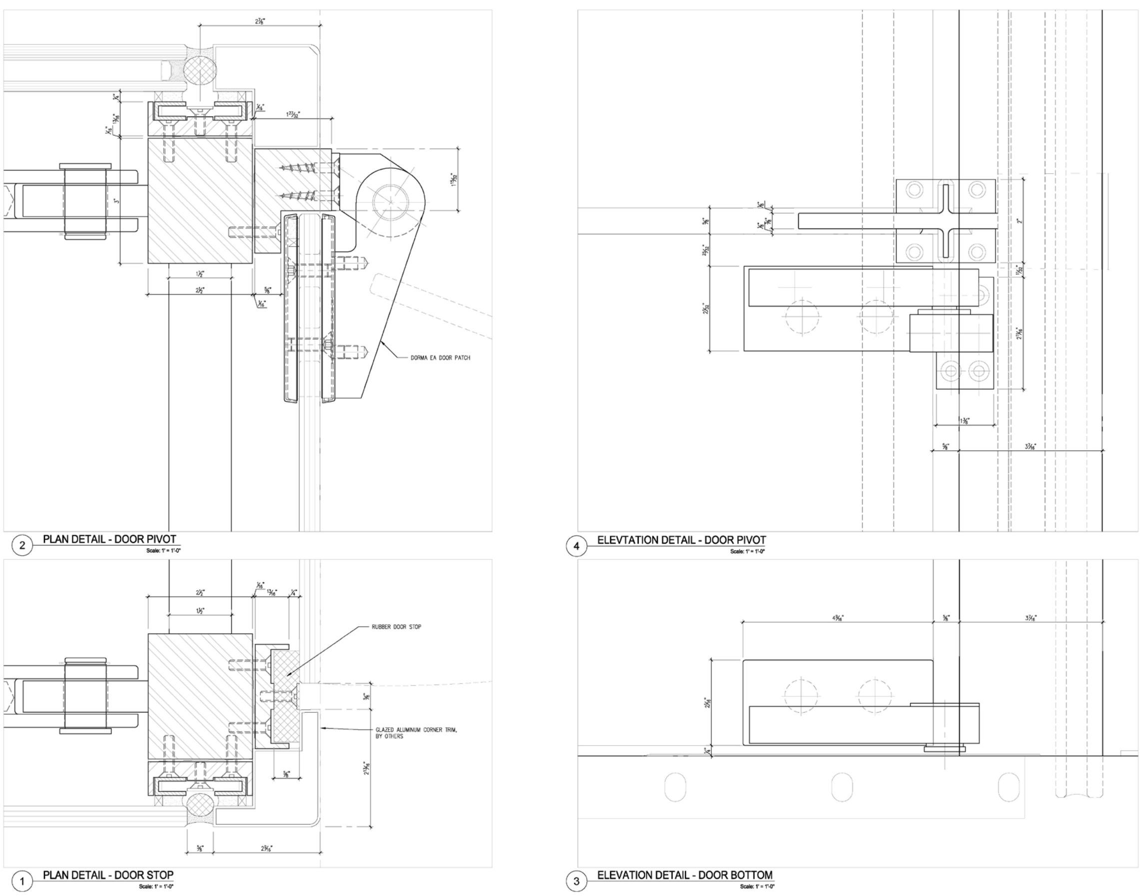


Figure 14: Cavity access door shop drawings.

cluded a track at the top of the cavity and a carrier that would move and lift maintenance personnel. It quickly became apparent that a track running the length of the double-skin wall cavity would present insurmountable problems: it would be interrupted by the support trusses, it would interfere with the shade placement and/or operation; it would not be possible to conceal the carrier in a stowed position; and any system that could provide the necessary access would, undoubtedly, be very costly. The team determined that even if a system could be devised that met all of the functional and aesthetic criteria, its costs would far outweigh its benefits.

The next avenue was to include a mobile, powered lift in the cost of the project. The constraints of width imposed by the access doors and the support trusses severely limited the possible choices. Of the machines that would fit through the access doors and could move laterally in the cavity, none approached the height necessary to reach the highest portions of the cavity. A custom-built machine was briefly considered, but was believed to be cost-prohibitive.

The appropriate solution turned out to be the simplest one. The team looked at the geometry of the cavity and access doors and determined that the most effective means of maintenance access was a simple extension ladder. We studied standard ladder sizes and made sure that they were maneuverable within the cavity and tall enough to reach the top. We then drew diagrams, for the Owner's use, showing how to maneuver and place one or more ladders within the cavity to reach every area (Figure 15).

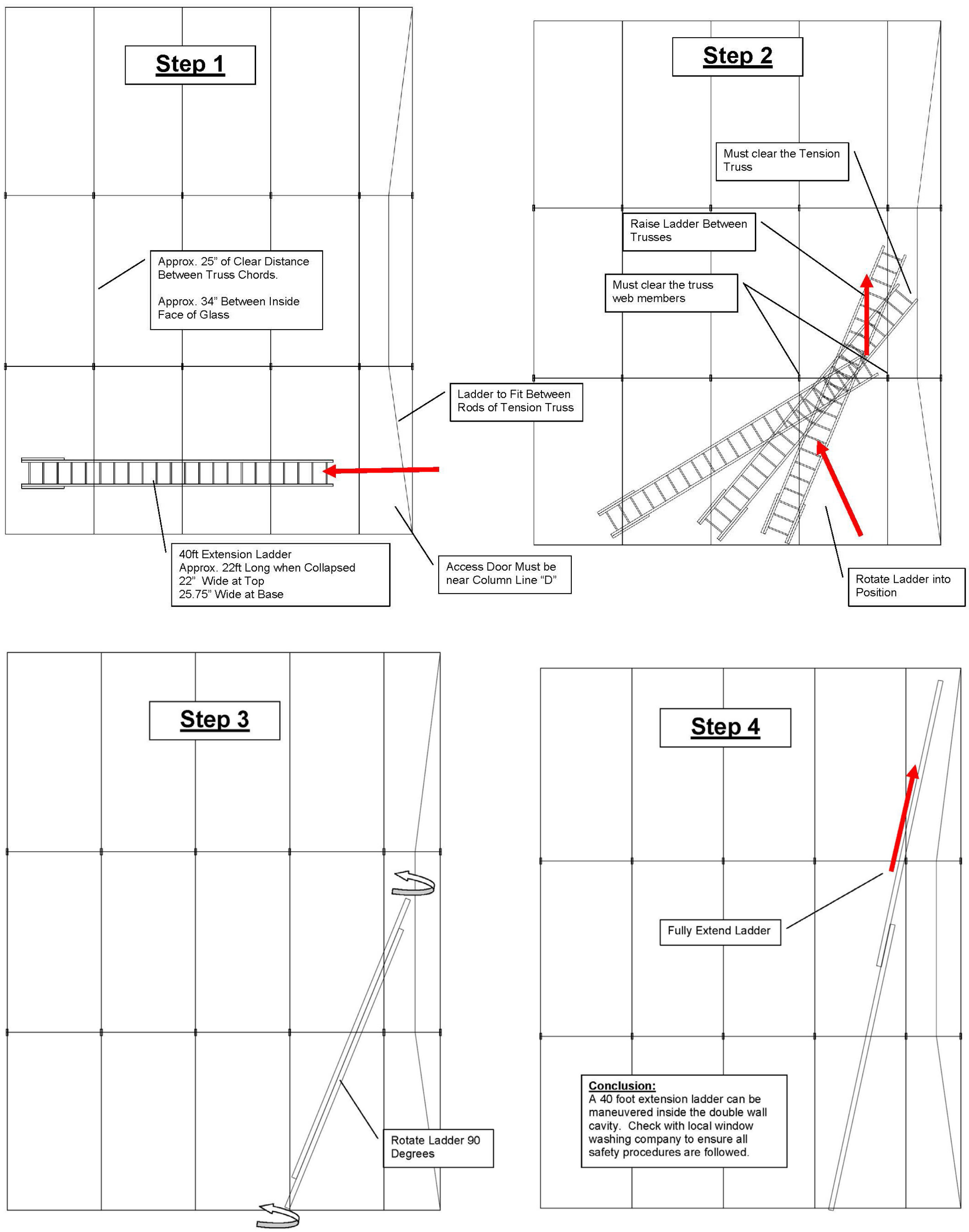


Figure 15: Cavity ladder access diagrams.

3.0 CONCLUSIONS

The unique programmatic requirements and site constraints of the Case Western Reserve University Tinkham Veale University Center resulted in a building design that included a number of challenging conditions. Paramount to this paper is a large west-facing wall that needed to be as transparent as possible and, at the same time, protect the occupants from solar light and heat gain. The design team investigated solar protection using exterior vertical fins, interior shading, electrochromic glass and a double-skin façade with integral shading.

After it was determined that the most appropriate solution for this building was the double-skin façade, the design team proceeded to develop the configuration and details.

The team determined that natural ventilation was not compatible with the building design and how the double-skin façade fit into it; and that ventilation would be fan-driven with intake from the bottom of the cavity through dampers and exhaust via a plenum and eight axial fans at the top. While this is not the optimum solution from an energy-use perspective, the fans will only run when the in-cavity temperature requires ventilation and should only occur when the sun is directly on the wall and the exterior temperature is relatively high. Environmental studies lead us to believe that these conditions will only occur for a small percentage of hours during the year. Having determined a ventilation strategy, the team then set out to optimize the use of the air layer within the double-skin façade. The resulting sequence of operations is: the cavity will be ventilated in the warm months to mitigate heat buildup and closed in the cooler months to create a pre-heated “buffer” of air between the interior and exterior.

The glazing configuration that was found to be most efficient for the Cleveland climate was to have monolithic glass in the exterior plane and insulated glass with low emissivity coating in the interior plane. Not only is this expected to provide the best thermal performance, it also allowed the aesthetic benefit of having the monolithic glass, with its flatter surface, on the building exterior. To further mitigate solar light and heat gain, roller shades were included in the cavity and were designed to be controlled based on the position and intensity of the sun. By automating the operation of these shades, they will deploy only when needed to block direct sunlight and, consequently, minimize obstruction of views into and out of the building. Lastly, the team examined multiple options for accessing and maintaining the cavity; ultimately settling on the simplest solution, ladder access to all areas.

We would like to note that all of the above conclusions contributed to the design of the double-skin façade and that final validation of these conclusions will not be complete until the building is occupied and operational. We anticipate that tuning of the various building systems and parameters (shade operation, mechanical setpoints, fan operation) will likely involve engagement over the first year of occupancy to address seasonal variations and optimize performance.

Finally, we would like to emphasize that, as is true with many aspects of building design, the conclusions reached here and the resulting design of the Tinkham Veale University Center double-skin façade has been tailored for this particular project in this particular location. Original research done for this project and the reviews we have done of double-skin façade literature reinforces the fact that final solutions are necessarily unique to every building. Components and concepts are translatable from precedent and published research, but to achieve optimal performance (be it functional, aesthetic or operational) a building design must react to vagaries of site, program, architectural vision and the myriad of other forces that exist in every project.

Acknowledgments

First and foremost, the authors would like to acknowledge Case Western Reserve University, particularly the Board of Trustees, Stephen Campbell, Joanne Brown and Nicholas Christie, for their support of the project, their willingness to take design risks and their continued engagement in the development and execution of the project. We would also like to acknowledge those who contributed their knowledge and experience in the development of the project and this paper: Ajla Aksamija; Paul Erickson; Jason Flores; Scott Foster; Ralph Johnson; Mark Jolicoeur; Norbert Repka; Paul Petska; Bryan Schabel; Chris Stutzki; and Bruce Toman.

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03.
ACHIEVING ENERGY INDEPENDENCE: *Methods and Case Studies in Healthcare for Use of Waste to Energy Technologies*

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ABSTRACT
This article reviews Waste to Energy (WTE) technologies that are currently available and how the healthcare sector can employ these for waste management and revenue generation. The available literature is reviewed to discuss specific case studies. The case studies also explore the role of local communities in these ventures. The financing, operations and maintenance of WTE projects is the key to their feasibility. Understandably it lies outside the core business of healthcare. The article reviews concepts such as Power Purchase Agreement (PPA) and Energy Performance Services Contract (EPSC), which are third-party investments and are used for similar energy projects. The article concludes with remarks; why these projects make business and environmental sense and how symbiosis between the communities and their large consumers, such as healthcare, is the key to sustainable development.

KEYWORDS: Waste to Energy (WTE), Healthcare Buildings, Power Purchase Agreement (PPA), Energy Performance Services Contract (EPSC), communities, symbiosis

1.0 INTRODUCTION

The healthcare industry is the biggest generator of waste in the United States, the second largest consumer of energy and consistently among the top ten users of water in any community[1]. The stated purpose of Energy Independence and Security Act (EIA) of 2007 is "to move the United States towards greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings and vehicles, to promote research on and deploy greenhouse gas capture and storage options and to improve the energy performance of the Federal Government, and for other purposes[2]."

The impact of EIA elsewhere is likely to be limited without healthcare's participation. According to a 2009 report, an average hospital spends about $72 million annually on the procurement of materials for its operations[3]. This is the second major cost of healthcare operations after labor[4]. A vast majority of those materials turn into waste. Hospitals are responsible for approximately 5.9 million tons of waste annually[5].

Symbiosis is close and often long-term interaction between two or more different biological species. All natural ecosystems are filled with examples of the inter-dependence for their own survival where biotic and abiotic components are linked together through nutrient cycles and energy flows. Figure 1 shows the seamless cycle between the waste and creation in nature. The "producers" employ photosynthesis to fuel nearly all other organisms by using "waste" as the nutrient.

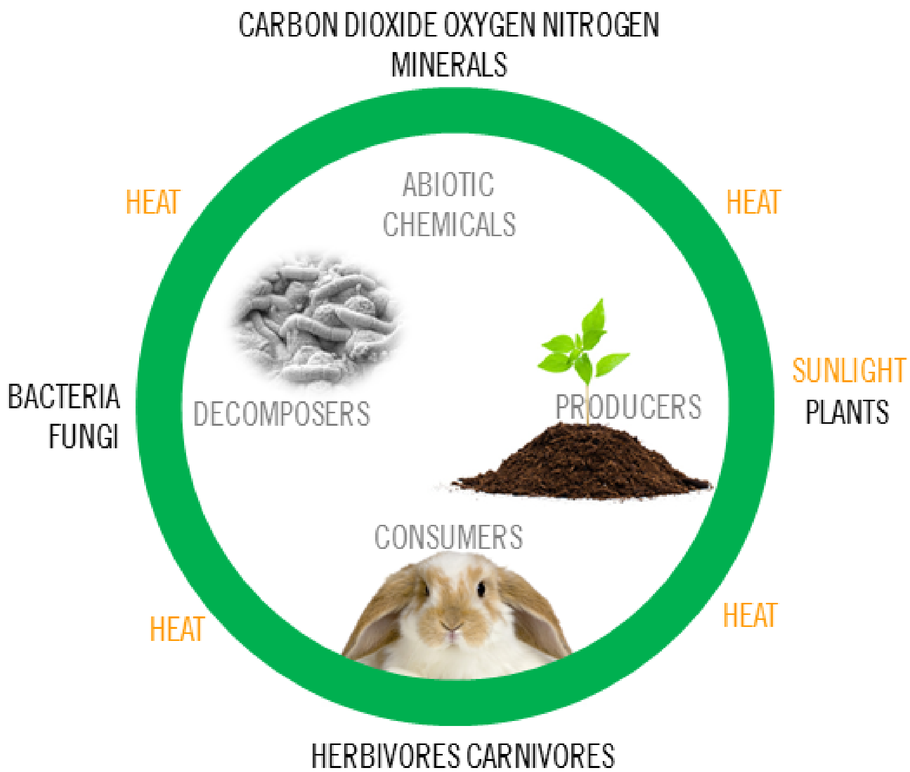

Figure 1: Waste absorption cycle in nature.

The interaction between the living and non-living organisms creates a man-made ecosystem which is comparatively less complex than a natural ecosystem. It is also at risk of disintegration since many of the key ingredients of naturally sustainable ecosystems are missing.

In order for the man-made physical environment to be sustainable, the cycles of creation and waste need better understanding. Tipping the balance to one side has repercussions for the environment and economics.

The United States produces largest per capita waste in the world at 4.5 lb per person per day[6]. In recent years there have been some efforts for reducing waste at multiple levels. According to the Environmental Protection Agency (EPA), we recycle about 34 percent of municipal solid waste (MSW) in the United States. There are about 87 operational MSW-fired power generation plants that are responsible for about 0.3 percent of total power generation. The rest of the solid waste ends up in landfill. Similarly there are about 400 plants that generate electricity from landfill gases. But the majority of them fail to capture the heat that is a by-product of power generation. Figure 2 shows the total energy consumption against the tiny fraction of waste being absorbed back by the US population as energy and recycled goods[7].

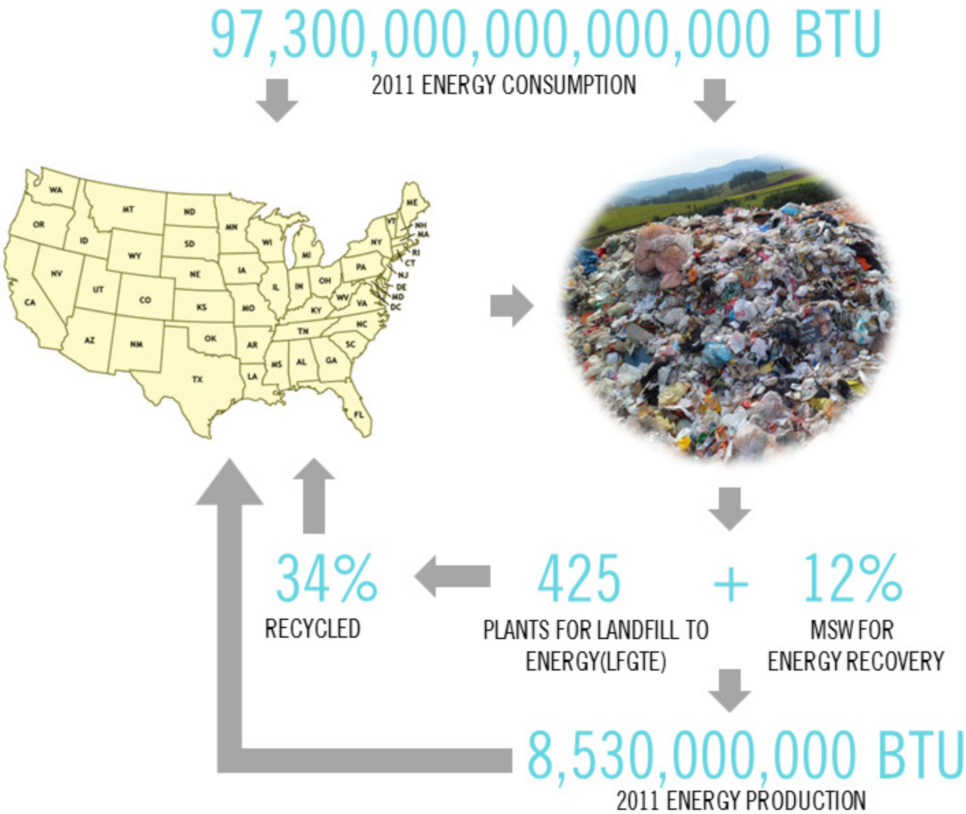

Figure 2: Energy consumption and waste cycle in United States.

Our planet has never seen this much human population in its existence. It required only 40 years for the population to double from 2.5 billion to 5 billion after 1950[8]. We are also consuming resources and producing waste at a much faster rate compared to our ancestors. Figure 3 shows a steep rise in per capita use of energy in the last 200 years.

