ARCHITECTURE AND HIGH PERFORMANCE BUILDING AT GEORGIA TECH: TEACHING DESIGN + TECHNOLOGY IN THE ENVIRONMENTAL CONTEXT

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INTRODUCTION

Integrative approaches to architectural design + environmental technology pedagogy are essential in educating future generations to respond to impending building energy use challenges. This paper will describe new approaches to incorporating building physics and building technology in the design studio via a diverse cohort of students and faculty, with strong emphasis placed on the development of innovative architectural strategies operating at the intersection of urban demographics, house and housing design, building performance, and sustainability.

The United States Department of Energy reports that our buildings account for forty percent of all energy consumed nationally. Our focus on high performance buildings at the Georgia Tech College of Architecture aims to reduce that percentage and meet the rising demand for design and building performance professionals to evaluate the environmental impact of design decisions. Continuing a twenty-five-year trajectory of research leadership, Tech students and faculty are leading the way in digital design, building simulation, engineering, and construction integration.

Over the past four years, students from various schools across campus have been working together in a seminar and design studio setting to expand 21st century housing options. Changing urban demographics, sustainability targets, and alternative energy requirements are investigated through smartly researched and elegantly designed housing and public space propositions.

The move from an ecologically aware architecture towards an architecture immersed in the emerging debates about carbon footprint and energy consumption is in part driven by increasing international concern over resource availability and delivery. Through reduced costs of alternative energy capture, higher efficiencies, rapid evolution of upstream technologies and applications and more robust software platforms along with growing social, political and economic debate, the

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definition of sustainability is evolving - moving to transform integral parts of architectural practice and education from a primarily aesthetic and assembly oriented trajectory to a more comprehensive understanding of the relationship between design thinking and building performance.[ii]

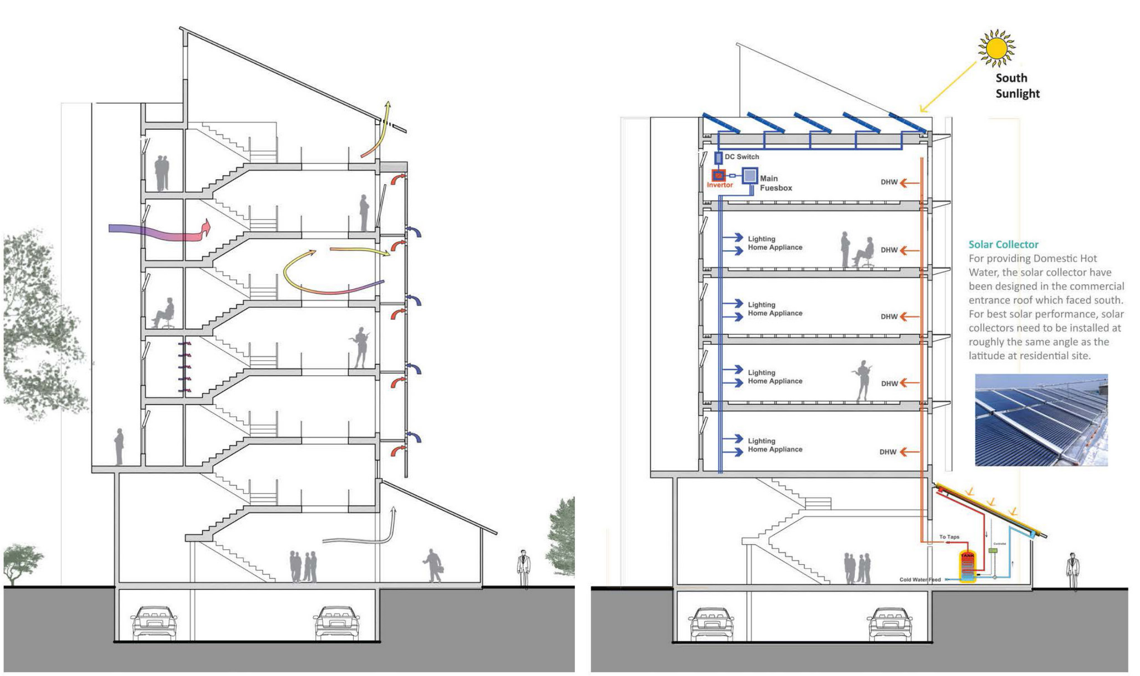
KEYWORDS
architectural and urban design; building performance; curriculum design; building construction; renewable energy

FIGURE 1. Zero Energy Design Studio at Georgia Tech: Exhibition of Faculty and Student work at Dwell on Design, Los Angeles, 2014.