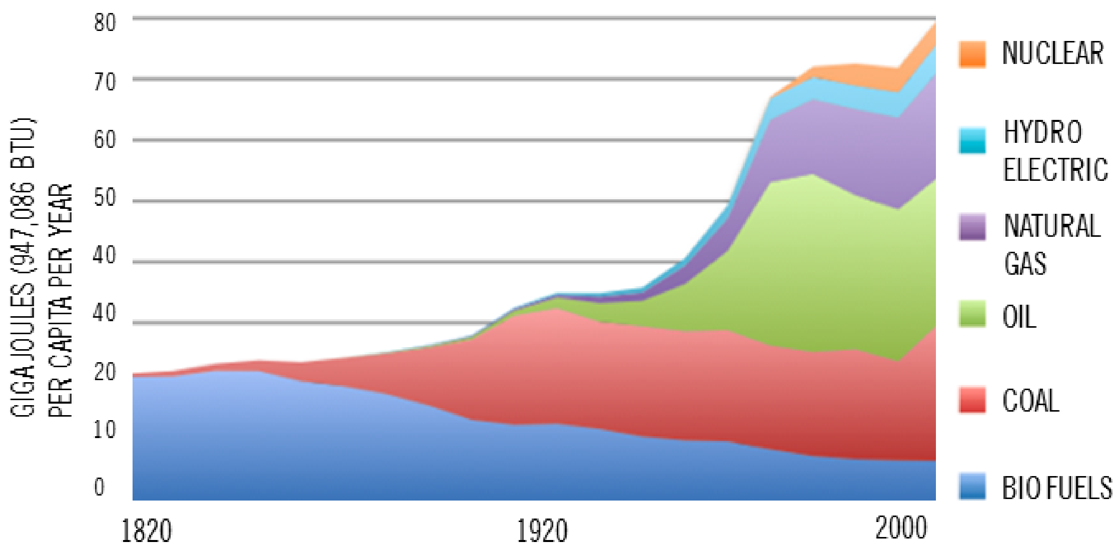

Figure 3: Energy consumption in the world (per capita) in last 200 years.

With population and energy consumption increasing at these rates, we are likely to generate waste proportionately.

With these statistics, the question is can the man-made ecosystems achieve the carbon and energy economy of natural systems?

WTE projects are a potential solution, since they provide a crucial link to that quest.

1.1 Healthcare and Waste

Healthcare operations are an integral part of developed communities. They are also one of the largest consumers of the resources. Hospitals produce 25 pounds of waste per day per staffed bed[9]. The environmental footprint of that waste is even larger, since the manufacturing process creates about 32 pounds of waste to make one pound of product in the United States[9].

Healthcare waste is complex because of its sheer volume and also because a small but significant amount of that waste, about 15–20 percent, is regulated by multiple agencies including EPA, OSHA, DOT, the Joint Commission, DEA, and others. Items such as regulated medical waste (RMW), pharmaceutical and hazardous chemical waste and radiological waste are 10 to 100 times more costly to manage than solid waste or recyclables[9].

Non-regulated waste, which makes up around 85 percent of majority of the hospitals' total waste stream, is not different from the waste generated by a hotel, where up to 60 percent is either recyclable or compostable[9].

Managing this waste is an economic and environmental challenge for the healthcare industry. The WTE projects can pool similar resources from the adjoining communities to create a local source of energy. Figure 4 shows the options that healthcare industry has.

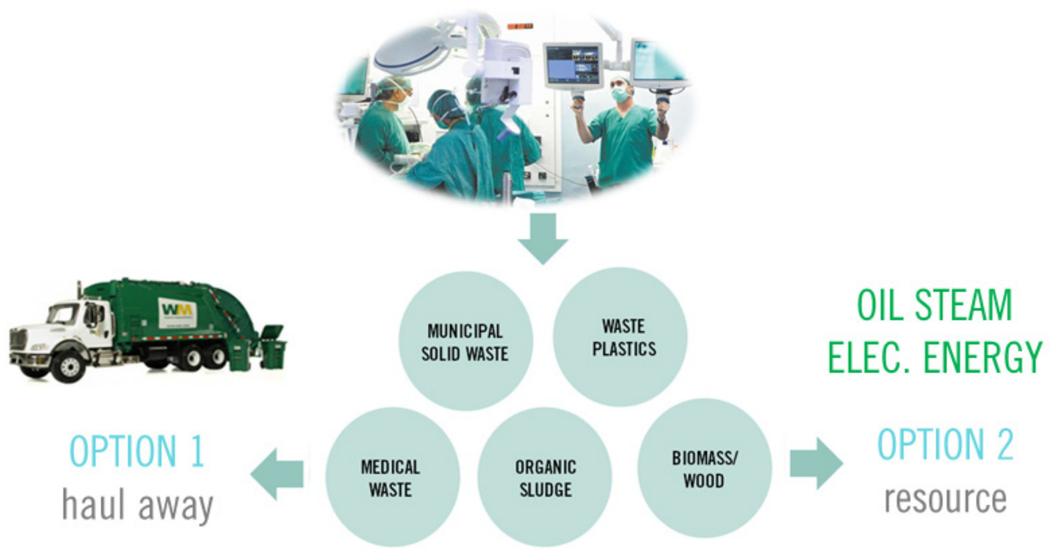

Figure 4: Healthcare waste management options.

The article reviews established and conceptual case studies in healthcare to demonstrate how waste management techniques can be used to improve energy and environmental impacts. It also addresses the economic aspect.

1.2 The Healthcare Energy Independence Challenge

Energy consumption in the healthcare sector in the United States is estimated to be 60 percent more than for similar size of facilities in Scandinavian countries[10]. The lower cost of utilities in the United States has allowed the industry to stay operational with these statistics. It can also be attributed to the lack of environmental regulations for buildings.

A recent study conducted by University of Washington in collaboration with the leading design/construction professionals of healthcare industry, established that a baseline Energy Use Intensity (EUI) of 250 kBtu/sf/year can be reduced to 100 kBtu/sf/year with efficient design of the systems for the new acute care facilities[10]. EUI for buildings is equivalent to miles per gallon (MPG) for auto industry. It measures the building's energy usage per year, based on the building's area. Figure 5 shows the baseline and target energy usages for healthcare to achieve this goal in different areas of energy utilization.

From the utility cost standpoint, it makes a strong business case for the energy efficient strategies since such efficiency would result in significant savings on a yearly basis.

The goal of energy independence can be realized by first optimizing the energy usage in healthcare buildings, which are typically the largest consumers of any local community. EUI reduction for healthcare would also help addressing the resilience of these systems in emergency situations. A building that consumes less energy would last longer with the limited resources.

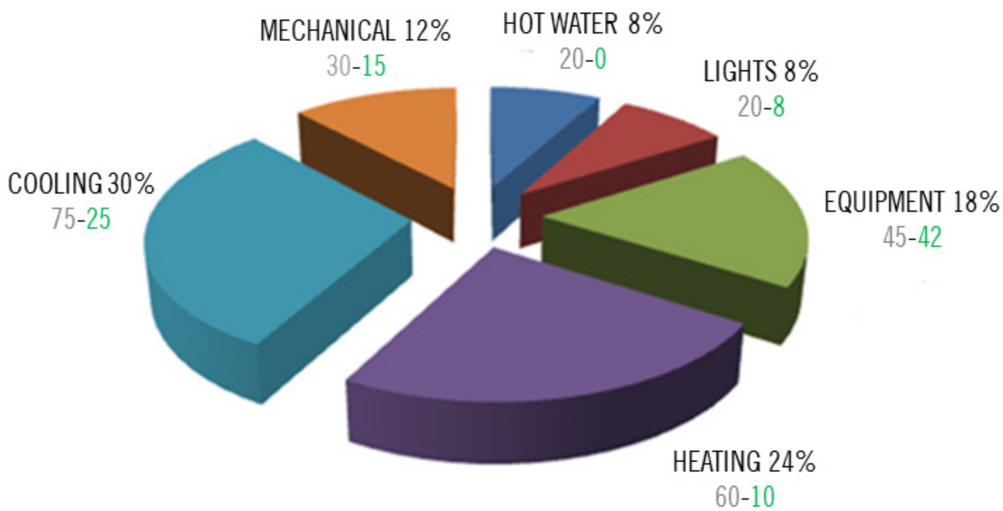

Figure 5: Energy usage split in healthcare buildings. The grey number represents baseline EUI, green number is the target EUI for reducing overall energy consumption. Together it will reduce the EUI from 250 to 100 kBtu/sf/year for acute healthcare facilities.

In reality this is the step one prior to the design for energy independence or resilience or both.

1.3 Project Delivery Systems

Healthcare facilities are starting to have a proactive approach in energy management according to the current surveys[11]. Newer and more improved technologies are being reviewed to upgrade the existing systems.

Most acute care facilities are sound businesses of larger scale that are well established in the communities. The operational cost reduction by employing energy efficiency methods is significant. The return on this investment for the energy upgrades in hospitals is so strong that there is potential for outside investment; if the capital is not available in the operational budget.

Energy Performance Services Contract (EPSC) and Power Purchase Agreement (PPA) are some of the prevalent project delivery systems that allow an outside entity to make an investment in an existing hospital for energy savings.

As these become more common, the energy efficiency goals will become more achievable. These contracts are also being employed for the on-site generation of electricity, steam, heat and chilled water.

Utility companies are potential partners in these ventures since they can create an efficient local system by avoiding transmission losses and capturing heat that can be sold to the buildings.

2.0 OPPORTUNITIES FOR WASTE TO ENERGY (WTE)

In all nature-based ecosystems the process of waste absorption is treated as a stepping stone towards the production cycle. Various elements of nature help in the decaying process, while generating the nutrients that help rejuvenate the production process. In an ideal man-made sustainable system, these processes should be emulated to create maximum efficiency. The following section reviews the prevalent technologies for WTE.

2.1 Waste Management by Incinerators

The EPA regulations heavily control this age-old method of reducing the volume of waste. Incinerators have been commonly employed by hospitals to burn medical waste. These systems also earned bad reputation for failing to address the pollutants.

However, the fact remains that some of the waste generated in hospitals has high heating values. Additionally, heat is the most effective way of destroying the hazardous waste.

Current advances in this technology have made tremendous progress in reducing the pollutants from the process that uses the waste as fuel input and produces heat and electricity. Figure 6 shows how the pollutants are controlled at five steps in a plant operated by Ecomaine[12]. The heat generated by incinerators can be captured for heating water and running turbines in the simplest systems

2.2 WTE Beyond Incinerator

There are a number of technologies that are able to produce energy from waste and other fuels without direct combustion. Many of these have the potential to produce more electric power from the same amount of fuel than would be possible by direct combustion. This is due to the separation of corrosive components from the converted fuel. This allows higher combustion temperatures in boilers, gas turbines, internal combustion engines and fuel cells.

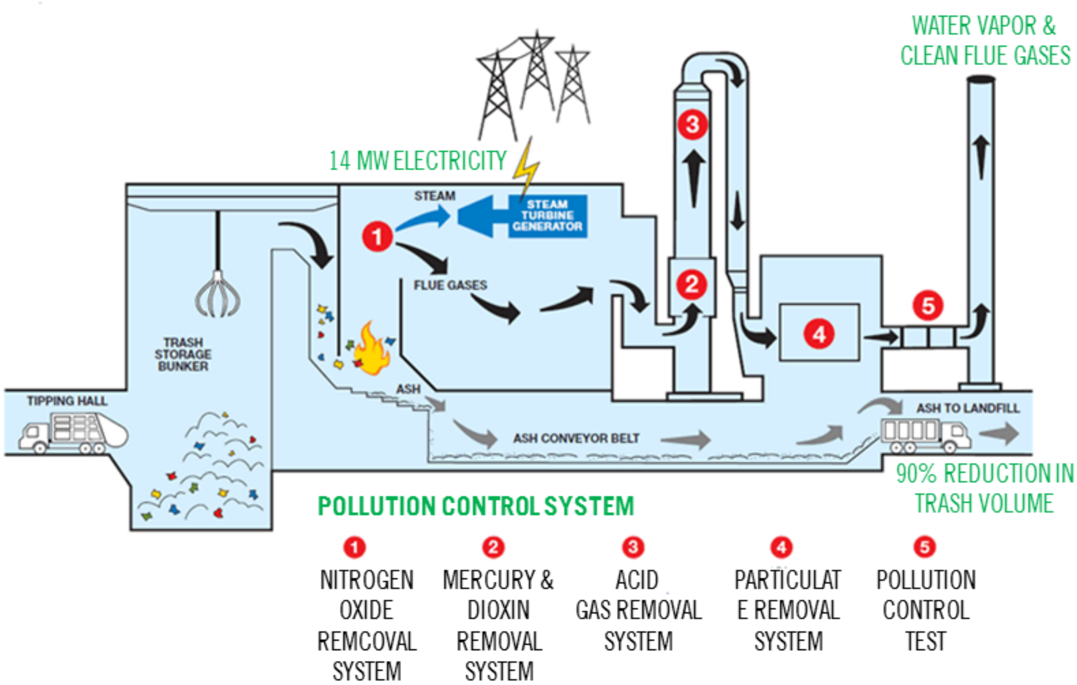

Figure 6: Pollution control for incinerator system.

A comparison of these technologies is shown in Tables 1 and 2. A Waste to Energy plant can have a combination of these technologies.

3.0 STRATEGIES FOR ENERGY INDEPENDENCE

The fossil fuel market is well established and commercially developed even though it is considered to have significant environmental, economic and political impact. It is also subject to the cyclical rise and fall of prices based on a variety of factors.

Lately the consolidated large consumers like hospitals are realizing that the unpredictable nature of energy prices is hurting their businesses.

Table 1: Brief overview of thermal WTE technologies.

	THERMAL TECHNOLOGIES			
	GASIFICATION	THERMAL DEPOLYMERIZATION	PYROLYSIS	PLASMA ARC GASIFICATION
HISTORY	Various patents from 1976	1980 patent for break even technology	1988 patent to meet air quality	2009 patent for WTE
PROCESS	Conversion of organic material into carbonaceous materials	Conversion of polymer into monomer or monomers	Thermochemical decomposition	Plasma torch powered by electric arc ionizes gas and catalyzes organic matter
FEEDSTOCK	Biomass	Biomass and plastic	Biomass, waste plastic and tires	Biomass, coal, oil sands, oil shale, MSW, hazmat, medical waste
REACTOR	>1300 F, Controlled steam and oxygen	600 PSI pressure, 480 F water	>800 F temperature, no oxygen, high pressure, endothermic, can be done in vacuum	Steam, electrodes, high voltage current, temperature of arc is 4000 to 25,000 F
OUTPUT	Synthetic gas	Light crude oil, carbon solids for fuel, fertilizers and filters	Char, biochar for soil enriching, bio oil, diesel oil, syngas, steel wire	Syngas, electricity and slag
USAGE	Fuel for gas engines and CHP plants	Sold as crude oil	Fuel for transportation and energy generation, steam	Slag grain is used in construction, metal is recovered and sold, syngas for electric and thermal energy
ADVANTAGES	Clean gas	85% yield efficiency process breaks down hazardous materials	Clean fuel, easier to meet air quality regulations than incinerators	Ecologically clean process, self-sustaining electric power
CHALLENGES	Efficiency is hard to achieve with MSW	Profitability is dependent on the cost of feedstock	Reducing the distance between biomass and pyrolysis facility	Investment cost, high energy required to run the plant
DEMOSTRATED PROJECT	Gussing, Austria and Pitea, Sweden	Carthage, Missouri, USA	Moscow, Russia	9 locations with 5 more projects in development

Table 2: Brief overview of non thermal WTE technologies.

	NON THERMAL TECHNOLGIES		
	ANAEROBIC DIGESTER	**ETHANOL FERMENTATION**	**MECHANICAL BIOLOGICAL TREATMENT**
HISTORY	First digester was built in 1859	Growth for etahnol industry began in late 1970's	First pilot projects were approved by Germany's federal governement
PROCESS	Microorganisms break down bio degradable material in the absence of oxygen	Metabolic process converts sugar to acids, gases and/ or alcohol type of anaerobic digestiion	Combines refuse sorting facility with a form of biological treatment such as composting and industrial waste
FEEDSTOCK	Biomass	Sugarcane, corn, sugar beets, cassova	Curbside refuse
REACTOR	Acetogens and methanogens are introduced in digestor by seeding process	Sugars, endogenous organic electron acceptor, microbes	Mechanical sorting of waste and the biological treatment
OUTPUT	Methane, carbon dioxide, traces of contaminant gases, fertilizers, soil conditioners	Ethanol, lactic acid, hydrogen, heat, carbon dioxide, food for livestock, water	Ferrous/non ferrous metals, plastic, glass. Alternately produce refuse derived fuel (RDF) by using gasifier or incinerator
USAGE	Fuel for CHP units to generate heat and electricity, digestate as feedstock for ethanol production or for making fiberboard	Ethanol is fuel for automobiles and used as an antiseptic, byproducts are used as feedstock for chemical industry	RDF is used in cement kilns
ADVANTAGES	Reduces carbon emissions from landfills	Alternative low emission fuel for automobiles	Waste does not need to be separated, it reduces the use of waste vehicles and keeps the recycling rate high
CHALLENGES	Wastewater from the process needs treatment, contaminant gases need monitoring	Some consider it responsible for rising food costs	RDF is not considered a preferred option by environmentalists
DEMOSTRATED PROJECT	Oakland, California at EBMUD, USA	116 ethanol bio refineries in USA	Sao Sebastio, Brazil

Some healthcare facilities are looking at the alternative resources. The energy projects of Gundersen Lutheren Health Systems discussed in later sections were conceived as a result of that approach.

Interestingly, they are finding out that by investing in energy management projects they are contributing to the health of the patients and the environment while saving money. The indirect advantages include positive public relations, as well as differentiation from competitive healthcare systems.

Resourcing from Communities

An acute care hospital is a community by itself due to its scale and complexity of operations. Most WTE technologies besides incineration need large amount of waste to be cost effective. That is why these operations can benefit from the adjacent residential areas and businesses. A careful review is required for the anticipated amount of waste the entire community would generate. The business model for WTE plant should be such that it does not incentivize the production of waste.

Case study 1

Perkins+Will's concept design for Embassy Medical Systems in Sri Lanka turned to the adjacent community for its energy needs. An anaerobic digester was proposed as a source of renewable energy for the hospital needs. The digester for the project in Sri Lanka was designed to be fed by 50-75 percent sewage and 25-50 percent agricultural residue and organic garbage[13]. The feedstock was proposed to come from the surrounding rural areas on the inland.

The process produces a biogas, consisting of methane, carbon dioxide and traces of other 'contaminant' gases. This would be converted into natural gas that will power the cogeneration plant to generate steam. Steam would produce electricity by turning the turbine. It would then be sent to the absorption chiller to create chilled water. Figure 7 shows the associated logistics of this project.

The project has been presented to the local government and is yet to be built.

It made a powerful statement about the symbiotic relationship between waste and energy for a community meeting its needs by pooling resources.

One of the important lessons learnt from this case study was to understand the dynamics of the community. These projects should have the necessary support from the local leaders and the government.

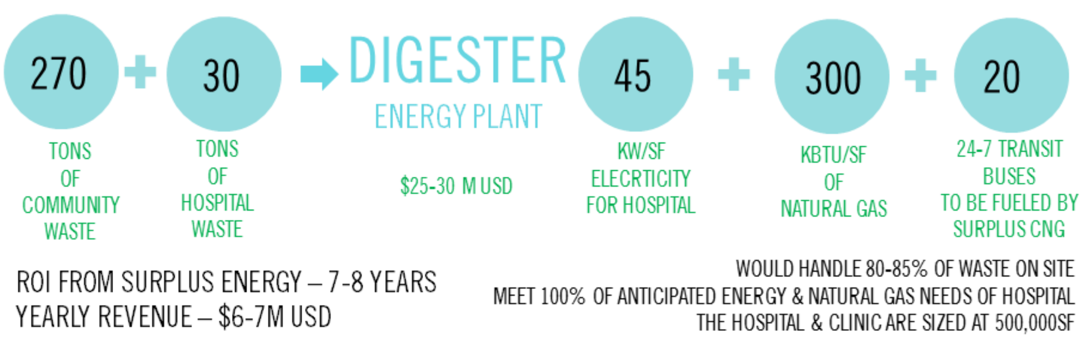

Figure 7: Conceptual diagram showing the operation of energy plant for Embassy Medical Center, Sri Lanka.

Case study 2
A Pyrolysis facility with medical waste and municipal solid waste (MSW) was studied by Phoenix Machinery, Safra for St George Hospital, University Medical Center in Beirut, Lebanon[14].

Lebanon generates about 11 tons of medical waste per day nationally, where 50 percent of it comes from Beirut the and surrounding areas. Most of it is dumped in the landfills without being treated. This has enormous long-term implications on landfill emissions and the health of scavenger population.
After considering various options for medical waste treatment, Pyrolysis was considered the most suitable option for the hospital. It is a controlled process of incineration of waste without the presence of oxygen. This process mainly produces three products:
- Syngas, used for producing steam
- Oil recovered from PVC, used for the generator
- Bio char, used in fertilizers or filters.

Since most of the feedstock is recovered in one of the three forms, emissions from the pyrolysis process are lower than the simple incineration. Additionally the process can be developed to handle a variety of wastes.

The system was designed to treat different wastes such as municipal solid waste (MSW), sewage and oil sludge, automotive shredder residuals, e-waste, rubber and tires, medical waste, plastics, agricultural waste as well as cleaning of the contaminated soil.

Figure 8 illustrates the associated business plan for the facility. For that country the return of investment was only 3.2 years.

3.1 Energy Management Projects of Gundersen Lutheran Health Systems (GLHS)

In 2007 the energy costs were increasing at a rate of $350,000 per year for GLHS. In February 2008, a program called "envision" was developed to achieve 100 percent energy independence by 2014 by its leadership[15]. Most projects that are coming out of this plan currently have multiple levels of engagement with the surrounding communities and local governments.

Case study 3
This was the collaboration between GLHS and a local brewery. The waste water in the brewery was being treated by employing Upflow Anaerobic Sludge Blanket (USAB) digester system which also generated bio gas.

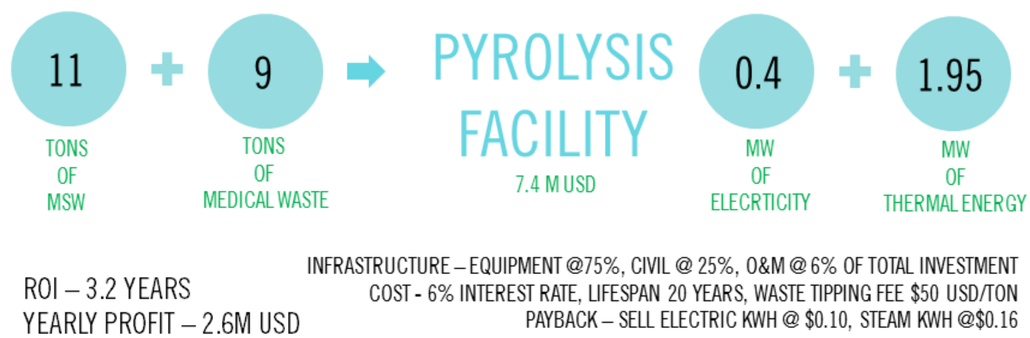

Figure 8: Conceptual diagram showing the operations of energy plant for St. George Hospital University Medical Center, Lebanon.

This was being exhausted to the atmosphere through a flue. GLHS decided to capture it to fuel a Combined Heat and Power (CHP) plant.

There were challenges in terms of controlling the hydrogen sulphide which could corrode the system. A good system of communication amongst various parties kept the project on track. Currently, the electricity is sold to the local utility company by GLHS. The recovered heat from the engine generator and exhaust system heats the digesters, boosting the biogas production levels in the winter months. The treated waste water is sent to the city waste water treatment facility and removed solids are used as soil amendments and/or sent to a landfill.

This is an example of a healthcare entity making an investment in the local community with benefits at multiple levels.

Case study 4
GLHS understood the value of teaming and partnering with other organizations to achieve its energy goals as it started a renewable landfill gas–fired energy project. The early analysis showed that a generator at the landfill site would be the cheapest option to generate electricity. But it would not capture any heat. This heat would be able to offset the thermal loads in the long run for the hospital. There was an opportunity to run a pipe from the landfill site to the hospital campus to transport landfill gases. GLHS reached out to USDOE Midwest Clean Energy Application Center for Research. Their analysis showed that engine generator's exhaust and jacket water system would supply significant portions of space heating and domestic hot water for two of the hospital campus buildings.

In September 2010, GLHS selected a turnkey engineering firm to design and build the landfill gas renewable energy project at their Onalaska campus. It is estimated that the county will collect approximately $300,000 a year from selling of the landfill gas to the hospital, while Gundersen Lutheran anticipated generating $800,000 a year in revenue from selling the electricity to the utility company and in addition realizing thermal energy savings from the recovered heat and avoided boiler fuel consumption.

This is an example of what a public-private partnership can achieve in a community for both its economy and the environment.

3.2 On-site Generation

According to the estimates, it takes 3 kWh of energy to deliver 1 kWh to the consumers. The rest is lost in transmission losses[16]. Current codes require a mandatory resilience for healthcare operations to continue in emergency situations. Hospitals need to have standby power via generators. Some hospitals are investing in CHP plants to have on site source of energy for additional redundancy. This is more efficient since fuel is used to generate both heat and electricity, while eliminating transmission losses. It also allows for better peak load management for utility companies.

The surplus heat and electricity can be sold to the other components of surrounding communities.

With contracts like PPA and EPSC the hospitals just have to provide the space for on-site energy generations systems. The utility company finances, manages and maintains the plant.

A similar contract between Hartford Steam Company, NJ and Hartford Hospital has the following features[17]:

- Provide 1.4 MW Fuel Cell CHP Plant by the year 2013
- Sell excess heat to the local magnet school.
- Low emission and quiet operation.
- Reduction of 6700 tons of CO_2 annually
- Plant will occupy only 2,250 SF of space
- Plant will operate on natural gas at 90 percent efficiency.

With this arrangement the hospital is meeting its own energy needs and also supporting the local school.

Conceptually a project like this could be fueled by waste instead of the natural gas, similar to the GLHS example. The logistics would need to be evaluated for the size of the hospital and the community that it serves.

4.0 CONCLUSION

There is a need to conceive the WTE projects as integral to the development of communities. This would help create local sources of energy, reduce the waste that goes into the landfill and generate local jobs.

The process of waste management is a stepping stone towards production process in nature. By exploring the symbiotic relationships between the waste and creation in various components of the community, we can create developments which may sustain themselves both economically and environmentally.

Healthcare delivery systems benefit from a reliable stand-alone energy delivery system in emergency situations. Recently many of the hospitals are improving their infrastructure in disaster-prone areas. On-site power generation plants are being considered an integral part of this strategy.

The WTE projects take that concept one step further by addressing the problem of waste that the healthcare industry has to deal with on daily basis.

The production of waste is continued even in an emergency scenario. In fact, one of the main issues in disaster situations is the waste management.

This waste can be channeled towards the production of energy as one of the first few things that could be done in these areas. It would be beneficial to a lot of functions that save life or normalize it after the disaster.
The ownership of such WTE system is dependent on the healthcare facility's comfort level with such a venture. Alternatively the contracts like PPA (Power Purchase Agreement) and EPSC (Energy Performance Services Contract) create the desired results without having to undertake the added responsibilities.

The selection of the system is dependent on the available feedstock from the hospital and the adjacent communities. The thermal and non-thermal processes can be combined to create the most efficient system for energy and other by-products.

Pyrolysis can handle a variety of waste with least amount of emissions. MBT promotes recycling without the need for curbside separation of refuge. Non thermal processes convert waste into nutrients for agricultural use. An ideal WTE system would consider the economics along with the population growth and other businesses of the area.

The local authorities and community leaders need to be taken into confidence for the issues relating to the emissions control. There are instances where these projects gain bad reputation due to the lack of proactive measures by the operators.

The next frontier for these projects would be to achieve the resource efficiency that is comparable to the eco systems found in nature.

Acknowledgments
Ajla Aksamija and Kalpana Kuttaiah who worked tirelessly through the multiple drafts of this article and helped guide the direction of research. Rick Hintz and Doug Pierce for providing the valuable data and information from their archives. Breeze Glazer and Blaire McCarry for pointing to the relevant research resources in all these years. Tom Reisenbichler, Kelly Whitney, Randy Hood and Lilla Vessey for supporting my efforts in Dallas office.

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04.
INTERDISCIPLINARY TRAINING IN MEDICAL SIMULATION: *A Comparison of Team Training Courses in Simulation Programs in Hospital Healthcare Systems, Medical Schools and Nursing Schools*

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ABSTRACT
As the area of computerized, high-fidelity medical simulation training has evolved, a new approach has developed centered on an offering of course work in interdisciplinary teams-based learning. This article compares the varied types of team-based training offered at simulation centers in educational institutions and healthcare system-based centers in order to identify how this learning style impacts the simulation spaces we design. The research data is drawn from journal publications regarding team-based simulations and the self-published course offerings and yearly reports of both educational and hospital-based simulation centers. Interdisciplinary learning in simulation is currently more prevalent in healthcare system settings, but has lagged in higher education settings. For students training in health science disciplines, much can be gained by "training the trainers" to provide cross-discipline simulation experiences in higher education settings. As simulation training continues to evolve at a rapid pace, architects and designers will need to future-proof their designs through flexibility.

KEYWORDS: interdisciplinary, experiential learning, inter-professional, medical simulations

1.0 INTRODUCTION

"The basic understanding comes from thinking but deeper understanding comes from experience - putting understanding into action."
- Satish Kaku

Kaku's statement highlights the essence of medical simulation training. Borrowing first from the simulation training model used by the aviation industry to teach and retain pilot skills, healthcare providers adapted simple, low-tech simulation equipment for medical education and practice in the healthcare industry. CPR training with Resuscitation Annie is an example of the first simulation trainers. With the explosive growth of computerized technology, simulation equipment has become more sophisticated, increasing the opportunity for realistic, high-stakes training of medical professionals in a low-risk environment. Parallel to the development of simulation technology, educational models in higher education and professional training are evolving with a greater emphasis on collaborative, or team-based learning.

The concept of collaborative learning is inspiring educators to take simulation a step further from team-based learning within a given discipline to team-based learning among multiple health science disciplines. This approach to education models more closely what happens in a real healthcare setting where healthcare staff work across discipline or specialty. An example of a hospital-based healthcare team might consist of the attending hospital physician, the patient's primary care physician, the nurse, the pharmacist, and the physical therapist. Health care educators are looking for guidelines for the use of high-fidelity trainers in cross-professional education. Institutions for higher learning, however, have traditionally educated health professionals with little cross-pollination among disciplines. There are a few examples, however, for successful integration within some programs or schools. With the integration of technology in the classroom, the use of simulation training has evolved quickly and is becoming a central part of most health science degree programs. The purpose of this article is to review the use of interdisciplinary learning within simulation training in both hospital-based programs and education-based health science simulation centers, including descriptions about what courses are being offered and what disciplines are involved in the team training. A review of simulation design in light of these findings offers opportunities for improved learning environments that integrate interdisciplinary and simulation training.

1.1 Reviewed Programs and Institutions

This article provides a review of a limited number of simulation programs identified for their well-known and distinguished reputation within the field of simulation training. Programs that have conducted and published research in team training, as well as programs that are active in the associations and societies for simulation education have also been identified and reviewed. The most active and influential of these organizations include The Society for Simulation in Healthcare, The International Pediatric Simulation Society, and the National League for Nursing. Research and publications provided by these organizations identified smaller but innovative programs. The programs fall within three categories: Health Sciences Programs, which include Medical Schools and Allied Health Schools, Nursing Schools, and Hospital Based simulation training. The article includes a case study overview of some of Perkins+Will projects for the simulation.

Table 1: The reviewed programs that incorporate simulation training.

Health Sciences Programs	Schools of Nursing	Hospital Based Programs	Perkins+Will Projects
Stanford School of Medicine	Simulation Innovation Resource Center (National League of Nursing)	Mayo Clinic, Rochester, MN, Jacksonville, FL, Phoenix, AZ	Long Island University School of Nursing
Pennsylvania State University	University of Colorado at Denver	Hamad Medical Corporation	Hamad Medical City Simulation Center
Pennsylvania State College of Medicine Hershey	University of Kansas	Texas Children's Hospital	Minnesota State University at Mankato, School of Nursing Simulation Department
The Johns Hopkins University School of Medicine	St. Mary's Medical Center for Education	Cleveland Clinic	Mayo Clinic, Jacksonville, FL
Harvard Medical School	Texas Tech University	The Johns Hopkins Academic Medical Center	

2.0 THE THEORY OF EXPERIENTIAL LEARNING

Simulation training is learning by doing, or what is formally known as experiential learning. The theory of learning by doing, or experiential learning, suggests that learning is a holistic, integrative perspective that combines experience, perception, cognition, and behavior[1]. The techniques of action research and the laboratory method have long been in place in health science education. This process of learning begins with here-and-now experience to validate and test abstract concepts and skills. Action research and training are based on a feedback process, which helps learners understand how impulses, feelings and desires are transformed into concrete purposeful action. This is the central premise of military and aviation simulation training, which now also informs medical simulation training. In this approach to learning, attributed to Dewey's model of experiential learning (Figure 1), the impulse of experience gives ideas their moving force. Postponing of immediate action allows opportunity for observation and judgment, resulting in more purposeful action. This cyclical pattern, coupled with the feed-back loop (simulation debrief), is fundamental to the repeated, patterned experiences of medical simulation training. "Learning by doing" results in the adaptation of abstract learning into action, and a continuous transformation where learning is created and recreated[2].

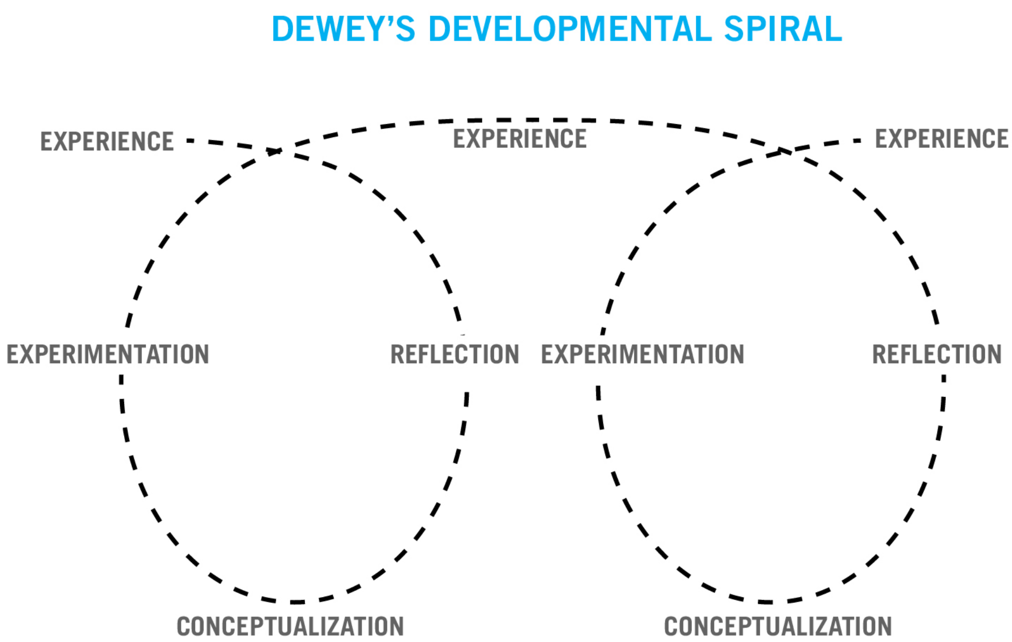


Figure 1: Dewey's model of experiential learning.

Medical simulation training scenarios also consider the emotional impacts of patient care, which are often intensified in team-based events. Russell and Barrett's Circumplex Model of Emotion (Figure 2) graphically demonstrates the experience of active doing and emotion, resulting in imprinted learning. Simulation scenarios often involve conflict, unexpected symptoms, or life-threatening events, which require the learner to observe, process, judge, and act based on previously learned or rehearsed skills. This process of experience, emotion, and imprinting is the framework for comprehensive learning in the medical simulation curriculum. By providing team-based, interdisciplinary training scenarios, a program offers a more accurate model of an actual healthcare setting, where interpersonal dynamics, hierarchy, and team roles are all a part of the complex, emotional environment in which healthcare professionals function.

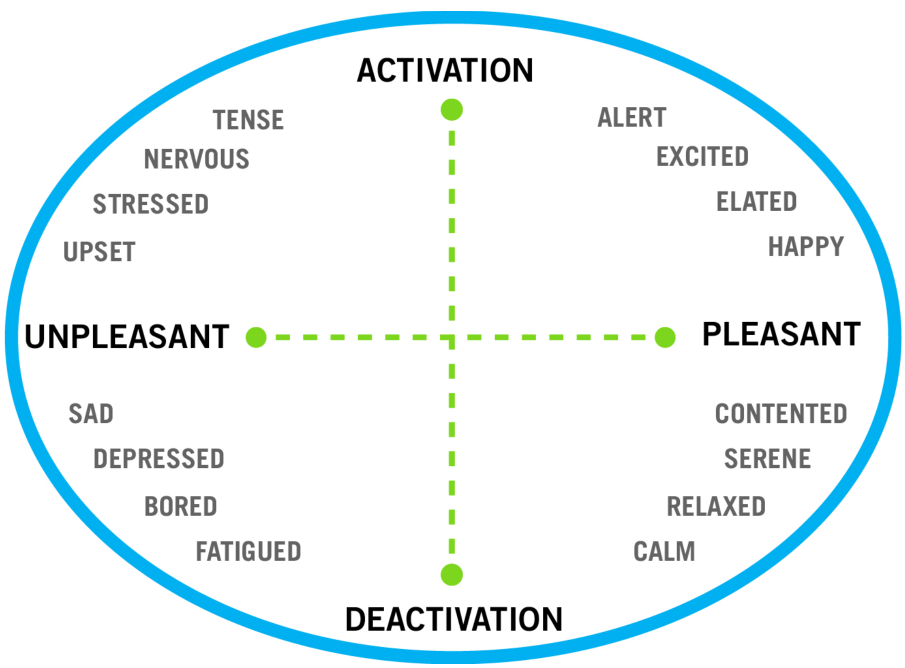


Figure 2: Russell and Barrett's circumplex model of emotion.

2.1 The Value of Cross-Discipline Simulation Training

The simulation setting now goes beyond the implementation of basic task simulators to the use of sophisticated, realistic high-fidelity simulation mannequins, known as Human Patient Simulation (HPS) or High-Fidelity Simulators (HFS). HFS is defined as a replicated clinical experience using a computer-driven full-bodied simulator with physiological responses to interventions. The simulations occur in a realistic context that emulates an actual clinical scenario and incorporates visual, tactile, and auditory cues[3].

For the purposes of focused education, the health science degree programs have traditionally taught and trained within a segregated model, offering courses for each degree track without cross-pollination of other majors. Often the course schedules for health science colleges offer foundation courses and skill-training that are required by multiple disciplines, but for each vocational major--for example, nursing, radiology technology, or respiratory therapy by itself. Classes for the same core fundamentals in other disciplines are offered separately in the schedule. Once students enter the actual healthcare environment, however, they discover that patient care is delivered by a team of health professionals. Effective patient care and patient safety require that healthcare professionals understand their individual disciplinary roles within the team, and demonstrate communication skills to enhance team function. Simulation training allows students and healthcare teams to "practice on plastic" without risk of harm to an actual patient.

2.2 Program Comparisons in Medical Schools

The most extensive and impressive simulation facilities available tend to be located in higher education settings. Several medical schools—Johns Hopkins University School of Medicine, Stanford School of Medicine and Harvard Medical School—boast well established, high-tech centers that cater to the training needs of medical school students, residents, and surgeons. The size of the facility and the prestigious reputation of the educational institution does not, however, consistently correlate with well-developed, thriving interdisciplinary training.

At Harvard and Stanford, the simulation training emphasis is on the medical school without evidence of professional staff training in association with the academic medical center affiliated with each school. Both schools use a physician-centric model focusing on training, for example, anesthesia crisis resource management, emergency medicine crisis resource management, active resuscitation, evaluation and decision making. Both programs, however, were early pioneers for medical simulation training; Stanford's program was founded in 1986 and Harvard's center opened in 1993[4]. The focus of simulation within each institution's medical school may be a result of their long established simulation programs, and the model they have for training physicians seems to be working for them.

Harvard has a robust outreach program for "training the trainers." Their program for training simulation instructors has an international reach and offerings in multiple languages. International offerings in 2013 were located in Australia, Hong Kong, Singapore and Spain[5].