TEACHING DESIGN AND TECHNOLOGY IN THE ENVIRONMENTAL CONTEXT

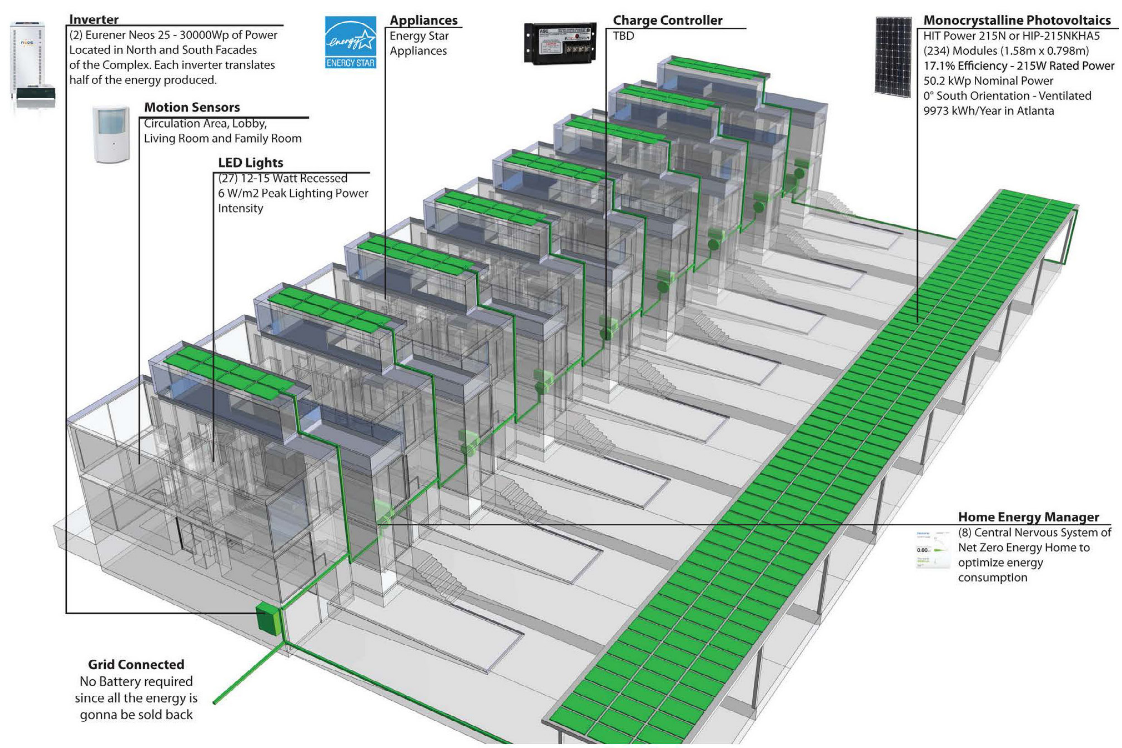
The term "flexible practitioner" is short-hand for the creative and intellectual nimbleness that the Georgia Tech faculty believes is essential not just in preparing students for the job that awaits them, but rather for the path of the career that stretch ahead of each student twenty or thirty years ahead. To meet these challenges, we are continually refining our courses and

FIGURE 2. Inman Park Town Homes and Midtown Atlanta Midrise: Examples of student design work indicating general strategies for energy conservation, building systems and performance.



Midtown | Katrine Bundgaard, Nai-Yuan Chang, Mindy Ren, and Roya Rezaee

Ellsworth Industrial Blvd | Students' Names Here



curricula, reorganizing this college to better stimulate the development of students' intellectual, critical, and creative design skills while also fostering their ability to situate decisions within an ethical framework of architectural and social practices. Working across boundaries and in tandem with other disciplines in the College and the Institute, along with the leading professional firms of the region and nation, and through exchanges with sister schools around the world, Georgia Tech's architecture program seeks to prepare students to be flexible, socially-engaged architects capable of expanding knowledge of the built environment and advance architectural practice.[iii] Our research-based pedagogical methods are crafted to enhance the learning experiences of architecture and engineering students at various points within program curricula. Our rich palette of course offerings are tailored to different levels of complexity and focus areas, and create new opportunities for the application of building physics and building technology in relation to the development of innovative architectural solutions.[iv]

HUGE DEMAND FOR DECREASED ENERGY COST AND A MOVE FROM HOUSES TO HOUSING

While the size of the average American home has grown over the last 15 years, the total United States energy consumption in homes has remained relatively stable. Advances in energy efficiency have offset the increase in the number and average size of housing units according to the latest data from the Residential Energy Consumption Survey (RECS). Newer homes tend to feature tighter building envelopes and other characteristics that have elevated the status quo when it comes to energy conservation. Likewise, there is a growing interest among the general population to move towards greater awareness of alternative energy platforms.