In contrast, the Simulation Center at Johns Hopkins functions as part of a partnership between the school of medicine and the Johns Hopkins Hospital. The Simulation Center provides training for both current health care professionals and future professionals. Standard course offerings are designed to be team-based. Current required courses include, for example, "OB/NICU Team Training" and "Difficult Airway Management for the Interdisciplinary Team." The proximity of the center to the Hospital's services may enhance the interaction between the inter-professional staff of the hospital and the medical school; the simulation center is located in the outpatient building on the hospital campus[6].

Of the investigated schools, Pennsylvania State College of Medicine Hershey offered the strongest program in cross-discipline training. This program is relatively new, started in 2010. Course offerings include "Resuscitation Training as Part of a Team," as well as graduate nursing courses designed to promote teamwork and team communication in critical care areas. One of the most interesting offerings is a course called the "First Four Minutes." This is a teamwork-based simulation focused on emergency care. Pennsylvania State requires this course of all residents, nurses, and respiratory therapists every two years. Outreach to the larger medical community is a another strong component of this center. Four courses are offered to healthcare professionals: "Introduction to Simulation," "Teaching with Simulation," "Using Simulation for Assessment," and "Simulation Technician Training." For the non-professional community, the center offers a hands-on CPR training course, and a youth apprenticeship program. The center also hosts a "Resuscitation Academy for EMS managers" in south-central Pennsylvania[7].

2.3 Program Comparisons in Schools of Nursing

Nursing represents the largest group of health care professionals. Most nursing students are trained within the confines of their disciplines with limited access to inter-professional education (IPE). Yet, all levels of nursing education standards currently include requirements for inter-professional collaboration[8]. The Quality and Safety Education for Nurses initiative lists teamwork and collaboration as one of its six core competencies[9]. The National League for Nursing, in recognition of this goal, has developed a course for nursing educators called "Sim-Based Inter-professional Education." The course is designed to help the faculty learn basic terminology in inter-professional (or interdisciplinary) education, and the specific competency domain that can be addressed in inter-disciplinary simulation[10]. In 2012, The National League for Nursing facilitated a think-tank for inter-professional simulation training in nursing schools.

At the University of Colorado at Denver, weekly team-based simulations are mandatory for students in all health profession programs. These programs include nursing, medicine, pharmacy, physical therapy and dentistry. One such program involves patient-mentors who guide the team to better understand the experience of health and illness.

The University of Kansas has limited access to a pediatric patient population, so students complete 25 percent of their pediatric clinical rotation in simulation. Inter-professional simulation that uses an electronic medical record connects student disciplines. Medical students review a pediatric patient's chart, use the electronic order entry process, and write orders to admit the patient. Pharmacy students located 40 miles away retrieve the orders, verify the medications, and assign medications ordered to products in the formulary. Nursing students review the case before meeting in the simulation lab with medical students and pediatric residents to proceed with the scenario.

At St. Mary's Medical Center for Education in Huntington, West Virginia, students in nursing, medical imaging, and respiratory care meet weekly for a clinical learning day. Students rotate through simulation assignments as an inter-professional emergency response team.

Texas Tech University uses the TeamSTEPP training designed by the Department of Defense to teach techniques in team leadership, situational monitoring, mutual support and communication. The skills are then used when participating in other cross-disciplinary simulation scenarios. Texas Tech also runs simulation for integrated communication skills with EMS personnel, nurses, residents, fellows and students to improve trauma patient care[11].

2.4 Program Comparisons in Hospital-Based Simulation Centers

Consistently, hospital-based simulation centers provide more simulation programs to interdisciplinary teams. At Mayo Clinic, multi-discipline teaching is integrated at each hospital location. Most courses involve team-based training for resuscitation, airway obstruction, trauma events, and quality and safety. Each location supports training for medical students and residents, allied health professions, nursing, and staff. In Florida, family and patient care-providers are trained for care of geriatric home health needs following hospital discharge[12]. Mayo Clinic's current published scenario library offers over 60 team-based scenarios for adult care. A similar volume is offered for team-based pediatric care[13].

The Texas Children's Hospital Pediatric Simulation Center focuses on crisis management in pediatric care. Team based simulations are offered in Mock Code, Advanced Life Support, Labor/delivery and Resuscitation and Neonatal intensive care Advanced Procedure Skills Training. Scenarios are multi-discipline based with demonstration of roles and responsibilities, and with communication skills center stage in the simulation scenarios. Courses for delivering a new diagnosis and bad news are part of the center's offering, providing staff the opportunity to practice communication skills in a low-risk environment[14].

The Cleveland Clinic simulation center is also multidisciplinary and provides published scenario lists for adult and pediatric care. Most courses are team-based, focused on emergency care, critical care, the operating room, and the outpatient clinic[15].

The Johns Hopkins Hospital uses the Johns Hopkins University School of Medicine simulation center for interdisciplinary training. Scenarios focus on communication, roles and responsibilities, and technique in emergency, trauma, and critical care scenarios[6].

3.0 OPPORTUNITIES FOR DESIGN FOR INTER-DISCIPLINARY EDUCATION: CASE STUDIES OF PERKINS+WILL PROJECTS

Consistently, healthcare clients and higher education clients endeavoring to design and build new facilities for medical simulation express an interest in inter-disciplinary education opportunities. They know they want a center that provides opportunity for future curriculum development and expansion, but they have a hard time imagining what that development might become, or how to design for it. Flexibility is the key attribute that clients request. While this article focuses on flexibility in planning and stacking, it is important to note that providing a flexible infrastructure is equally important to the facility. Partnering with experienced engineers for the design of audio visual and information technology components is of great importance in safe-guarding opportunities for new equipment and teaching methods.

All simulation center space programs include classrooms and briefing rooms, and simulation rooms that represent different kinds of patient care spaces, for example, inpatient rooms, exam rooms, operating rooms, and trauma rooms. All simulation programs provide support spaces for the training, including supply and storage rooms, observation rooms, and control rooms. Providing “in between” spaces where students and teams can interact before and after a training event encourages interdisciplinary interface, “in between” spaces refer to those types of spaces where spontaneous peer-to-peer exchanges of information and learning occur. These can be study spaces and social spaces. How the designer organizes the building circulation can provide opportunities for spontaneous interaction. How the program is zoned or stacked in the building should be considered. By providing adjacencies that encourage use of the building in ways that co-mingle multiple disciplines, interdisciplinary interaction is increased.

3.1. Case Study 1

Programming analysis for the Minnesota State University at Mankato was developed for a new clinical sciences building by Perkins+Will. The project has had a long evolution with several iterations of a new college of allied health and nursing building dating to the late 1990’s. Paulsen Architects originally established a basic project vision and space needs. In 2005, HGA prepared a pre-design report, developed the space program with more comprehensive space needs and room criteria. Due to construction constraints, the program was reduced and focused on clinical laboratory spaces. In 2012, Perkins+Will was engaged to provide complete design services, including program verification for a new clinical sciences building. The project goals, established with the client, center on fostering inter-professional interaction and collaboration, and providing flexibility in the built environment.

A portion of the visual space program is shown in Figure 3. A separate grouping identifies opportunities for shared spaces used by all allied health science disciplines. The design team has included shared meeting rooms, hoteling space for faculty, and break out learning areas called integration stations. A large portion of the program (approximately 36 percent) has been identified as shared space. This program is zoned together to encourage peer-to-peer learning and increased efficiency. This co-habitation allows for ownership of specific simulation spaces, and shared interface for foundational skills learning. By co-locating the simulation spaces for shared scheduling, team based scheduling is encouraged. In this model, opportunities for spontaneous sharing and collaborative learning between majors are increased.

Construction documents have been completed in November 2013, and the project is scheduled for completion in January 2016. Post occupancy studies are recommended in an effort to quantify collaborative inter-disciplinary interface and training.

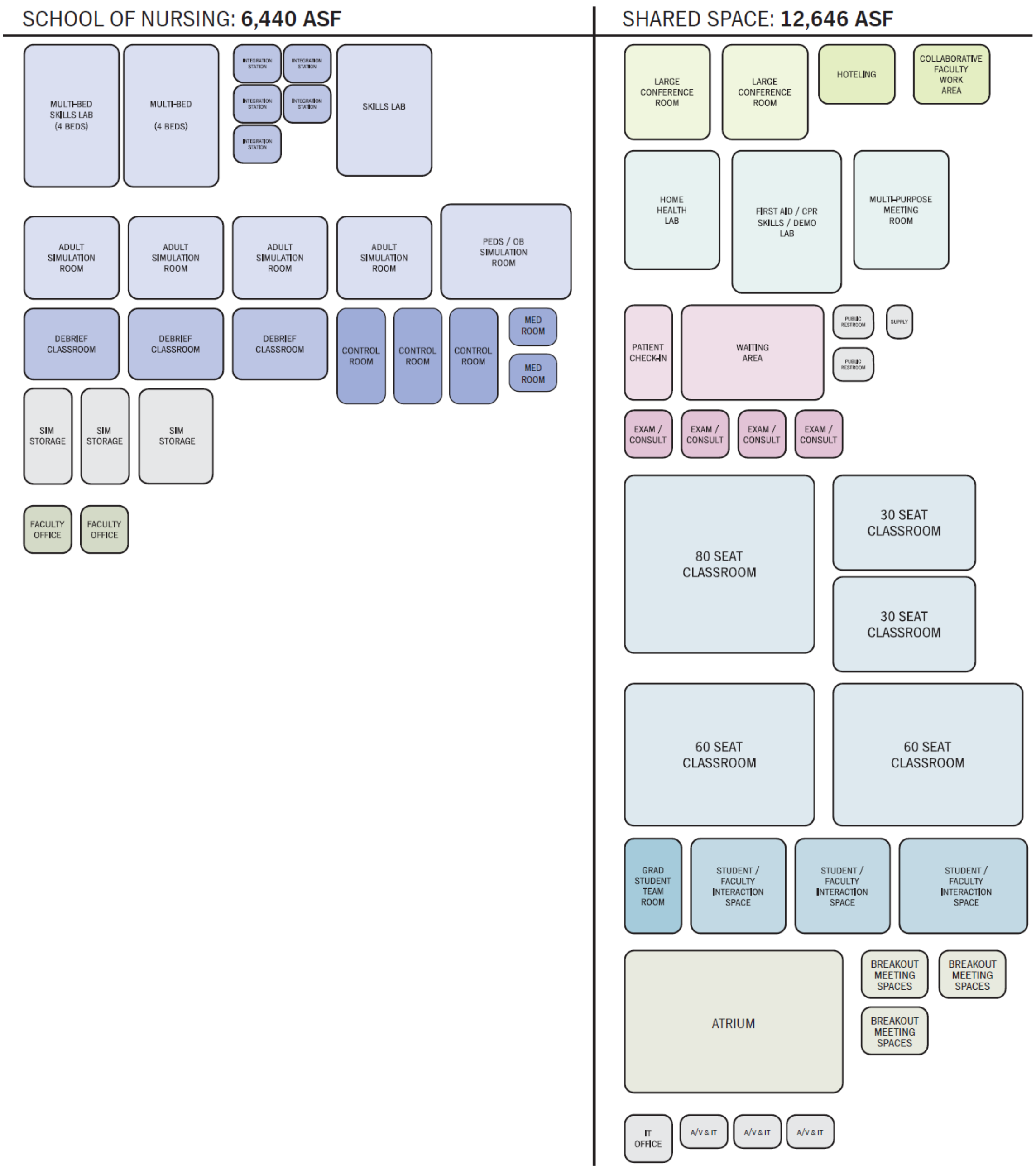


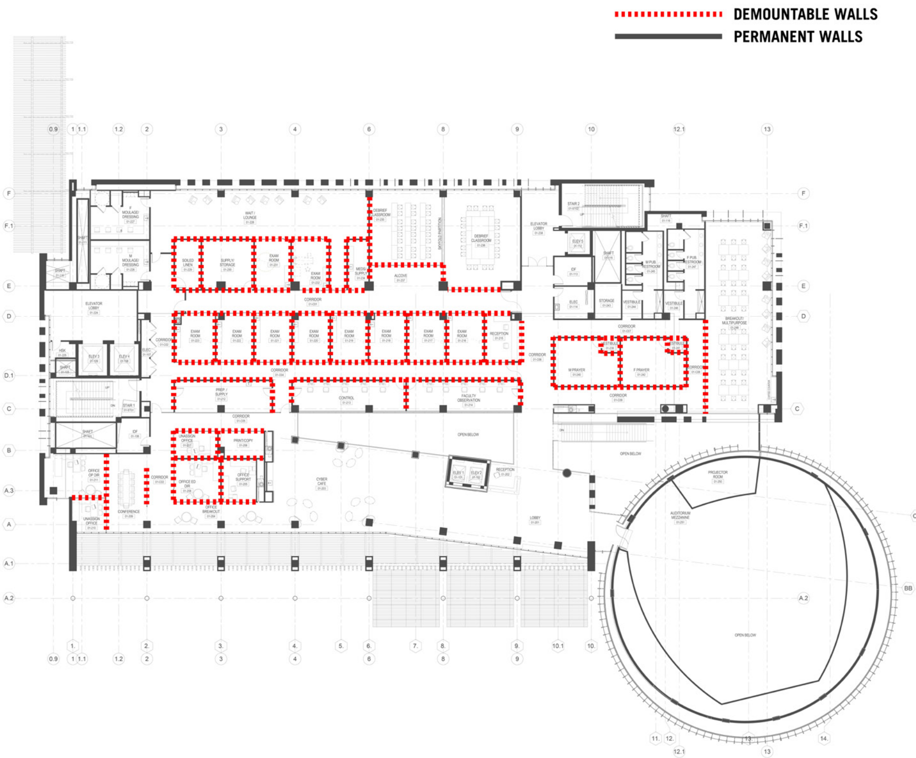
Figure 3: Minnesota State University at Mankato, visual space program for nursing and shared program.

3.2. Case Study 2

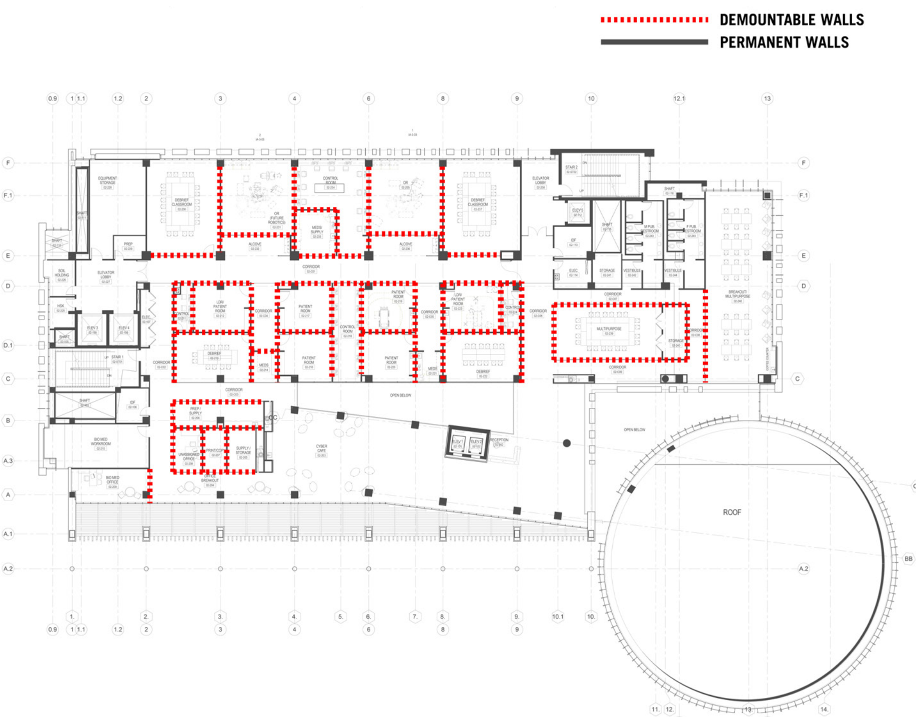
Not dissimilar to the Minnesota State University project, the program for the Hamad Medical City evolved over time with changing needs and educational trends. Originally, the center was envisioned as a dedicated skills lab and simulation suite for nursing with a total program size of 1500 square meters. Over time, the program reach increased to include training spaces for multi-discipline learning. This change in scope resulted in a final program of 14,000 square meters, which ultimately inhabited the full existing structure of the education building intended for the simulation center, as well as a significant expansion of the building. The center is now designated as a training space for nurses, allied health teams, medical residents, and surgeons. The final user group included attending physicians and medical directors for the hospital's emergency department, cardiac, critical care and surgery units, as well as nursing staff. In order to emphasize the cross-disciplinary nature of the new center, Perkins+Will created a central spine through the building to enhance the visual connection between program spaces. Student lounges, study spaces and classrooms were stacked on each floor to provide opportunity for cross-discipline interface before and after simulation events. Because the healthcare system felt that the program would continue to evolve, a demountable partition system accounts for the majority of the plan partitions, offering maximum flexibility for reconfiguration. Traditional partition systems were used only where life safety exit required smoke and fire barriers. The wall system manufacturer was selected because of their offerings in both robust lab walls and sleek corporate powered and glazed systems (Figure 4). By merging these two product lines, Perkins+Will was able to provide designated mechanical chase walls to house plumbing and medical gas infrastructure, solid powered walls carry power and data connections. Glazed partitions on the corridor side of most spaces offer transparency. This feature was important to the client. A priority project goal was to provide visibility through the floor plate, creating a stage for live theater. This attribute is intended to provide a layer of learning for those passing through the space. Deep alcoves were planned as a related feature in the corridors outside of classrooms, skills labs, and operating rooms to provide spaces for student groups to gather and observe in real time.

To enhance flexibility, the building was planned on a module grid to work with the existing column structure. This allows the demountable partitions to be fabricated in a few standard widths for ease of future reconfiguration. This module was designed into the ceiling plane as well. To allow for future reconfiguration of the partition system, a techzone ceiling system was used throughout the building with lighting, HVAC diffusers and returns, and sprinklers integrated into the 6” band or technology module, which repeats every 6’-0” throughout the ceiling plan. To further accommodate flexibility in the learning environment, classrooms were located adjacent to one another with automated operable partitions between the rooms. This allows the classrooms to flex from 40 person rooms to 100 person rooms for large lecture (Figure 5).

The Hamad Medical City Simulation Center is currently under construction with completion scheduled for January 2015. First post evaluation studies will include review of the ease of installation of audio visual and IT systems for initial occupancy. Review of the ease of reconfiguration is a future goal.

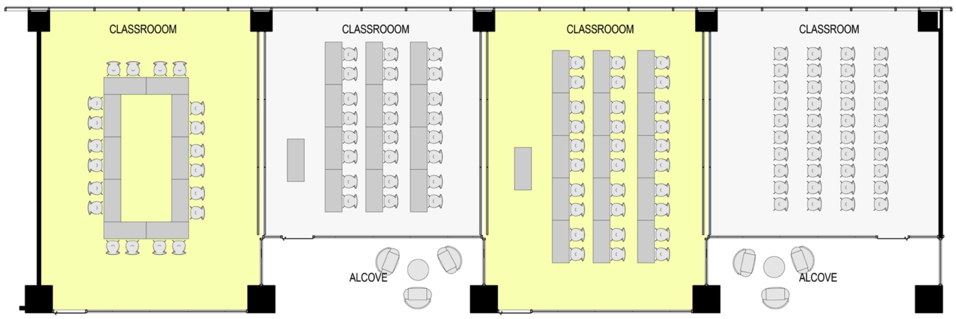


Second Level



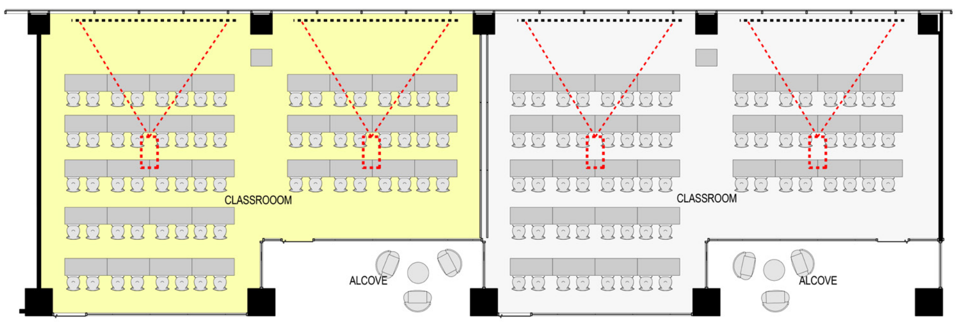
Third Level

Figure 4: Hamad Medical City Simulation Center, partition diagram of demountable walls and permanent walls.



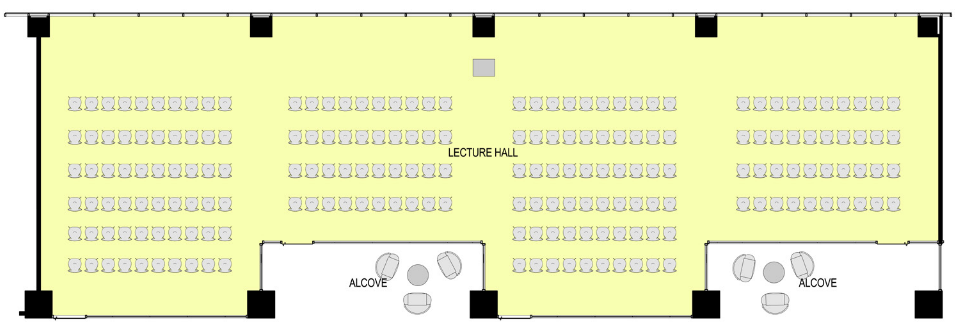
20 SEATS 24 SEATS 30 SEATS 40 SEATS

Option A: Individual Classrooms



64 SEATS 64 SEATS

Option B: Paired Classrooms



200 SEATS

Option C: Large Lecture Classroom

Figure 5: Hamad Medical City Simulation Center, classroom adjacencies.

3.3. Case Study 3

In Rochester, MN, the Mayo Clinic client group had years of experience in simulation training. The new center in Jacksonville, FL was designed to accommodate a similar course offering and operational plan. This multi-discipline center opened in January of 2013. The center is located in an outpatient office building near the main hospital and occupies 75 percent of the floor plate, with another tenant leasing the remaining 25 percent of the floor. The project was planned with expansion in mind, providing the opportunity for growth when the remaining square footage becomes available to lease. The client provided a program for training spaces, but did not include space for spontaneous interaction of staff and trainers. Perkins+Will provided this added enhancement, increasing the corridor width to accommodate break out space and equipment staging. By shifting the training program off the curtain wall and toward the core, the corridors are flooded with daylight. As a result this double duty circulation space has a nicer quality and is not perceived as a corridor (Figure 6).

The space has proven to be adaptable. The education team has successfully used the flexible classroom spaces for training events that were not originally intended, including task training and tray work. The center has also been used for patient family training for patient discharge. This user group was not originally intended to use the center.

As a result of these unanticipated opportunities, the team has identified areas for improvement. The training technicians find that they are doing much more intensive preparation than they originally imagined. The preparation room, equipped with standing height cabinets and storage, does not provide opportunities for seated work, which would relieve fatigue during prolonged preparation. In addition to the general lighting in the preparation spaces, adjustable task lighting would have been beneficial. Decentralized preparation supply was not programmed. The staff meets this need by using movable procedure carts. Deeper alcoves to accommodate this function immediately adjacent to simulation rooms would have been useful. The multi-purpose classrooms were carpeted at the client's request. The training events that are occurring in these spaces are often messy and spills have resulted in increased maintenance. An easy to clean resilient surface floor would have been a better choice for these spaces.

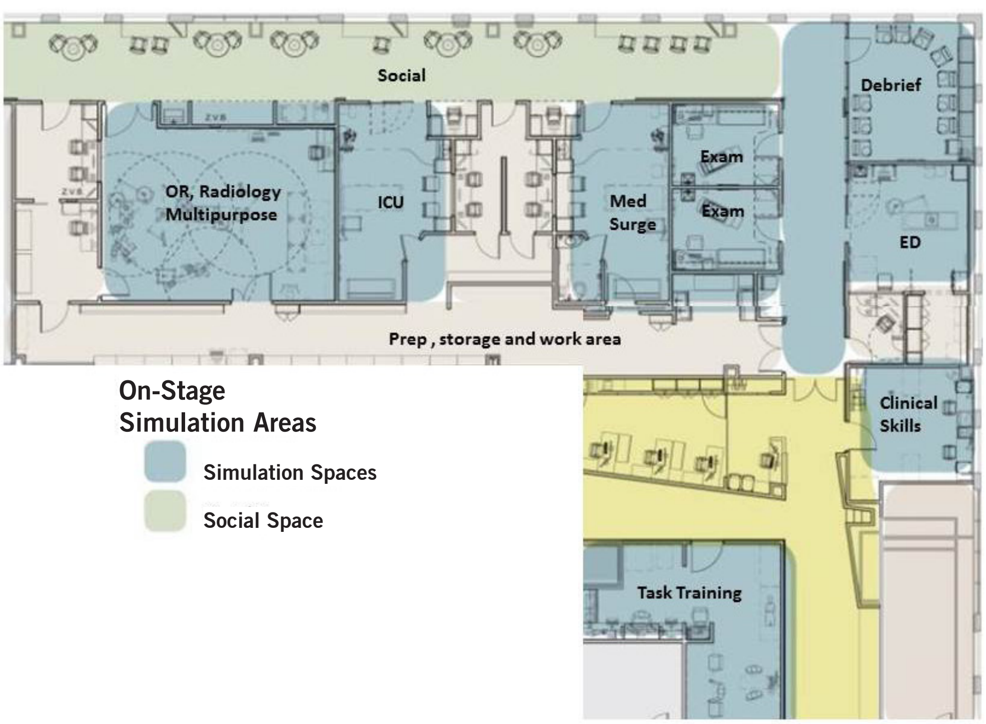
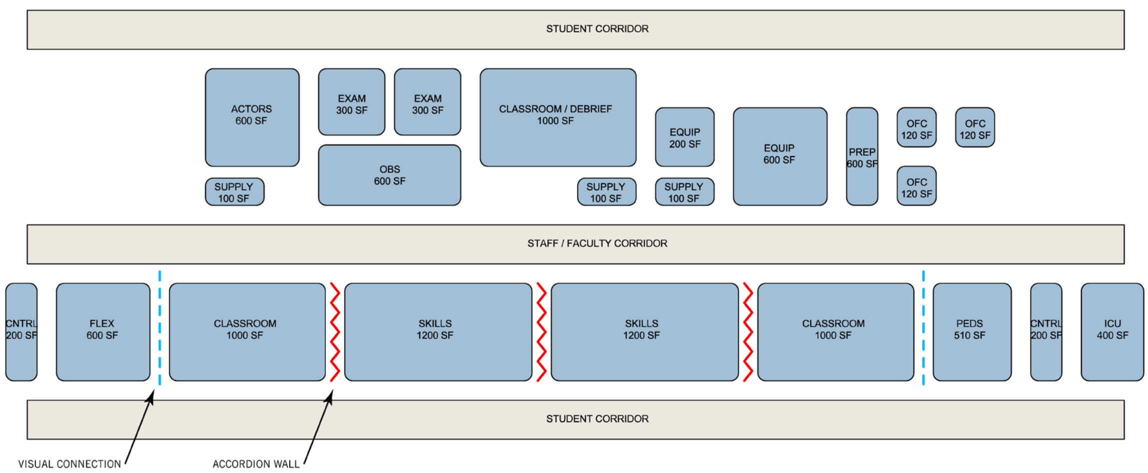


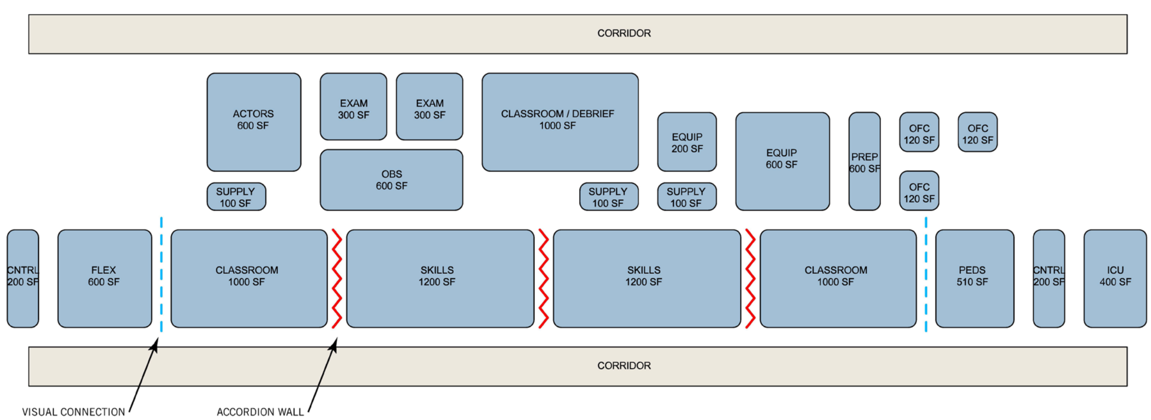
Figure 6: The Mayo Clinic Simulation Suite, Jacksonville, FL.

3.4. Case Study 4

The Long Island University School of Nursing in Brooklyn has engaged Perkins+Will for design services for a new school and simulation center to open in late 2014. The school's faculty is currently engaged in an initiative to integrate the health science disciplines through curriculum for simulation. While the simulation center will be part of the school of nursing, course offerings for inter-disciplinary training are under development, but not yet fully formed. Studies most recently developed for the school considered visual connection and flexibility using mobile partitions between skills labs, classrooms and skills labs, and classrooms and simulation rooms (Figure 7). Fundamental skills nursing labs and classrooms will be grouped together on one floor of the building with the simulation center zoned for a separate floor. This stacking will allow the center to serve as a destination for all health sciences disciplines on campus.



Option A: No separation of faculty and student circulation



Option B: Separation of faculty/actor and student circulation

Figure 7: Long Island School of Nursing, adjacency studies for classrooms, skills labs, and simulation rooms.

4.0 CONCLUSION

The current body of literature addressing inter-professional team-based learning in medical simulation training suggests increased assimilation of team training in hospital-based centers, and those centers in higher education that share space with an academic medical center program. The team-based culture prevalent in actual healthcare, fosters a commitment for learning together. In higher education, nursing schools are driving some of the most innovative inter-disciplinary programs in response to core competency requirements of accrediting agencies. The literature confirms the author's previous assumptions regarding challenges in implementing team-based learning within the higher education environment. Challenges to be overcome include scheduling across multiple programs, co-locating programs, to integrated learning programs across departments.

Integrated, experiential learning is being adopted as an important tool in the competitive healthcare and education market. Healthcare reform and care reimbursement criteria create greater pressure for healthcare systems to improve quality and patient safety. Confirmation that the field of medical simulation is growing, and evolving at a very rapid pace demands that the design profession continue to develop solutions for flexibility, modularity, and collaboration in programming, planning, and design implementation. Development of prefabricated headwall systems, plug-and-play headwall systems, modular systems for camera, audio, and IT are all areas for potential development. Exploration of raised flooring and modular ceiling systems in simulation spaces will further enhance the adaptability of these systems for future technology.

Acknowledgments

Minnesota State University at Mankato: Perkins+Will, Minneapolis office. Hamad Medical City Simulation Center: Perkins+Will, Atlanta Office. Long Island School of Nursing: Perkins+Will, New York Office. Mayo Clinic Simulation Center, Jacksonville, FL: Perkins+Will, Atlanta Office. Thanks to my colleagues in these offices who have shared their work and knowledge to better the area of simulation across the firm. And special thanks to Dr. Michael Seropian, SimHealth Consultants, whose knowledge of simulation learning has impacted many of these projects.

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05.
A ZERO NET ENERGY BUILDING PILOT STUDY:
Low Energy Strategies for Weygand Residence Hall at Bridgewater State University

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ABSTRACT
Residence Halls provide a unique educational opportunity for students, since they can learn about and experience a lifestyle that embodies sustainable practices and engages them as active participants in reducing energy use for the building. The Massachusetts State College Building Authority (MSCBA) and Bridgewater State University (BSU) took advantage of a Zero Net Energy Building (ZNEB) pilot study to research design strategies and building systems that will advance the planning and design of future residence halls. Perkins+Will led a collaborative design and construction team, which included Rist Frost Shumway Engineering and Bond Brothers Construction. Working closely with MSCBA and BSU, the team developed a detailed case study that ultimately led to successful identification and implementation of low energy strategies for the Weygand Residence Hall at BSU.

This article defines the framework and decisions that were made at each step of the journey from conceptual design and projected energy calculations to building operations and maintenance. A ZNEB requires significant energy load reductions by implementing energy-efficient design strategies, including the optimization of building envelope, smart and efficient system selection and a renewable energy generation plan. High occupancy and significant energy demand in residence halls necessitate consideration of new ideas about energy consumption as well as policy changes to enable paradigm shifts in user behavior to reach a ZNEB goal. This study positioned BSU to implement several strategies that reduced energy consumption at Weygand Hall and provided lessons learned for future residential hall designs.
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KEYWORDS: zero-net energy building design strategies, building performance, residence halls

1.0 INTRODUCTION

1.1 Zero Net Energy Pilot Study
Simultaneous with the project design for Weygand Residence Hall for Bridgewater State University (BSU), the project team conducted a Zero Net Energy Building (ZNEB) pilot study. The purpose of the study was to answer the question: what would it take to make this residential hall a ZNEB project? With ZNEB as an inspirational goal, the team focused on researching low energy strategies pertinent to residence halls. We identified challenges of getting to ZNEB in this particular building type, and prioritized incorporating strategies that maximized energy efficiency within budget. Our measure for success was trifold: identification of challenges and opportunities using new and proven technologies, implementation of low energy strategies supported by energy modeling and cost analysis, and clear documentation of the process to help MSCBA understand lessons learned to overcome similar challenges in a future residential hall with a ZNEB goal. This study led to a comprehen-

sive investigation on the energy consumption for Weygand Hall. Working in collaboration with MSCBA, BSU, consulting engineers, and the contractor, the study's methodology followed four overarching steps toward energy reduction: 1) minimizing building loads (passive strategies), 2) maximizing energy efficiency (active strategies with mechanical, electrical, and plumbing systems), 3) generating renewable energy on site, and 4) reducing energy consumption from a building's operation perspective. Of these four steps, it is important to understand that the first three are driven by design decisions, while the fourth step is defined by operational decisions. In establishing these four steps, the process was holistic from the beginning, involving design and operations throughout the discussions.

This project was literally a platform for testing new technologies and measuring performance. Aside from the educational value of the study, MSCBA and BSU had great interest in implementing sustainable strategies investigated. Being able to leverage this knowledge for future residential halls led to rigorous analysis of strategies, including energy modeling, life cycle cost and simple payback analysis (Figure 1). When the project began in early 2011, no published ZNEB residential halls existed (and still to this date do not exist). Our key literature resources were mainly European. The book *Net Zero Energy Buildings: International Projects of Carbon Neutrality in Buildings,* by Karsten Voss and Eike Musall gave the team a great overview of low energy strategies for small to medium residential projects[1]. None of the examples were actual residential halls and none achieved ZNEB but many of the synergies between efficient building systems and low energy strategies allowed our team to envision ideas for testing and analysis. This book became a wealth of precedent studies to revisit when our own explorations seemed failed. The design team also looked closely at the Passive House Institute, especially for envelope strategies such as super insulation and keen attention to wall and window interface details[2]. For life cycle analysis methodology, the team referenced *A Life Cycle Approach to Buildings: Principles, Calculations, Design Tools* published by Detail Green Books[3]. This resource helped us understand different approaches for life cycle assessment as they relate to design, economics and tools. It was with this understanding that the team decided to create a succinct payback spreadsheet to track upfront cost, energy and utility cost (not published in this spreadsheet version) and life cycle cost. Several iterations of this spreadsheet were analyzed, and it became a valuable design tool to make decisions based on energy efficient synergies between strategies, the integration of systems, and the cost value to the project. With energy modeling calculations that considered energy demands for the building, the engineering team was able to analyze yearly energy reductions produced by the different strategies. Then, the contractor's cost estimating team, assigned first cost value to each strategy which allowed the team to calculate payback in years. While the engineering team focused heavily on energy aspects and making sure the energy model data was accurate, the contractor was able to offer envelope and detailing suggestions that are not explicitly considered by energy model software. The chart below illustrates the final iteration with accepted strategies. The lower portion of the chart lists renewable strategies being considered that will get the building to ZNEB. The two main strategies analyzed are a Photo-Voltaic (PV) panel array and a Wind Turbine. Both remain under consideration for the project: the PV panel array strategy requires additional surface beyond the PV-ready building roof, while the Wind Turbine (currently under study) would be located at the top of an adjacent campus hill to capture prevailing winds. Early iterations of the chart included strategies studied, but not accepted. These were: super insulation, triple layer glazing, interior light shelves to harvest daylight, natural (non-continuous) restroom exhaust and suite ventilation, and plug load controls. The rejection of these strategies is discussed in Section 2.

There were three tiers for prioritizing the acceptance of strategies. Priority was given to strategies with minimal upfront cost impact (these were mainly passive strategies), second priority focused on energy efficient system (the valance and geo-exchange combination proved to be most energy efficient through energy modeling and design), and third priority considered impact to user behavior, such as the window kill switch strategy and the policy change to ban individual micro-fridges in the suites.

1.2 Energy Challenges in a Residential Hall

Residential halls consume high levels of energy because they are occupied 24-hours a day, 7-days a week, unlike an office building. In this case, the project includes 500 new beds of student housing and a new location for the Wellness Center. The inherent high energy use of the program offered economy of scale for systems and energy conservation ideas. In the following section we discuss how we took advantage of this economy of scale to reduce energy loads (Figure 2).

Other energy challenges inherent for this building type can be addressed through plan layout and building shape. For instance, residential halls are typically or-

ACCEPTED STRATEGIES *Strategy Description*	*upfront cost - ACTUAL*	*% of project budget*	*annual $ savings*	*payback (yrs)*
Geo-exchange Heat Pumps 63 Closed Loops	$ 764,190.00	1.47%	$ 34,526.00	22.13
Valances compared with fan-coil system	$ (419,364.00)	0.00%	$ 10,574.00	0.00
Shower Drain Energy Recovery 35 plumbing stacks	$ 72,000.00	0.02%	$ 10,000.00	7.20
Lighting Efficiency 27% reduction from baseline	$ 82,000.00	0.04%	$ 19,535.00	4.20
Improved Wall & Roof Insulation R-29 Walls, R-49 Roof	$ 241,953.00	0.04%	$ 3,326.00	72.75
Improved Glazing 0.22 U-Factor, 0.44 SC	$ 49,198.00	0.01%	$ 13,728.00	3.58
Fiberglass Window Frames	$ 1.00	0.00%	$ 4,078.00	0.00
External Shading heat mitigation	$ 141,732.00	0.00%	$ 1,578.00	89.82
Window "Kill Switches" prevents energy waste	$ 105,000.00	0.20%	*	*
Temperature Set Points (82° F / 68° F)	$ 1.00	0.00%	$ 20,624.00	0.00
No Micro-fridges	$ 52,942.00	0.03%	$ 15,981.00	3.31
Comprehensive Accepted Building Strategies	**$ 1,089,653.00**	**2.10%**	**$ 133,950.00**	**8.13**

UNDER STUDY - TO GET TO ZNEB *Strategy Description*	*cost - ESTIMATED*	*% of project budget*	*annual $ savings*	*payback (yrs)*
PV Panels - Weygand Hall Roof Only	$ 1,224,500.00	2.35%	$ 40,376.00	30.33
PV Panels - ZNEB Potential	$ 9,500,000.00	18.27%	$ 314,261.00	30.23
Wind Turbine	$ 4,752,000.00	N/A	$ 747,804.00	6.35

Notes:

1. *Based on $52M project budget, bid in 2012, union labor rates located in Bridgewater, Massachusetts*
2. *Accepted strategy costs are derived from actual project data and reflect dollar increase of material above base code*
3. *kBtu/SF/yr refers to "site" energy consumption*
4. *Based on 50% reduced occupancy during summers*

Figure 1: Cost Analysis Matrix—This chart was continually updated to track strategies throughout the ZNEB study. Energy modeling was used to determine projected payback and the contractor provided up front cost information. This iteration uses as-built numbers and payback calculations for accepted strategies.

ganized with a double loaded corridor, restricting daylight access into the corridor. Minimizing Lighting Power Density (LPD) is extremely important for energy reduction; thus the design concept for Weygand Hall is based on a courtyard, surrounded by the living-learning pods oriented along single-loaded corridors with study spaces. The porosity of the courtyard is an important aspect of the student's experience and also help extend natural light deeper into the building (Figure 3).