Georgia Tech's entry to the 2007 Solar Decathlon gave the high performance building group at Tech a working prototype to study the economic viability of such a building and was one point of origin for several new courses offered in the College: The Zero Energy House and Green Construction. Ongoing research into the practical application of PV at the residential scale continues to use Tech's Solar Decathlon house as a reference related to feasibility, efficiency, applying risk assessment models, examining building enclosure strategies, and various new material applications. The solar decathlon has served to advance other research projects at Tech in the area of solar panel installation velocity. The solar decathlon prompted some other conclusions which have become drivers for this next phase of applied research:

- The sheer cost of the Solar Decathlon exercise led to a re-evaluation of the role a single family house has on broader questions related to settlement patterns, affordability, energy delivery methods, and access by the general public.

- Urban settlement patterns can and should inform energy debates. There are other applied research challenges that can be woven together to include higher density, energy positive, affordable housing solutions; working at this intersection places the energy debate in a much broader context, which will be described in greater detail below.

- There are a number growing community based initiatives focused on understanding the new forces in play as urbanized areas like San Francisco and New York City work to address issues associated with the minimum standard for creating liveable and affordable urban dwellings. Similarly, as Sunbelt cities like Atlanta continue to experience a move away from satellite single family bedroom communities towards center-city, mid and high-rise housing blocks, are in demand. But as the debate around what constitutes an acceptable and affordable standard of multi-family living emerges, sustained focus energy generation and conservation is missing.

ARCHITECTURE AND THE HIGH PERFORMANCE GROUP AT GEORGIA TECH

The High Performance Buildings PhD concentration and Post-Professional Master of Science program in High Performance Building at Georgia Tech are developing new knowledge and new tools to inform design and investment decisions with concentration on the use of building physics and building technology for sustainable architectural design. Our students and faculty are focusing on quantitative expressions of energy performance. Emphasis is placed on the analysis of the energy performance and environmental impacts of buildings, as well as on the integration of these metrics in the development of innovative architecture.

The foundation of the high performance buildings program is a sequence of physics-based courses in modelling, simulation, HVAC systems and controls, building enclosure, risk analysis, and renewable energy technologies. Students are encouraged to take cross-disciplinary, studio-based courses that include architecture, mechanical engineering, building construction, and business. The program is founded on a first-principles approach to building physics, envelope design, modeling and analysis, life-cycle assessment, applied simulation, AEC Integration, and critical ecological thinking.

ZERO ENERGY HOUSING INTERDISCIPLINARY DESIGN STUDIO

Zed-H Studio (www.zedhstudio.com) is a funded[v] multidisciplinary design and physics based design studio focused on the comprehensive design and modelling of all aspects of ultra-low energy developments, from land procurement through energy and risk modelling, taught by four faculty members with student teams from architecture, high performance building, electrical/mechanical engineering, and building construction. At a conceptual level, the students and faculty focus on sustainable architecture via the pursuit of technically "provable" reductions in energy use, ecological impact, and greenhouse gas emissions for the life of the project. At a practical level, a key part of the design activity requires that students incorporate high-performance active and passive energy systems, test all aspects of the design via several energy related software platforms, and construct viable real estate proforma and cost estimates. Likewise LEED, Passivhaus, and the Living Building Challenge serve as part of our course bibliography.

The potential impact on the discipline and profession of architecture is far reaching. Our School, like so many, is confronted with emerging opportunities for architects to participate in national debates and grant initiatives concerned with how buildings perform in and over time as well as how they function aesthetically and programmatically. Though the proposed trajectory appears to the students at first to be linear, the process of design is not. Teams embrace an iterative process whereby design decision making and subsequent technical analysis worked in dialogue continuously throughout the semester. Those responsible for energy analysis craft their methodologies to permit quick changes to working assumptions about building configuration, envelope, systems, energy use, etc. Those responsible for design must be prepared to accept technical feedback and adjust designs accordingly.

Using a variety of simulation tools produced in house at our Institute or available through the DOE, etc., student teams develop their proposals, characterizing:

Site cost and choice: Students form teams and work together to identify one or two sites which meet a number of criteria, most importantly, cost. Land cost are a determining factor in the feasibility of any construction project, and because of the additional funds required on the front end of any low energy project, land values must be factored into the Performa at the outset.

Building Design and Building Simulation: Students work iteratively on the building design, much like a typical design studio, with the exception of including the data into to the spread sheets much like the one you see in the accompanying illustration. Students navigate the design process using two software platforms the Manual J Load Calculator, Ecotect, and Residential Energy Load Calculator developed in house which give the students immediate feedback on design choices.

Energy demand and energy production: Energy demand is based on a number of factors - time of year, occupant load, site conditions, etc. Students construct energy models based on a variety of energy kits which are explored through the first half of the class, and include a variety of leading edge energy platforms.

Building operational strategies and mechanical and electrical systems: Commonly envisioned low and net zero buildings utilize a complex set of interacting energy-saving measures such as phase-change materials, wind-catchers for passive cooling and ventilation, passive solar windows, insulation panels, heat recovery modules, and intelligently controlled solar shading. Engineering of these systems requires that the design team ensures that energy targets are met while maintaining reliable comfort and power availability.

Building Furnishing: Smaller, Flexible spaces require deeper consideration for use needs. Students work to define not just room sizes; the real challenge is to understand how the spaces will be used on an daily and basis, and how to maximize use for disabled inhabitants.

Construction specifications and building processes: Students prepare an outline specification, evident in the attached images, and by working with architecture and building science faculty, prepare a general plan for construction. Initial cost estimations through development and return on investment are included.

In early design, the novel platform described above allows the creation of schematic models of the design concept and management of different criteria by which best options can be judged. In later stages, the emphasis shifts towards closer inspection of the systems and their dynamic interactions. This requires adaptive and high fidelity simulation, reflecting a progression from insight informed by simple schematics towards simulations that replicate physical behaviour as accurately as possible on the computer.

Financial proformas are developed at the very outset of the course, beginning with the cost of real estate, working through the "costs" associated with borrowing money, unit prices associated with construction, risks associated with implementing new technologies as well as general risks associated with development, marketing fees, real estate fees, and ultimately profit. These discussions are at the very least eye opening for the students.

By all indications, the course continues to be a success. The student evaluations place the course in the upper percentile of interdisciplinary electives. For the final review, a number of developers, contractors and representatives from the State energy agencies interact with

Changing inputs to reduce the EPC

- Changing the Elevator type used
- Adding a shading overhang to Windows
- Using triple glazed windows with 12mm argon
- Using EIFS finish, insulation board, sheathing, batt insulation, gyp board
- Use of Membrane, 150mm HW concrete, batt insulation, suspended acoustical ceiling
- Reduce the windows on the South and west façade
- Reducing lighting load in residential and hotel by switching to LED instead of incandescent

[E.1] Energy Need — For Atlanta

$Q_{design,nd}$ [kWh/m²/yr]	58	Q_{ref_nd} [kWh/m²/yr]	100	EPC_{nd}	0.58

[E.2] Reference Value and EPC calculation

$E_{design,del}$ [kWh/m²/yr]	98	E_{ref_del} [kWh/m²/yr]	149	EPC_{del}	0.66

[E.3] Reference Value and EPC calculation

$E_{design,p}$ [kWh/m²/yr]	-399	E_{ref_p} [kWh/m²/yr]	286	EPC_{p}	-1.40

[E.4] Reference Value and EPC calculation

$CO_{2design}$ [g/m²/yr]	-89246	CO_{2ref} [g/m2/yr]	64230	EPC_{CO2}	-1.39

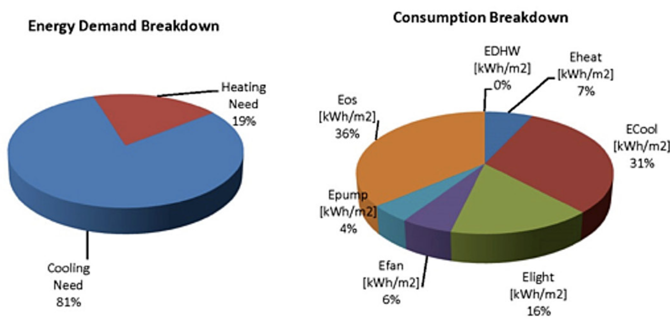


FIGURE 3. Sample Energy Calculations from the Studio demonstrating how changes to building systems impact energy performance.

the students first in a formal session and then later in an informal conversation to discuss strategies for implementation. Our efforts to align architecture, building performance and engineering continues to have an impact on two related courses, Façade Design and Transformation, and the Comprehensive Design Studio in our Masters of Architecture program.