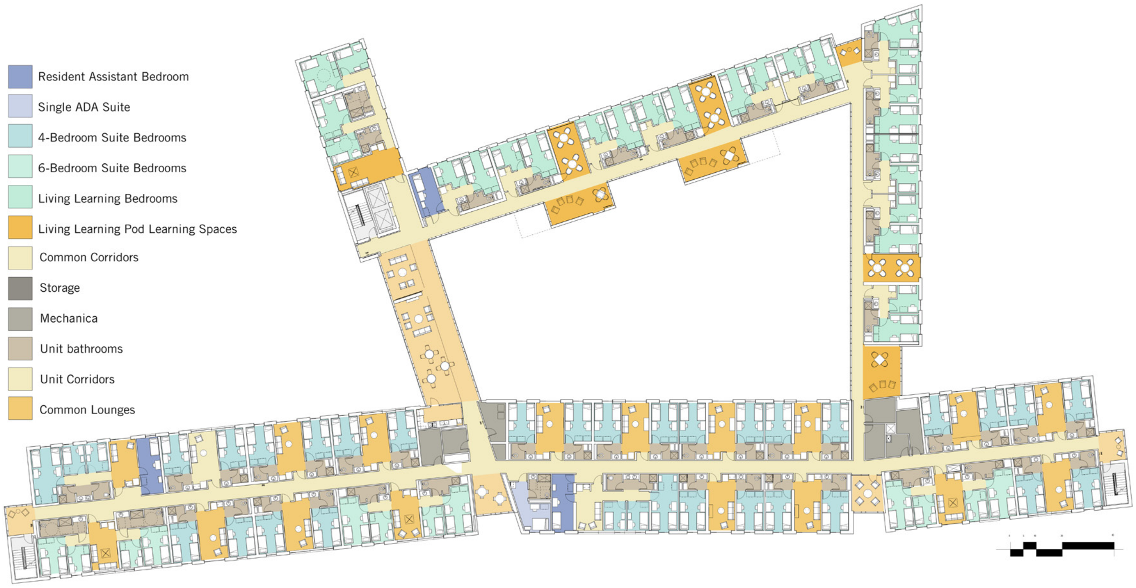


Figure 2: Typical Residential Floor plan—Located on East Campus, the hub of residential life on campus, the 500 beds are grouped in two prime categories: suites and living / learning pods. The suites are programmed in three types that include 4-bed doubles, 4-bed mixed singles and doubles, and 6-bed mixed singles and doubles. Twelve Residential Assistants' suites are split among the three residential levels. A Residential Director apartment at ground level has private access, which is also connected to the rest of the building.

Figure 3: Courtyard at Night—The ground level is open on one side through a loggia that frames a view to the campus lawn. Hundreds of commuting students experience the courtyard on their way to class. At a campus level, this courtyard links to a series of residential green spaces providing students more intimate spaces to retreat and gather as a community.

2.0 STEPS TO A ZERO NET ENERGY BUILDING

Our research methodology followed four steps. It was approached as a cyclical process as strategies were investigated, tested, analyzed, retested and vetted. There could also be synergies between strategies, which mean that an idea investigated in one step might influence another idea attempted under a different step. Similarly, strategies might cancel each other out or be redundant. We found that this methodology streamlined our decision-making process and helped focus the research on energy usage. In the following sections we discuss these four steps and some of the investigated salient strategies (Figure 4).

Step 1 focused on strategies that have no cost associated with them because they harvest natural resources, such as daylight, or incorporate strategies that enhance the performance of the envelope and systems. Step 2 focused on energy efficient strategies that will in turn reduce energy consumption. Step 3 investigated renewable energy production systems to power the building. Step 4 focused on building operations, an important step in achieving ZNEB. At this step, the responsibility is in the hands of the owner. This is where policy and educational outreach becomes an integral part of maintaining low energy consumption behavior.

Before beginning these steps, the team agreed to adopt the ZNEB definition as set forth by *The Massachusetts Zero Net Energy Buildings Task Force*, which states that ZNEB is optimally efficient and over the course of a year generates energy onsite using clean renewable resources in a quantity equal to or greater than the total amount of energy consumed onsite. With the engineering team, Energy Use Intensity (EUI) baselines were established based on 168,000 GSF for the Residential Hall and 12,000 GSF for the Wellness Center. Benchmarks were defined as follows:

- 104 kBtu/sq. ft. based on CEBECS data[4]
- 8 kBtu/sq. ft. EO 484 (2020)[5]
- 55 kBtu/sq. ft. Weygand Hall goal (this goal was exceeded at 54 kBtu/sq.ft.)[6].

Energy modeling and simple payback analysis were conducted at every step to fine tune strategies and meet energy goals, as shown in Figure 1. The design team, the owner, the user and the contractor, met regularly to discuss analysis results and determine how to move forward. It is important to point out that strategies should be vetted early on. However, when cost is a determining factor, some flexibility is needed to better gage market cost. This may require revisiting strategies later in the process. For instance, for Weygand Hall many strategies were accepted at the end of the design development phase, but others more dependent on market cost, were reconsidered during the construction documentation phase and even during construction. Throughout the process, the design team shared an Excel file that

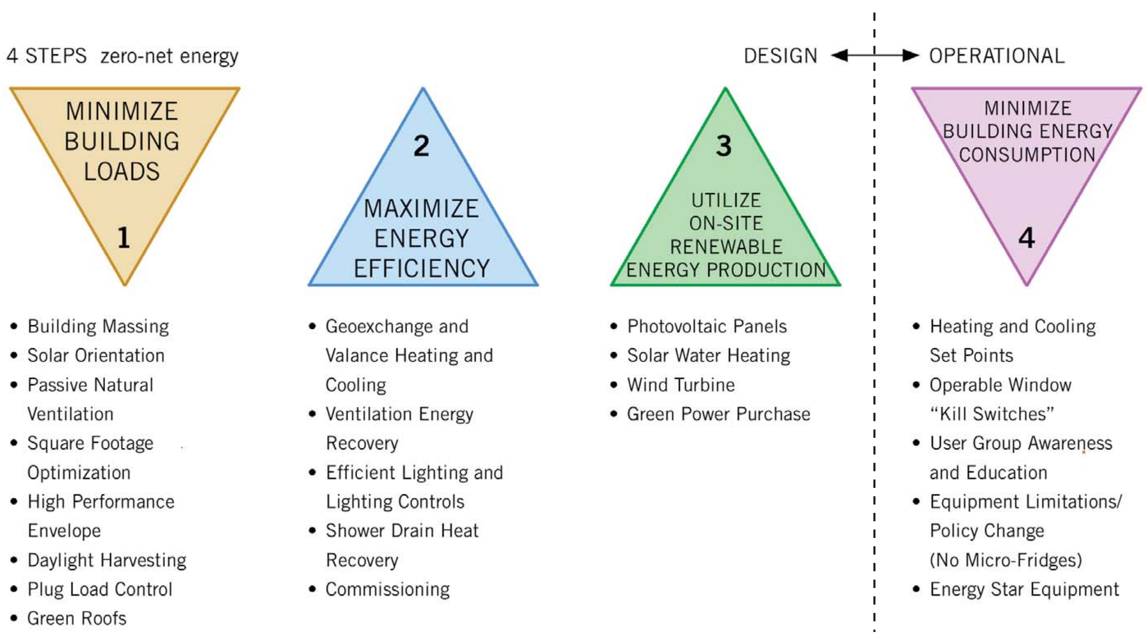


Figure 4: Four Steps in the ZNEB process—Research process was guided by these 4 steps.

tracked strategies. This was a live document that helped educate each other, vetted pros and cons and kept the process transparent (Figures 5, 14, 18, 19).

2.1 STEP 1: Minimizing Building Energy Loads

Step 1 focuses on energy reduction strategies necessary to achieve zero-net energy consumption, such as, building massing and orientation, optimized square footage, daylight harvesting, envelope optimization, and lighting and plug load control (Figure 5).

Building Massing and Solar Orientation Weygand Hall's orientation was influenced by site constraints, such as preserving a primary pedestrian path through campus, creating a defined boundary between the residential campus and the existing train rail, and formally linking the new courtyard to a series of existing courtyards in neighboring buildings. The building is primarily oriented north-south (tilted 12 degrees from north), considering the solar heat gain on the long southeast and southwest elevations. In the New England region, solar heat gain is desired beginning in the middle of the fall season, when temperatures are more consistently in the lower digits, and continue this trend through middle to late spring. The strategy to mitigate solar heat gain during the summer on those long facades included higher insulation values for the building skin, material selection (elevations with east and west exposures have less glazing) and solar shading devices at larger glazing areas. Another mitigation strategy was the creation of the courtyard, because it becomes a shaded oasis for much of the summer day, which allowed the design team to place more glazing in those elevations (Figure 6). During colder months, these glazed courtyard elevations will accept solar radiation to help heat the common spaces.

Harvesting Wind through Natural Ventilation By studying wind roses, seasonal winds and prevailing winds were determined. We learned that frequent winds are sustained from southwest, which factored into the casement windows being oriented to this direction to capture more wind flow into the building (Figure 7).

The University has traditionally used double or single hung windows for residential halls. While a large volume of air is able to flow through those window types, there were three concerns that led the design team to consider the advantages and disadvantages of awning, single hung and casement windows. The three concerns of these windows were safety of the students, the ability to achieve a tight seal to prevent air leakage (particularly heat escaping in winter), and the ability for students to place a portable electrical fan unit on the window sill (Figure 8). It was ultimately decided to provide casement windows with interior tamper-proof screens to allow maximum air flow into open windows without compromising safety. The following are the key advantages and disadvantages analyzed in conjunction with other strategies and systems:

Awning Window Type:
- Compression air seal at weather strip
- Ideal for valance system
- Half of window opens to scope air in
- Hard to capture prevailing winds
- More light penetration (no middle rail)
- "Kill Switch" installation
- Screen on inside / crank mechanism
- Student's fan units on window sill
- Appropriate to scale and character.

Single Hung Window Type:
- Not air tight due to the inherent sliding motion
- Not ideal for valance system: Valance are passive devices relying on convective air, excessive air infiltration disrupt performance
- Half of the window opens
- No effort to capture prevailing winds
- Middle rail disrupts light penetration
- "Kill switch" installation/operation OK
- Screen on outside / slide mechanism
- Student's fan units on window sill
- Smaller scale residential character.

Casement Window Type:
- Compression air seal at weather strip
- Ideal for valance system
- Entire window opens to scoop in air
- Window angle captures prevailing winds
- More light penetration (no middle rail)
- "Kill switch" installation/operation OK
- Screen on inside / crank mechanism
- Student's fan units on window sill
- Appropriate to scale and character.

Considering an existing window fan use culture in residential halls at BSU, the team planned for operable window use and studied "kill switches," which were accepted under Step 2.

Square Footage Optimization One way of reducing energy is to scrutinize program needs, discover the right programmatic adjacencies and optimize program layout in the building. In turn, the building cost is reduced

STEP 1 minimize building loads

Strategy	Energy System Option	Impacts	Advantages	Disadvantages
Orientation	Reduce Southwest Envelope Exposure	building footprint relation to campus space created	reduces energy loads	has to be balanced with future building sites
Natural Ventilation	Harvest Wind	windows	casement windows scoops air flow into building	none
Square Footage	Optimize Program Layout	programmatic square footage and adjacencies	optimizes building volume, right sizes building	square footage tradeoffs, smaller spaces
Envelope	Green Roofs and Cool Roofs	roof and waterproofing, soils substrate, vegetation	storm water retention, reduce heat island effect, amenity	installation cost, operation and maintenance, some require watering
Envelope	Optimize Roof Assembly	roof thickness, insulation quantity, Goal is R=60 Roof	reduce heat loss through roof	initial cost, possible increase of roof thickness
Envelope	Optimize Wall Assembly	wall thickness, Code Wall R=15.6 but goal is R=40	reduce heat loss through walls	initial cost, possible increase of wall thickness
Envelope	Energy Efficient Glazing	glazing and mullion, Code Window R=2.2	reduce heat loss through glass and reduce mean radiant temperature	thicker heavier assembly
Envelope	External Solar Shading	window and envelope detail	reduce heat gain	initial cost, maintenance
Daylight Harvesting	Optimize Daylight	optimize window wall ratio, glazing selection and light shelves or screens	reduce lighting electric consumption	initial cost of light shelves or screens
Lighting	High Efficiency Lighting Fixtures	light fixture selection, power loads	lower electric consumption and reduced internal heat	limits fixture selection
Mixed Mode Ventilation	Motor Actuated Windows Controlled by BMS System.	envelope, windows, controls	"free cooling", system shut off	
Mechanical System Decoupling	Operable Windows with Window "Kill" Switches	windows, 4% of floor area operable	casement windows scoops air flow into building	added system components
Intermittent Bathroom Exhaust	Intermittent Restroom Exhaust	ductwork, controls, occupancy sensors, make-up air, access	systems shuts off when not is use	maintenance, complexity, potential poor odor & moisture control
Lighting, HVAC Control	Occupancy Sensors	occupant behavior	reduce energy consumption	initial cost
Plug Load Control	Reduce Plug Loads	controls (occupancy sensor or card key switch)	reduce energy consumption	initial cost and maintenance, policy and enforcement
Plug Load Control	Green Power Strip	policy and enforcement	reduce energy consumption	policy and enforcement

Figure 5: Step 1 Matrix of strategies considered for minimizing energy loads.

by constructing what is needed and having less spatial volume to heat or cool with mechanical systems. In early conversations with users, it was determined that students were willing to compromise space within their bedrooms and suites in exchange for larger and more common spaces such as lounges, study rooms, common kitchens and games and recreational space (Figure 9). Throughout the project, requirements for universal access were not compromised and common spaces were distributed and balanced through the building's plan. This exercise of space optimization is a delicate balance between programmatic needs, future flexibility and public-private space allocations.

High Performance Envelope The New England region is heat-dominated, which means that the main energy concern is preventing heat loss during cold months. As a result, two of the most energy efficient strategies for the building's envelope is maintaining a low ratio of glazing (60 percent solid walls – 40 percent glazing) and insulating walls and roof with high thermal resistance (R-value). We studied super insulating the building and established an aspirational goal of R40 for walls and R60 for roof. We also developed details with insulation continuity to prevent thermal bridging. In this process we defined the following qualities:

- Sealed holes, cracks and penetrations
- Air tight construction (windows / doors / wall-roof)

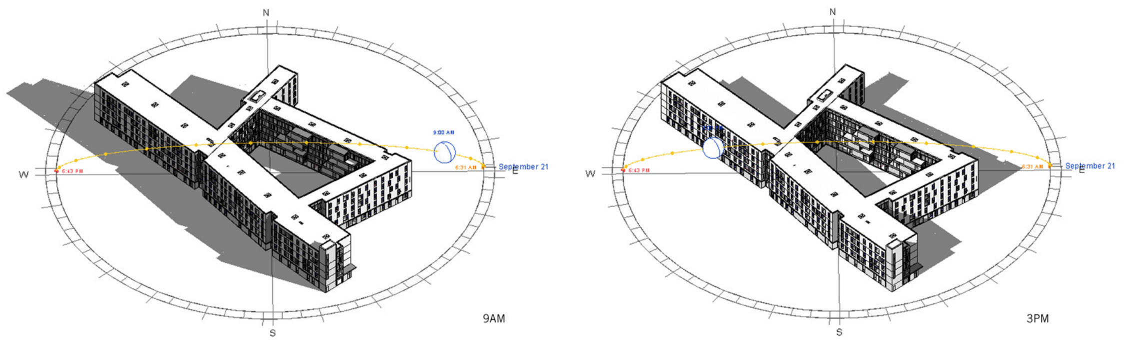


Figure 6: Building Shading Studies—These diagrams illustrate sun angles in the morning and afternoon of September 21. The courtyard is in shade for much of the day. Similar studies were performed for winter and summer seasons.

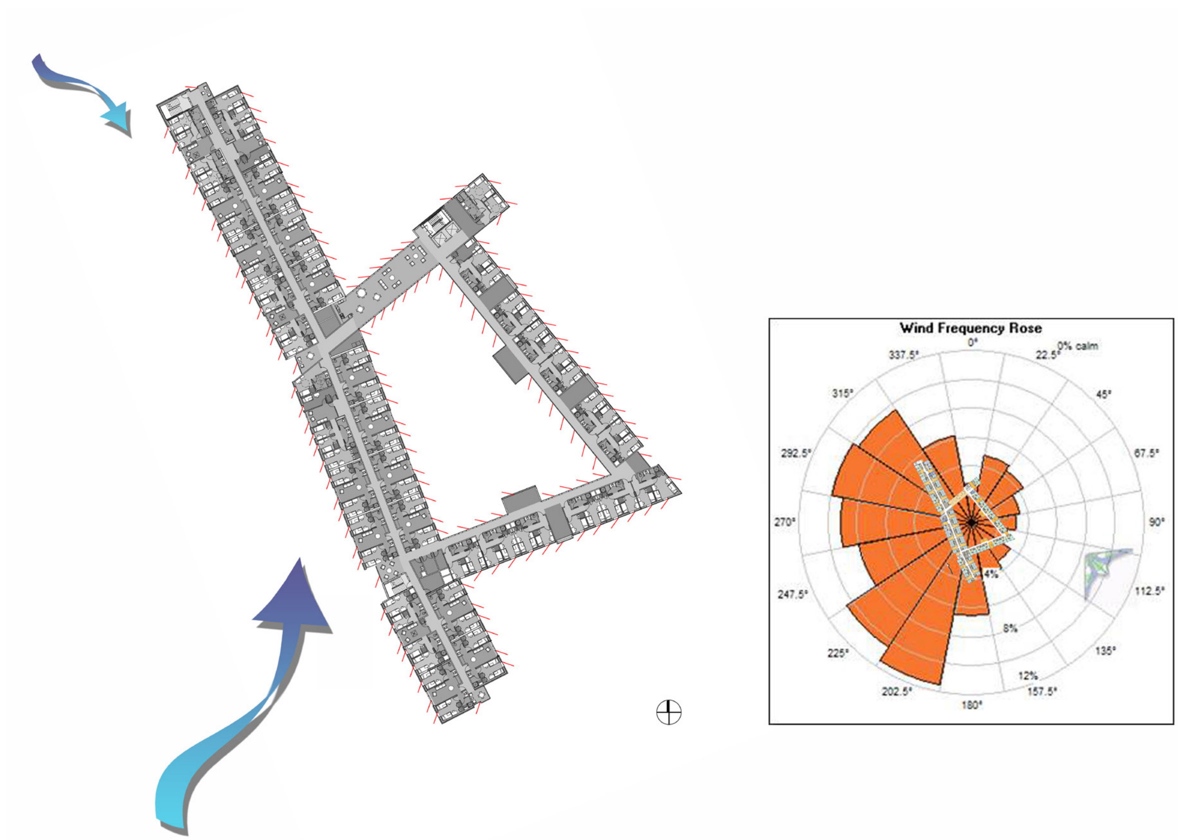


Figure 7: Natural Ventilation Diagram—Casement windows were oriented in the direction of the prevailing southwestern winds to "scoop" more air into the building.

- Insulated foundations and under slab
- 40% glazing (maximum)
- Heat recovery ventilation to provide fresh air.

Since the R-value required by code is R15.6 and the industry standard is R19, we analyzed different types of insulation to improve these R-values for the envelope while maintaining a thin wall and roof assembly. The criteria for considering these insulation materials include climate relevance, ease of installation, durability (resistance to degradation), and ease of replacement at the end of life, cost effectiveness, toxicity, flammability and environmental impact. Also, the owner was concerned about risks associated with using emerging technologies and materials that are unproven. Due to this concern, the design team focused mainly on ideas, materials and systems with proven technologies.