JOINING ENERGY RESEARCH, SETTLEMENT PATTERNS, DEMOGRAPHICS, AND AFFORDABILITY

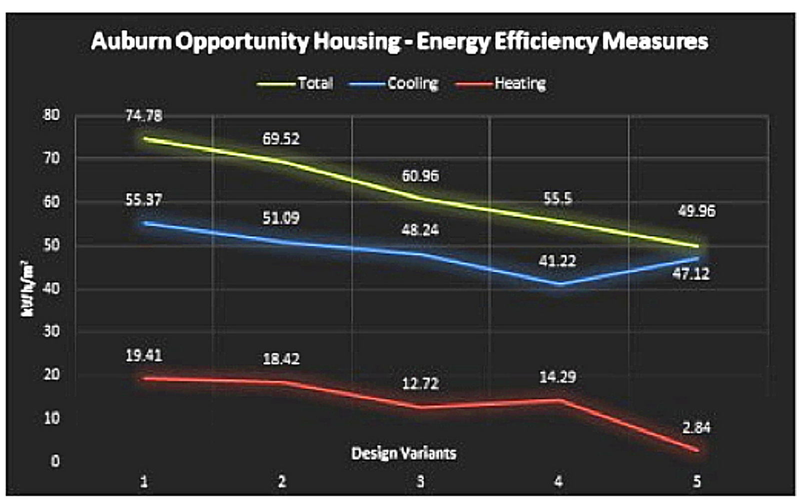
The studio works with a number of consultants from various disciplines. Sarah Watson, the deputy director at the Citizens Planning Housing Council, and Lisa Blecker of Resource Furniture in New York challenge the students to consider changing urban demographics and the need for smaller spaces. As populations surge in American urban environments, changing demographics are creating new opportunities to rethink housing typologies and business models. In 2013, The CHPC curated "Making Room"[vi], an exhibition exploring the relationship between lifestyle, economics and urban multifamily dwelling typologies. This growing body of work by the CHPC provides a foundation to our design and research and is directly informing other groups such as the Institute for Public Architecture in New York. "There's a very fixed idea of what an apartment needs to be," says Watson "Who you expect to live in the unit will affect the design."

FIGURE 4. Students, faculty, and guest critics reviewing projects, Fall 2013.

Each team within the studio researches the unique needs of various user groups and designs accordingly for flexible housing typologies. Resource Furniture's work in the area of transformable environments serves as state of the art examples to the studio, providing a fast forward move into understanding design at small scales. Each semester, Lisa and Sarah host a seminar for the students in New York, and both serve as guest critics on design reviews in Atlanta. Companion goals of sustainability, compactness/affordability, and zero energy design are equal design drivers.

We are benefiting from deep knowledge of energy systems by drawing on expertise across campus disciplines, and likewise from our regional partner Southface Energy Institute. For over 35 years, Southface has provided technical assistance to the southeast regional design and construction community via expertise in building science, energy efficiency and green design for new and existing buildings including single family homes, multifamily buildings and commercial structures. Southface develops and manages local, regional and national programs and operates with over 50 full time employees and generated annual revenue of over $5 million dollars in 2012.

FIGURE 5. Auburn Avenue Opportunity Housing: Impact of design variants on heating and cooling energy needs of the building.



A NOTE ON DIVERSITY

Particularly impressive is the diversity of the student cohort participating in the course. Over the last two years, we've had students representing Korea, Croatia, the United States, India, China, Brazil, Columbia, Poland, and Turkey, with a gender balance of 50/50, all working in various team structures to problem solve. Knowing that each student's unique experience will be shared in their home context is potentially the greatest achievement of all related to this exercise.

CASE STUDY 1: AUBURN AVENUE OPPORTUNITY HOUSING: LOW EMBODIED ENERGY, HIGH EFFICIENCY

Daniel Alhadeff, Namarata Dani, Tyrone Marshall, Junying Shi, Paul Szymkiewicz

Auburn Avenue Opportunity Housing, located on Atlanta's historic Auburn Avenue[vii], is a multifamily urban mixed use development located east of the downtown business district. Primary goals of this project include the creation of comfortable, flexible and healthy work/live environments, combined with low-energy demand, low-embodied energy materials, site water management, and on-site renewable energy production. Advanced thinking on neighbourhood composition led the team to reconsider Atlanta's typical housing block typology, creating a new, flexible, energy-efficient prototype applicable to other similar sites.

The team worked out building size and program with overall energy performance and conservation as a top priority. Detailed thinking on the building envelope was initiated at the very beginning of the design process. Figure 5 below illustrates the impact of energy-performance design decisions on heating and cooling before HVAC equipment is introduced into the project. The horizontal axis represents incremental design variants that improve building energy performance.[viii] At each variant, energy need of the building was calculated via simulation (EPC). The team started with a variant 1, a cross laminated timber structure with code minimum parameters for insulation and fenestration, and by adding new efficiency measures to improved (lessened) energy transfer needs of the building, ending up with around 50 kWh/m^2 yearly heating and cooling demand. For example, in variant 2 high performance windows replaced code minimum and North-facing windows received lower U-value and slightly higher SHGC than the rest of the façade. In variant 3, walls were insulated to continuous R29 and roofs to continuous R53. In variant 4, window shading devices as well as highly emissive wall and roof surfaces improved solar gain game. Finally, in variant 5 infiltration measures reduced the air exchange rate per hour to approach 0.08 ACH-Nat.

Mechanical ventilation is provided by mini-ERV's efficiently exchanging air in each unit. Each unit is also equipped with a unit controlling system that intelligently manages HVAC operation and gives guidance to the occupants advising them when it is beneficial to open windows and ventilate naturally based on pressure, temperature and humidity sensors inside and out. HVAC operation is automatically turned off when windows and pivot doors are kept open. Pivot doors open into the interior courtyard encouraging their use and fresh air exchanges.

Otherwise wasted heat from the heat pump is salvaged by a heat recovery unit that transfers that heat into a domestic hot water tank. No fossil fuels are used in this project to maximize the potential for on-site solar PV installation, which is pre-wired for future option of battery storage. A 15,000-gallon rain water tank with automatic flow inducer supplements the water supply by using graywater to supply the toilets. Multi-family projects such as this lock in a great amount of carbon (CO_2) in the massive amounts of timber used in its construction (approx. 2900 m^3). The project uses timber from Georgia that is both plentiful and renewable.

The benefits of the total system include the elimination of thermal bridging in standard stud framed walls, structure and insulation in one layer, greater humidity and infiltration control, lighter structure and net CO_2 sequestration in contrast to CO_2 generation (Portland cement). Offsite prefabrication leads to an extremely versatile and flexible system in design and on-site modification by using familiar labor techniques and tools.

The main conclusion of this experimental analysis is that during a 24-month test period (using Wufi software) moisture content in the wood structural layer of the proposed CLT wall assembly is stable and stays around 10% in the Atlanta climate.[ix] A ventilated façade system (high-density phenolic resin engineered wood panels) contributes as the first layer of defense, not only protecting the building from wind and water, but also lowering the summer thermal gain and managing moisture.

Circulation spaces were limited to vertical stair wells with low-E insulated channel glass glazing with aerogel cores. These common areas were analyzed in terms of the need for air conditioning and impact on adjoining units. Simulation (IES) showed that leaving those spaces unconditioned would result in an approx. 2% increase in energy use by adjacent units during extreme months (July/January). Even in July, natural ventilation could be used 12% of the time to condition those spaces, aided by the natural stack effect, and even more so during the shoulder seasons.