For the most part, the insulation materials studied have been in use for many years but some are more common in the construction industry of the New England region. The considered types of insulation included:

- Aerogel for skylights
- Spray polyurethane foam (SPF)
- Insulating Concrete Forms
- Rigid Panels
  - Walls: Extruded-Polystyrene (XPS R5/in.)
  - Expanded-Polystyrene (EPS R4/in.)
  - Roof: Isocyanurate Boards (R 6.67/in.)
  - Polyisocyanurate (Polyiso R 6.5/in.)
- Structural Insulated Panels (SIPs)
- Fiberglass batts and blankets (R-2.9 to R-3.8)
- Natural fiber
- Cotton batts (blue jeans)
- Loose-fill (including cellulose, R 3.7/in.)
- Straw bales
- Reflective insulation and radiant barriers.

Of the materials listed above, the building uses SPF for sealing cracks and holes, rigid panels for roofs and walls, fiberglass batts for interior acoustical separation and mineral fiber for rain screen and spandrel glass applications.

The strategy for improving the roof and wall assembly was mainly based on higher insulation values but the team also considered a white roof membrane and quality materials with proven durability. There were three roof scenarios analyzed for rigid panels of Isocyanurate boards:

- R 6.67/in. x 9" total = R 60 value (aspirational goal)
- R 6.67/in. x 5" total = R 33 value (base)
- R 6.67/in. x 7" total = R 46 value (alternate)
- R 6.67/in. x 6" total = R 38 value (built).

The wall insulation strategy required an R-value analysis of different wall assemblies and combinations of insulation types. Two specific wall assemblies that were considered (brick and composite panel rainscreens) are discussed in more detail to illustrate the design process, decision-making and specific issues relating to thermal performance (Figure 10).

For the brick assembly wall, the team initially considered fiberglass batt or sprayed foam insulation inside the metal stud wall, as supplemental insulation to reach a higher thermal resistance. This idea was ultimately not pursued because when metal studs come in contact with exterior sheathing, they act as a thermal bridge through which 15 percent of thermal resistance is lost. In this scenario, providing 4" of exterior rigid insulation was more cost effective. The maximum thickness of the exterior rigid insulation was determined by the longest brick anchor available to span from the brick all the way

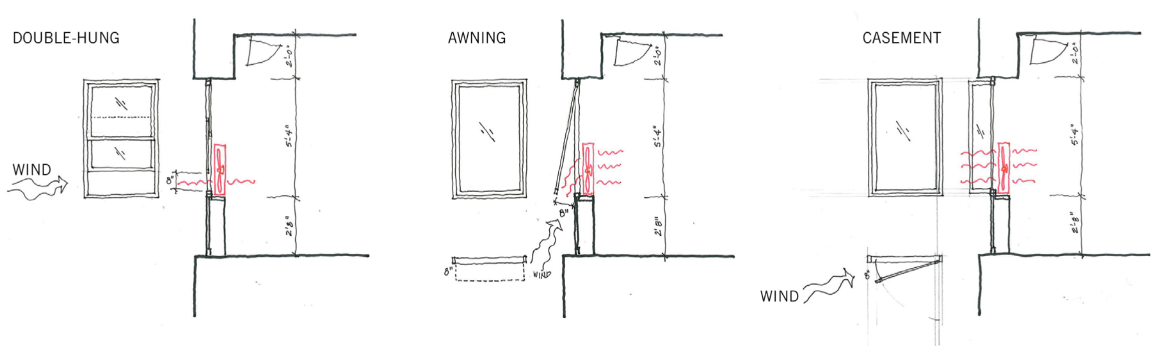


Figure 8: Window Type Study—With MSCBA and BSU, the design team determined three window types to study: awning, single hung and casement windows, studying the advantages and disadvantages of each.

Figure 9: Game Room Photo—At ground level there are a variety of amenities, such as a living room, study areas, game room, mailboxes, laundry, and multipurpose rooms.

back to the exterior sheathing. The total R-value of the brick wall assembly is 27. Similarly, the phenolic panel rainscreen wall assembly excluded fiberglass insulation inside the metal stud wall. Initially, rigid insulation was specified for this wall but more refined research determined that mineral fiber insulation was a better technology based on flame spread testing. The thickness of the mineral fiber insulation was specified as 4" with an R-value of 18 (total wall assembly R-value of 21). During construction, 5.5" of insulation was ultimately installed due to an excess of air space within the cavity. NFPA requires the air space be exactly 1", therefore additional insulation was installed to accommodate this requirement, increasing the total R-value of the wall assembly to R25.

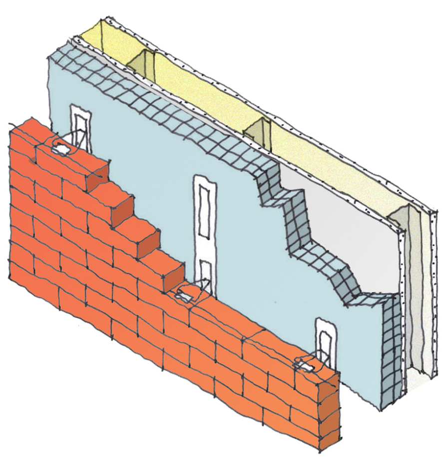
Glazing areas were improved in three ways. First, the team specified low emissivity (Low E) coated glass, a product that emits low levels of radiant energy without compromising transparency and visibility. In addition, the glazing has two layers of glass with argon gas infill that further helps achieve a higher thermal resistance. Triple glazing insulated unit with argon gas infill was studied but not pursued due to cost and the fact that the mullions and hardware needed to be upgraded to carry the additional glass weight (Figure 11).

Second, fritted panels with 40 percent and 60 percent of frit density were specified at the large curtain wall areas of the courtyard to reduce the solar heat gain by an estimated 15 percent. In Figure 3, the fritted glass is perceived in the lighter shades of glazing. The third improvement to the glazing system was to use fiberglass window frames for all windows in the building (not curtain wall mullions). Although metal frame manufacturers for windows and curtain wall have been developing better thermal break technologies to prevent heat transmission thought the metal, our research indicated a very low heat transmission through fiberglass frames that translated in greater comfort for the interior spaces. There are fiberglass manufacturers that also include a suspended film between the glass, which equals the performance of a triple glazed unit but without the increased weight. The team studied including the suspended film technology but determined it was not feasible due to cost premium and lack of competitiveness in manufacturers around the New England region.

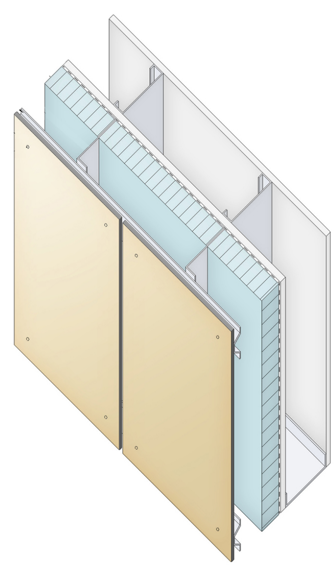
Exterior shading ideas included strategies utilizing louvers, exterior screens and exterior shading (brise-soleils). Through solar shading studies, it was determined that horizontal exterior shading in southeast and southwest exposures was the most effective (Figure 12).
These shades were designed to admit more light in the winter and block light during the summer months (Figure 13). Along with the fritted glass, these shades provide heat gain and glare control, while allowing views to the outdoor. On the southwest façade of the courtyard, the shading devices and the cantilevered Learning Pods act together to shade the corridor and interior study areas.

Daylight Harvesting– Daylight harvesting strategies studies included a variety of ideas but only some were adopted for performance optimization and maintenance reasons. The different strategies and reasons for adopting or rejecting them were:
- *Thinner building footprint:* adopted wherever possible, particularly the living-learning part of the building.
- *Optimal window / wall ratio (40 percent / 60 percent):* adopted throughout the envelope to maintain adequate thermal values without compromising daylight and outdoor visibility.
- *Glazing selection:* high visibility glass was specified to admit more light.
- *Light shelf:* This light redirecting mechanism was studied to extend light penetration into bedrooms and living rooms but it was rejected as the spaces were shallow enough to admit appropriate daylight levels. Also, both interior and exterior light shelf require periodic cleaning, otherwise a 70 percent efficacy reduction will occur. This represents a maintenance issue taken into consideration.
- *Glare reduction with shades:* Accepted with privacy shades for the bedrooms (0 percent opening in shade fabric) and glare control shades for the living spaces (5 percent opening in shade fabric). In the living rooms, shades allow for unobstructed views, reduced heat gain and surface brightness control.
- *Tubular daylight:* devices were rejected due to the many roof penetrations needed and the fact that the roof real estate may be used for renewable energy strategies in the future, such as PV panels.

Plug Load Controls– Along with daylight harvesting ideas, the building design includes high efficient lighting with reduced lighting power density, 27 percent reduction from baseline, and individual room lighting controls. There are occupancy sensors in every space,



BRICK WALL ASSEMBLY



PHENOLIC PANEL WALL ASSEMBLY

Figure 10: Wall Assemblies—Brick and phenolic panel exterior wall rainscreen systems.

so that lights are off while no one occupies the spaces. Another option to minimize energy loads was the use of plug load controls. The idea was to have separate color coded electrical outlets for appliances and equipment that the students tend to leave on even when they are not in used, such as computers, printers, phone chargers, etc. These outlets are typically connected to a wall switch that can be turned off at once, disconnecting all electric service to the outlet. The University conducted a study to determine if this was a viable investment or

Characteristics	Baseline	Alternate	Specified / Installed
Manufacturer	Viracon VE1-2M or equal	Viracon VE1-2M or equal	PPG Solarban 60
Glazing Thickness	1/4"	1/4"	1/4"
Glazing Layers	Double	Triple	Double
Argon Gas	No	Yes	No
Low-e Coating	Yes	Yes	Yes
Winter U-value	0.29	0.13	0.29
Summer U-value	0.26	0.13	0.27
Shading Coefficient	0.44	0.37	0.44
Visible Light Transmittance	67%	43%	70%
Solar Heat Gain Coefficient	0.38	0.32	0.38
R-Value	4	5	4

Figure 11: Glazing characteristics chart.

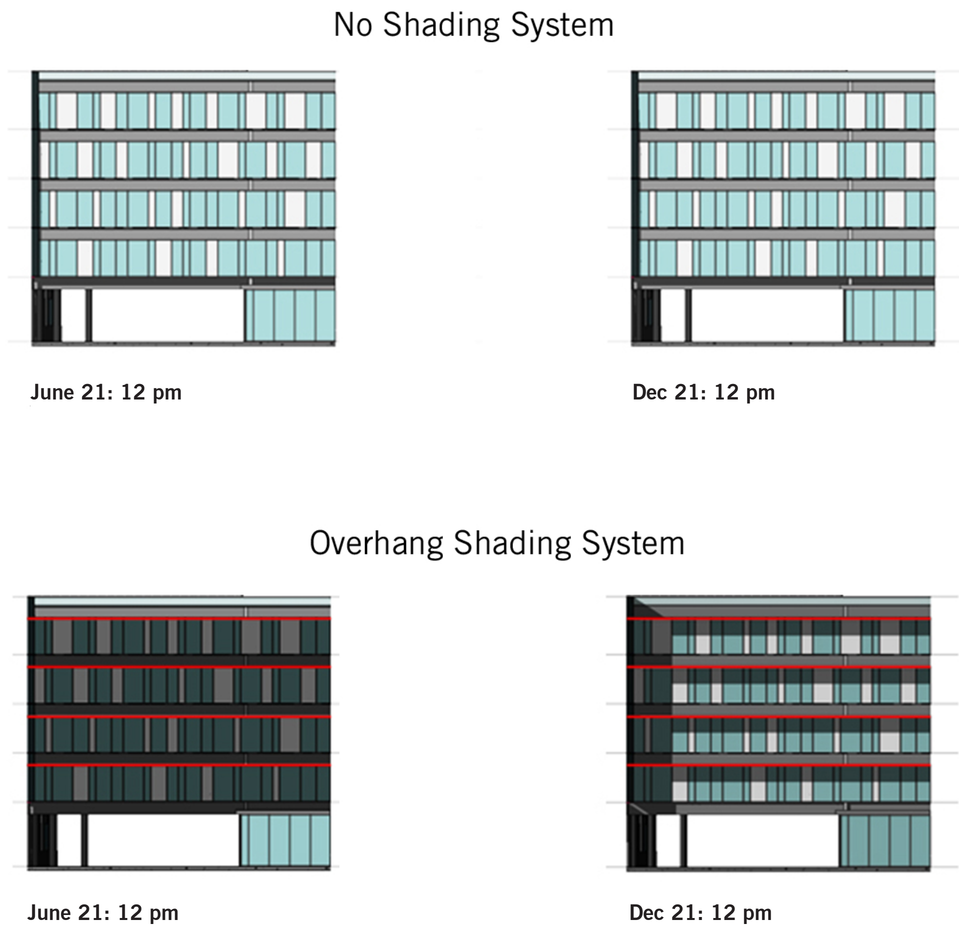


Figure 12: Shading studies informed the best locations for brise-soleil on the building façade.

if educating the students could offer the same energy conservation results. Two suites in a neighboring residential hall were used for the study. One was the experimental control in which no plug controls were installed, except that the students were told the importance of unplugging their equipment and how it would lead to energy conservation. The control room was metered for energy use. The second suite was set up with plug controls and metered. The students were told how to use the system. After a few months, there was no energy consumption difference between the two rooms, and both achieved similar energy reduction. The University interviewed the students in both groups and it was determined that education and orientation led to the same outcome: an awareness to unplug and turn off equipment. With this result, the University decided not to invest in plug controls but rather develop a robust orientation program for residents. This idea was incorporated under Step 4, building operations.

Green Roofs– Green roofs were considered to reduce heat gain on the roofs of the Living-Learning cantilevered Pods at the courtyard. The Pods have visual access to adjacent roofs, which led BSU to desire the aesthetics of a green roof. For maintenance reasons, the University preferred an extensive green roof system,

Figure 13: Living Learning Pods.

which uses removable trays of planting, instead of an intensive green roof system where the plantings are placed above the roof membrane. The Pod roofs are designed to receive the tray plantings if the University decides to install them in the future, but they are currently not installed due to cost and maintenance concerns. These roofs, as well as all the other roofs, have white membranes to reflect solar radiation and reduce heat island effect.

2.2 STEP 2: Maximizing Component Energy Efficiencies Systems

Step 2 considered efficient building systems, such as ventilation systems, heating and cooling with geo-exchange energy, lighting controls, efficient motor controls for fans and shower drain energy recovery among others. In studying different strategies, the team assessed the levels of minor and major energy saving consequences (Figure 14). The systems that were incorporated into the project are described below.

Geo-exchange and Valance Heating and Cooling– Closed loop geo-exchange pumps and valance heating and cooling systems were studied, and it was found that they would provide significant energy savings. A geo-exchange system uses the earth for a heat source and a heat sink. Climates with extreme heat and cooling needs can extract the most efficiency out of a geo-exchange system. The building must be operational during all seasons to maximize efficiency since it relies on a balance loop of heat exchange. A simplified way to describe this is in terms of cooling and heating demands: cool earth temperatures are extracted in the summer leaving the earth with hotter temperatures, while hot temperatures are extracted in winter months leaving the earth at a cooler temperature. Residential halls are traditionally occupied only during the school year; however BSU has summer programs and is able to prioritize occupying this building during the summer months to maximize energy efficiency. Through analysis, the design team, consulting engineers and GZA GeoEnvironmental, Inc., determined that Weygand Hall would require 63 wells for the geo-exchange system. The residence hall site is located directly next to an open campus quad for recreation and provides an ideal location for the wells (Figure 15).

Paired with valances in all resident bedrooms and living rooms for heating and cooling, this strategy will increase user comfort, decrease energy cost, and lower maintenance demands. Valance heating and cooling functions without fans or filters, using water in coils to regulate room temperatures. Air circulation is slow and efficient, keeping a consistent temperature within a space without draft currents. Design considerations were studied so that the valances are mounted close to the ceiling with options for architectural enclosures to conceal the coil and drain pan. It was decided early on in the process that ductwork and piping would be consolidated in one area of the suites in order for the ceiling height to accommodate the valance without compromising daylight and views (Figure 16).

The following is a summary of the pros and cons considered while selecting the geo-exchange and valance system combined strategy:

Pros:

- *Optimum energy efficiency*– the geo-exchange system's ground heat source/sink temperatures can be considered constant and are not affected by weather conditions, therefore the system is exempt from seasonal temperature changes.
- *No fan or filter maintenance*– the valance system does not require fan energy to force air circulation, rather heat or cold temperatures radiates from the pipes.
- *Improved air movement*– the valance system is slow in moving air to prevent draft currents. There is no risk of temperature stratification due to the height and depth ratio of the spaces.
- *Reduced maintenance*– the combined strategy of geo-exchange and the valance system has reduced maintenance cost since both the heating and cooling is provided by the same system and components. Geo-exchange site piping offers a 50+ year expected service life. All other mechanical components are protected from weather decay indoors and are easily accessible by personnel.

Cons:

- *High initial cost*– simple pay back studies indicated a 22-year payback. Since the MSCBA owns the residential halls for life, they determined that it was a sound investment for the building's life cycle.
- *Well field limits future development on top of the land*– the University's master plan envisions this

STEP 2 maximize energy efficiency

System Type	Energy System Option	Impacts	Advantages	Disadvantages
HVAC	Geothermal Close Loop Heat Exchange Pumps	site availability and mechanical space, drilling bore fields	increased COP, low carbon heating and cooling source	initial cost, well field space
HVAC	Air Source Heat Pump	fan-coil location, ductwork	similar performance to geothermal without well field costs	Reduced heating capacity & efficiency , maintenance, footprint
HVAC	Valance Heating & Cooling	room ceiling & wall clearances, floor-to-floor height	Passive heating & cooling, zero fan energy, filter-less, low maintenance	delayed response to set point change, unconventional, location in rooms
HVAC	Modular Water-to-Water Heat Pumps	mechanical system design	increased efficiency as compared to unitary equipment, redundancy	limited manufacturers of equipment
HVAC	Ventilation Energy Recovery	ductwork, HVAC controls, equipment capacity	reduce heating and cooling loads	initial cost and size of equipment
HVAC	Demand Based Ventilation	HVAC controls	reduced fan & thermal energy	additional sensors
Plumbing	Shower Drain Energy Recovery	drain piping	reduced DHW energy from non renewable sources	initial costs, additional drain piping
Electrical	Building Wide Lighting Control System	lighting control design	increased control over building lighting	initial cost
HVAC & Electrical	Commissioning	project close out	confirms system efficiency and operation	initial cost

Figure 14: Step 2 matrix of studied strategies.

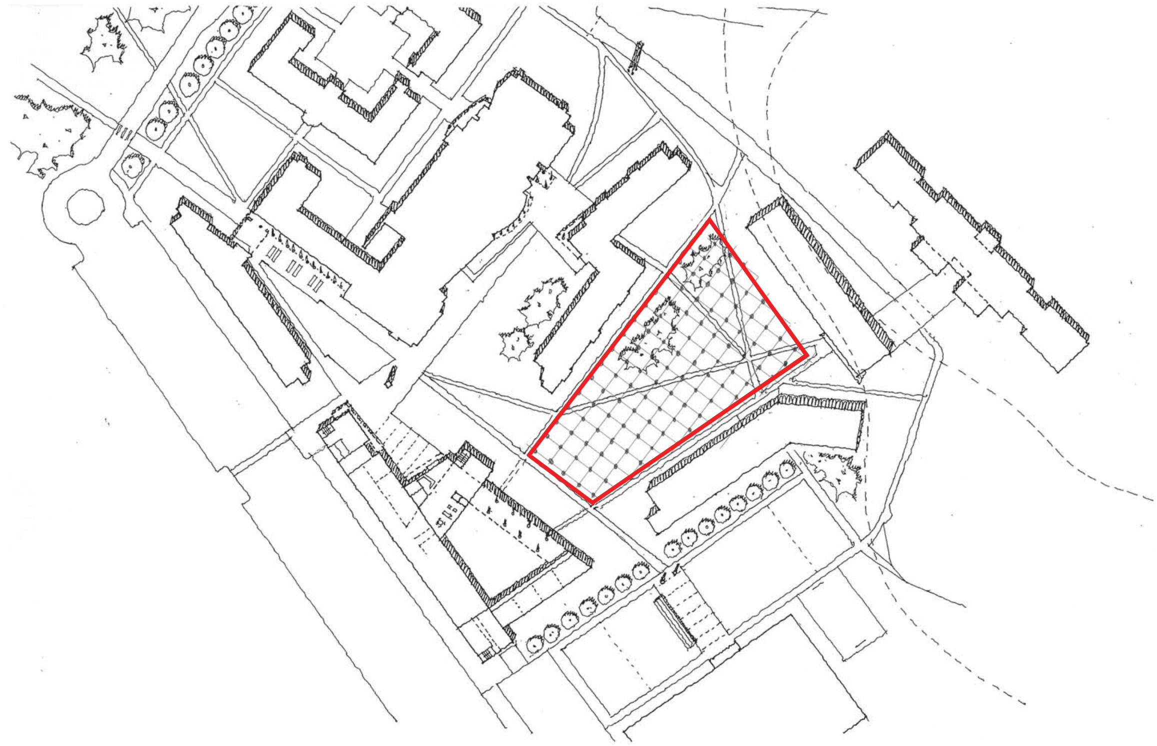


Figure 15: Field of 63 geo wells drilled on site.

land as recreational; therefore it was possible to dedicate its use for geo-exchange wells.