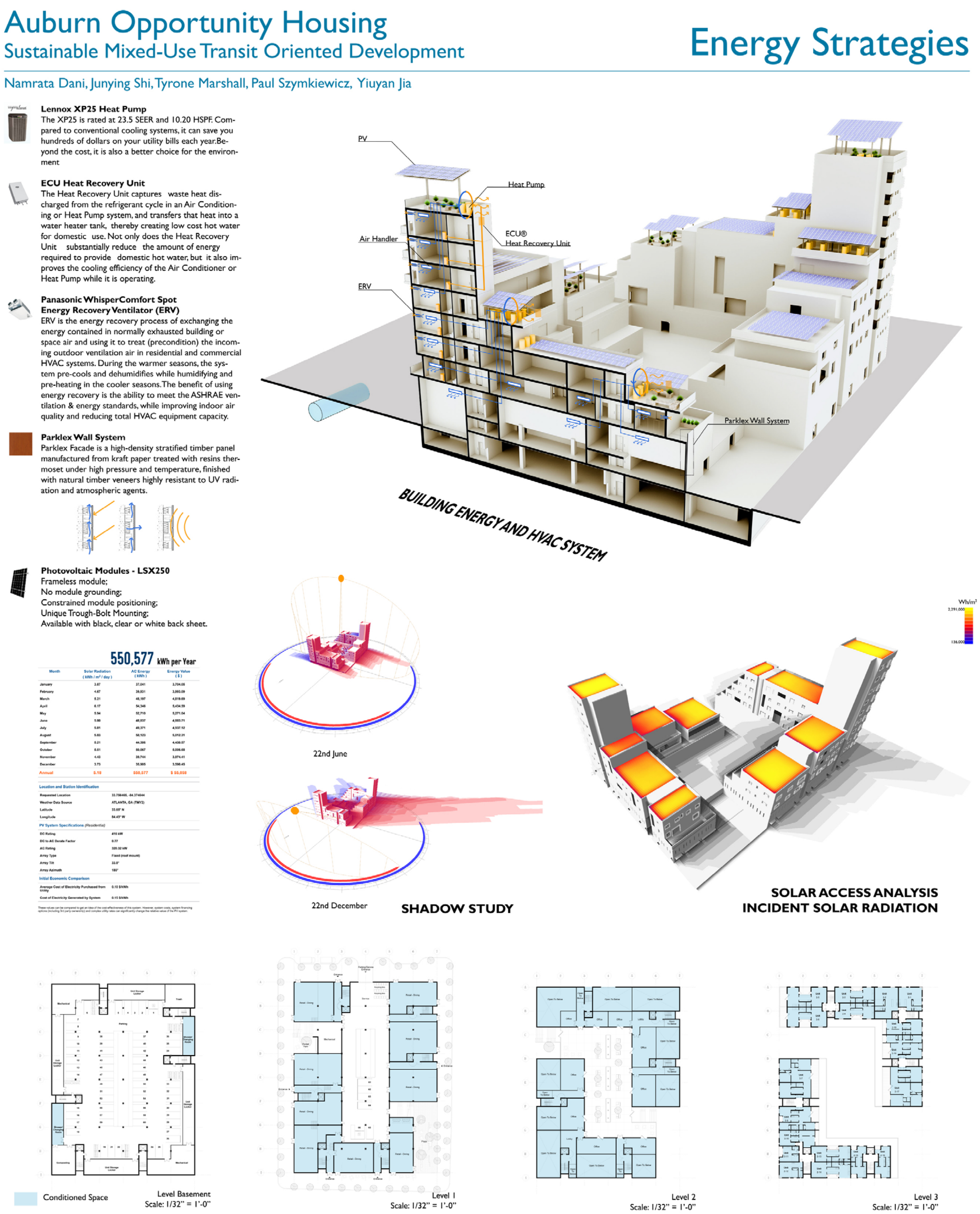
CASE STUDY 2: BRADY AVENUE MID-RISE: MULTI-FUNCTION BUILDING INTEGRATED PHOTOVOLTAIC FACADE

James Bramlett, Gustavo Carneiro, Po Kai Chin, James Van Horn

This project is situated in West Midtown Atlanta, an area which houses a mix of young professionals, older established businesses as well as start-ups, and students from nearby Georgia Tech. Recent commercial real estate developments in the neighborhood cater well to this demographic whereas the accompanying housing development has not matched them in creativity or originality. Located at the transition point between the sparsely developed industrial area just across the railroad tracks and the Westside's dense commercial landscape, the project activates the street with a reimagined, pedestrian-friendly intersection anchored by a two-story grocery store at the base of the tower. The market extends the existing urban edge onto Brady Avenue and provides a much needed public amenity to the neighborhood.

The team worked to develop a series of highly functional and flexible apartment typologies in an arrangement formed within a state of the art building enclosure system which serves as an energy generation systems and daylighting modulator. The tower block consists of 50 one, two, and three-bedroom units, arranged vertically which extend the full width of the building, providing ample daylight, cross-ventilation, and skyline views to residents. Many of the apartments have at least one bedroom/bathroom living space that can be self-contained and rented on a short or long term basis, providing the owner with either space for aging parents, older kids, or a secondary source of income to assist with mortgage payments. Many of the residences open onto either public or private "dogtrot" terraces punched through the building mass. Residents also have access to a lawn and a reflecting pool for storm water detention on the roof of the grocery.