- *Valance units can be difficult fit in low floor-to-floor*– the design team studied carefully the height of the perimeter spaces and the interface of the valance unit with the window.
- *Simultaneous heat/cool requires 4-Pipe*– this duplicity of pipes is part of the valance system and was considered in the total first cost for this strategy.
- *Unconventional equipment*– although unconventional for the USA or the New England region, these technologies have been used in Europe for many years. BSU and MSCBA were interested in incorporating these systems given the proven technology on the leading edge.

Shower Drain Heat Recovery– The team also identified the potential to save energy by reducing hot water loads. Shower drain heat recovery uses a copper piping system that recovers heat from warm water leaving the shower. This passive system reduces heating requirements for each shower because the recovered heat is use to continue heating domestic hot water. Weygand Hall's 140 showers, serving 500 residents daily, offer an economy of scale to multiply those savings. Since this system requires additional piping, initial cost and adequate space for the copper pipe was considered during design. With plumbing stacked on the four residential floors, Weygand Hall was able to provide one shower drain heat recovery pipe per stack, translating into 35 copper pipes to serve the entire building. The estimated payback on the initial cost is just seven years (Figure 17).

Enhanced Commissioning– In order to ensure building systems function as designed, MSCBA hired a commissioning agent. The commissioning process verifies through testing and adjusting that mechanical, electrical, plumbing and life safety systems are working efficiently. This strategy is crucial to the process, since energy savings may not be realized if systems do not work in the field as expected. Maintenance staff is also included in training and education meetings with the

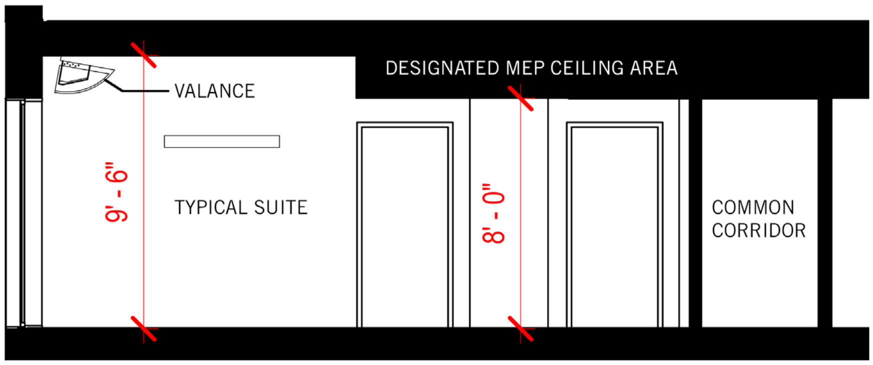


Figure 16: Sectional study of valance location above the window, designating an efficient MEP area within the ceiling while maximizing window height for daylight.

contractor and commissioning agent to ensure equipment is being used and maintained correctly.

2.3 STEP 3: Generating On-site Renewable Energy

Step 3 considered clean energy production strategies: photovoltaic panels (PV) on the new roof as well as surrounding campus structures, building integrated PV, solar water heating (SWH), on-site wind generation, and purchase of green power (Figure 18). These energy generating strategies have an initial high cost but offer energy cost savings through the life of the building. Simple payback studies were critical in determining which strategies were adopted immediately and which could be incorporated at a later date.

Photovoltaic Panels– It was estimated through energy modeling that 225,000 GSF of PV panels would be required to offset the building energy requirements and to reach ZNEB, depending on the combination of additional accepted strategies. This would require PV installation on Weygand Hall as well as another building on campus. If limited to the available Weygand Hall roof area, 29,000 GSF, PV panels installed would offset 12.4 percent of the annual energy consumption. Building integrated PV panels, PV panels mounted on the building façade or as part of the building shading system, were also studied. In the case of Weygand Hall, the initial cost did not offset the annual energy savings. Therefore, roof PV panel installation was prioritized. Since PV panels can be added at any point during the building lifetime, the roof of Weygand Hall was designed and built to be PV ready.

Solar water heating– SWH requires roof space similar to PV panels. Since the 5-story building has limited roof space, both strategies could not be efficiently accepted together. The SWH system was studied to provide hot water to building occupants throughout the year. Although gas and electricity back-up would be required for some winter days, the system would save annual utility costs for BSU. In parallel, the team studied and accepted Shower Drain Energy Recovery, as described in Step 2. The two strategies implemented together would not maximize energy savings or payback, and Shower Drain Heat Recovery was selected due to lower cost and higher energy savings as compared with SWH.

Wind Harvesting– With BSU's Facilities staff on board, the engineers studied wind harvesting opportunities on campus. A specific site near Weygand Hall was selected based on elevation, separation from third-party buildings, noise, and connection to campus operations center, and proximity to transportation for installation. Several turbine options exist with generation capacities between 100kW to 3MW. Due to interest in maximizing energy generation and payback on the initial turbine cost, the study focused on turbines generating 1.5 – 2 MW. A wind simulation for the site was set up and an estimated generation of 4,902,820 kWh of annual net production was determined with an example turbine chosen, which would power 30% of the BSU campus. Weygand Hall consumes an estimated 3,170,000 kWh annually, and would be brought to ZNEB with acceptance of a wind turbine. Any additional accepted strategies for Weygand Hall would provide additional power from wind generation for other existing or new campus

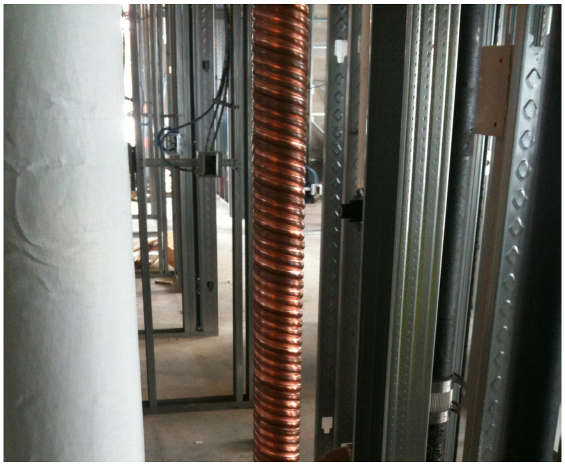


Figure 17: Copper pipe for shower drain heat recovery.

buildings. Wind energy use in this example would offset energy costs for electricity alone on campus, an estimated $747,804 per year.

Green Power– The final renewable power strategy studied was the purchase of green power. The strategy requires no equipment or maintenance costs and can be renewed or revised over the building's lifetime. Purchasing green power ensures that the electricity the building consumes is replaced on the grid with renewable energy sources. MSCBA purchased 70% of the Weygand Hall's total energy usage, 2,792,009 kWh, for 2 years through a renewable energy company. Although this large amount of energy is purchased from clean power generation, since the renewable energy is not generated on site, it cannot be counted towards the ZNEB goal.

2.4 STEP 4: Minimizing Building Energy Consumption through Operation

Step 4 investigated how user behavior shifts through policy changes and education could improve building function and user experience (Figure 19). The BSU Facilities and Residential Life departments were involved in sustainable charrettes throughout the design and construction process. In order to ensure success of all sustainable strategies implemented in the project and to maximize energy savings related to users interaction in the building, it was critical to have all parties input and commitment for the accepted strategies.

Temperature Set Points– Setting heating and cooling set points within the residence hall was identified early on in the process as an opportunity to reduce energy consumption. This strategy can reduce heating and cooling loads while providing adequate user comfort. The design provides the ability to adjust set points at any given point. Although the ZNEB study proposes 82 degrees as the set point for cooling at peak occupancy and 68 to 70 degrees for heating, the University believes that the set points through the heating and cooling seasons will more likely be acceptable to students in the range of 70 – 75 degrees. The University will analyze the success of this program over the year and adjust the set points if necessary in the future. Paired with an educational program weaved into Resident Assistant orientation, residents will be aware of the energy savings potential. Users can take pride in saving energy

STEP 3 utilize on-site renewable energy production

Strategy	Energy System Option	Impacts	Advantages	Disadvantages
Renewable Power	PV on Roof	roof	renewable energy source	initial cost, utility interconnect study/agreement
Renewable Power	PV on other campus surfaces (parking, roofs, land)	future building plans	renewable energy source, shading of vehicles	initial cost, utility interconnect study/agreement
Renewable Power	Building Integrated PV	building envelope, construction techniques	renewable energy source	initial cost, utility interconnect study/agreement
Renewable Power	On Site Wind Turbine	future building plans, local community	renewable energy source	permitting process, time
Renewable Power	Building Mini-Wind Turbine	building aesthetics, structural & electrical systems	educational, demonstrative	small energy production
Renewable Energy	Solar Hot Water	competes with space on roof for PV	reduced DHW energy from non renewable sources, increased COP as compare to PV	initial cost, additional equipment/space
Renewable Power	Purchase Green Energy	yearly utility cost	lower cost as compared to onsite equipment	slightly increased yearly utility cost, not ZNEB

Figure 18: Strategies for renewable energy resources.

while adjusting to feeling a couple degrees cooler or warmer than in a typical conditioned building. In this case, providing ownership to the users and knowledge about the building's systems will begin to shape positive attitudes towards building temperature and comfort levels.

Restroom Exhaust and Suite Ventilation– This indoor air quality strategy is discussed here since the decision making was heavily weighed from a user and optional point of view, although it technically belongs under Step 2. The design team studied the possibility of providing intermittent restroom exhaust control by users as needed and in part dependent on natural ventilation. This would have required students to be aware of when to turn on the restroom exhaust switch. This strategy is typically used in single residential applications but after discussions with BSU, it became clear that user awareness was not going to be enough to mitigate lack of ventilation complains. In addition, this strategy requires more local fans or sophisticated air flow control devices (automatic dampers). Continuous exhaust systems were installed in every bathroom with a 75-100 cfm/fixture. This system will control odor and moisture and be low maintenance. It was determined that the energy recovery in the system limited the energy penalty.

Window "Kill Switches"– Since the building design includes operable windows for each suite and in some common areas, the design team identified a need to minimize heat loss through open windows. Each operable window on floors 2 through 5 in the resident bedrooms and living rooms is equipped with a switch that indicates if the window is open or closed. The switches are factory installed in the window frames and are wired to the facilities building management system. The sequence of operation fully shuts off flow of hot or chilled water to the space when the window is in the open position. The presence of the switches in this case, prevents energy from being wasted through occupant misuse. The window switches act as an insurance policy, preventing misuse by the occupants. In addition, the operable windows with switches can be considered similar to that of an economizer system, with mechanical heating/cooling systems off at times when outdoor conditions permit. Energy modeling with these spaces in economizer mode indicates the potential savings of 25,000 kBtu of site energy saving per year.

Policy Changes and User Awareness– The Sustainability Charter, developed by the design team and BSU's Facilities Department, includes a Comprehensive Operational Plan. This plan includes a list of equipment allowed for students to bring into the residential hall (Figure 20). Mini-refrigerators are one of the biggest energy users in a residential hall and were not included on the list of allowed equipment. BSU and MSCBA made a commitment to eliminate these from Weygand Hall by purchasing full-size refrigerators for each suite. This program will also create ownership for building users who will be aware and proud of their contribution to energy savings. Although up-front costs are slightly higher, payback on this strategy is estimated at 3 years. In addition to efficient refrigerators, all common kitchen and laundry equipment within the residential hall are energy efficient models.

Parallel to the strategies listed above, the hope is for user awareness programs to foster a culture and community of Sustainable Ambassadors who will educate peers and future residents about sustainable living environments. As attitudes change and excitement grows related to green buildings, the strategies will strengthen based on how the building users function within the residence hall. BSU is also committed to conducting yearly educational orientations for residents and con-

STEP 4 minimize building energy consumption

Strategy	Energy System Option	Impacts	Advantages	Disadvantages
Non Traditional Heating & Cooling Operating Parameters	Heating/Cooling Set point Control	Occupant comfort	Reduce Energy consumption	possible complaints from occupants
User Group Education Awareness / Buy-in	Occupant education and awareness	Campus policy	Reduced energy consumption, reduced occupants complaints	time, cost
No Micro Refrigeration	Occupants Share Refrigerator	Privacy, building policy	reduced energy consumption	enforcement, complaints from occupants
Operations	Post Occupancy Evaluation	additional metering and analysis	forum to allow comfort and performance issues to be addressed	time, cost
Equipment Selection	Energy Star Rated equipment	Policy and Enforcement	reduced energy consumption	Enforcement, slight initial cost increase

Figure 19: Step 4.

Comparison of Electric Items Permitted in Residence Halls at Selected Institutions

ITEM	INSTITUTION					
	MIT	Harvard U.	Middlebury U.	Roger Williams U.	**BSU**	**BSU - ZNEB Policy**
Desk Lamp	Y	Y	Y	Y	Y (no halogen)	Y (energy efficient bulb, no halogen)
Alarm Clock	Y	Y	Y	Y	Y (battery)	Y (battery)
Radio/iPod dock	Y	Y	Y	Y	Y	Y
Small Fan	Y	Y		Y	Y	N (not energy star rated)
Computer	Y	Y	Y	Y	Y	Y
Surge Protector	Y	Y		Y	Y	Y
TV				Y	Y	1 per suite, energy star
DVD/VCR				Y	Y	1 per suite, energy star
Telephone	N	Y		Y	Y	Y (energy star, cordless)
Mini Refrigerator	Y	N*	Y (24 in. cubes)	Y	Y (up to 1.4 amps)	Y (up to 1.4 amps, 1 per suite)
Microwave	N	N	Y	N	Y (under 1000 watts)	Y (under 1000 watts, 1 per suite)
Blender		N**	Y**		Y	N
Coffeepot		N**	Y**		Y	N
Hair Drier	Y	Y	Y	Y	Y	Y
Hair Straightener/Curler	Y	Y	Y	Y	Y	Y
Electric Razor	Y	Y	Y	Y	Y	Y
Cell Phone + Charger	Y	Y	Y	Y	Y	Y
Green Strip Power						Smart Strip (SCG5)

* Allowed if purches from selected provider

** Allowed if there are kitchen facilities

Blank cells mean information was not available or item is not regulated

Figure 20: Comparison of allowed electric appliances on campuses compared with BSU's new ZNEB policy, developed in parallel with Weygand Hall project.

Figure 21: Whole building diagram of all accepted strategies.

tinue to enforce energy conservation behavior through Residential Assistant events (Figure 21).

3.0 CONCLUSION

The design team identified and studied strategies from conceptual design through project completion for reaching net zero energy goals. Building design considered sustainable strategies without compromise of aesthetic goals, ensuring a holistically designed building. In lieu of a typical linear process of adding several proven strategies and getting a result, the original aspirational goal for ZNEB was set early in the process and developed as a reiterative and integrated approach. Within the four steps described, project specific strategies were then tested, analyzed and vetted to maximize energy efficiency towards the ZNEB goal. Tracking clear cost and energy use data for each strategy provided confidence as strategies were accepted and implemented into the project. The study not only provides knowledge for future projects, but pushed the project to implement strategies that might not otherwise have been studied.

Strategies with significant energy savings on their own combined with many small scale strategies add up to save 54% energy from the code baseline at Weygand Hall. Two renewable energy plans for the project offer potential for reaching the ZNEB goal: a PV-ready roof and a campus wind study that if proven satisfactory could lead to a wind turbine on campus. This wind turbine, will have the capacity to provide clean energy for the Residential Hall as well as other buildings on campus. Although a wind turbine has a high initial cost, BSU's Facilities group encouraged the wind study because a turbine could generate power at a campus-district level. This campus wide strategy aligns with Bridgewater State University's commitment to minimize global warming emissions[7]. The wind turbine is an example of an important outcome in the ZNEB pilot study. The many charrettes and educational sessions, elevated discussions and allowed MSCBA, BSU and the design team to gain in-depth understanding of technologies and systems integration.

The ZNEB pilot study's measure for success was met as the team identified challenges and opportunities using new and proven technologies, implemented low energy strategies supported by energy modeling and cost analysis, and documented the process in a report that incorporates lessons learned for future residential halls with a ZNEB goal.

Accepted Strategies (Figure 21):

1. Fiberglass Windows; Double-pane with argon gas
   - Proven better thermal transmittance value through research and manufacturer testing information
2. Exterior Solar Shading and Interior Shades
   - Brise soleil system: benefits validated through

solar shading analysis and energy modeling
- Interior shades reduce glare and allow for user operability based on time of day and season

3. Lighting Controls
- Reduced lighting power density

4. Extensive Green Roof (Project Alternate)
- Lightweight, low maintenance, and long life
- Flexibility to add later to roof without adding structural support

5. Geo-exchange & Valance Systems
- Reduced maintenance, energy consumption, and equipment sizes

6. Shower Drain Energy Recovery
- Preheats water to reduce energy needed to produce hot water

7. Photovoltaic Panels (Project Alternate)
- Roof is available for future PV panel installation to reduce building electricity loads

8. Green Power purchase
- MSCBA purchased green power equivalent to 70% of the building's annual energy use

9. Temperature Set Points
- Heating and cooling set points to provide additional energy savings
- Can be adjusted to further save energy as user awareness influences user comfort levels

10. Window "Kill Switches"
- Implemented on all student suite operable windows
- Saves energy use when windows are open during comfortable days by shutting off heating or cooling systems

11. Allowable Student Equipment List
- Change in policy: students are no longer able to bring individual microwaves and mini-refrigerators. In turn, the University will provide one microwave and large energy Star refrigerator per suite.

Acknowledgments

This ZNEB pilot study would not have been possible without the commitment of the building owner, operator, and user. Our partnering engineers, owner's project manager, contractor, and design team were key in challenging preconceptions every step of the way. The authors thank and salute our team members:
[Owner] MSCBA Team: Edward Adelman (Executive Director), Janet Chrisos (Deputy Director) and Amanda Forde (Project manager) for believing in the process and being open to trying new ideas.
[User] BSU: Karen Jason (Associate Vice President for Facilities Management and Planning), Joe Amato (Facilities Manager), and Beth Moriarty (Residential Life Director) for being willing to challenge operational policies and engaging the entire campus community.
[Owner's Project Manager] Collaborative Partners: Joe Reilly and Patrick Murphy for asking the right questions.
[MEP/FP Design Engineers] Rist-Frost-Shumway Engineering, P.C.: Russell Schmitt (PE, Senior Mechanical Engineer) for being a relentless partner and offering technical insight into MEP systems.
[Construction Manager] Bond Brothers: Maxine Grant, Greg Williamson and Robert Mischler for providing several iterations of cost estimates.
[Architect and Interior Design] Perkins+Will Team*: Dana Anderson (Principal), Brian Healy (Design Director), David Damon (Project Manager), Andrew Grote (Project Manager & Architect), Chad Machen (Project Architect) John McDonald (Project Designer), Katelyn Cantelli (Interior Designer), Christine DiLallo (Technical Architect), Derek Johnson (Technical Architect) and Jeff Lewis (Technical Director) for a seamless collaboration from beginning to end.
*Jordan Zimmermann (Project Captain and LEED expert) and Yanel de Angel (Sustainability Champion)

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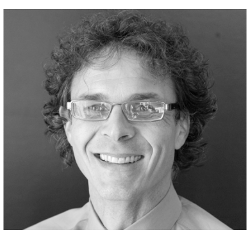
02. 

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ISBN 978-0-9815436-6-6

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