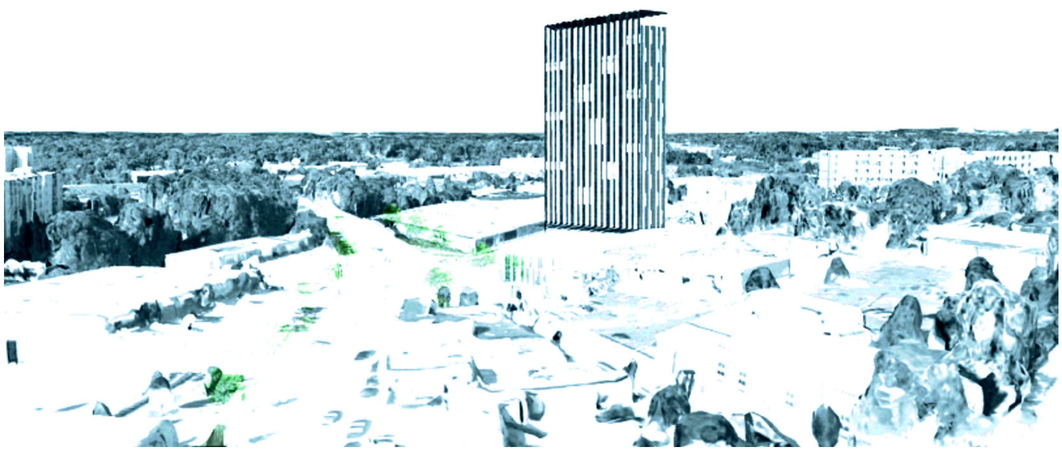
FIGURE 6. Auburn Avenue Opportunity Housing: Building section with energy delivery diagrams.



The site is well situated with a high number of peak solar hours throughout the year, and opportunities for passive solar gain in the cooler months. The energy kit in the tower block consists of an array of multizone split systems, monocrystalline BIPV, and solar vacuum heat pipe collectors. Energy demand for the tower portion of the project is 44% heating and 56% cooling. Energy delivery balances over a 12 month cycle, however generation falls short in June through September with electricity purchased from Georgia Power. In 2015, the levelized cost of electricity, understood as LCoE=(sum of costs over lifetime)/(sum of electricity saved over lifetime), is 13.4 $/kWh while the levelized costs of renewable energy is 12.1 $/kWh.

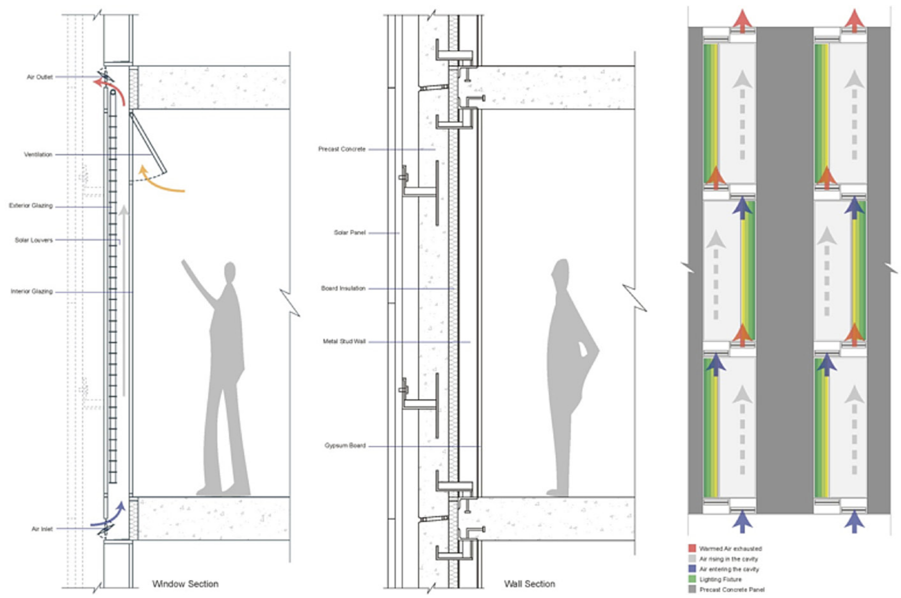
The building façade is designed as a layer system, beginning with the interior spaces, including textiles/blinds, a box window system described below, an aluminum armature, and a series of vertically and horizontally oriented PV panels. The integrated panels function as a primary source of energy generation, and at the same time shade parts of the building, functioning to reduce cooling loads. The panels serve as an integral part of the tower's cladding and shading system, lend a sense of verticality to its tall, broad form and are used extensively to reach the project's ambitious low energy goals.

FIGURE 7. Brady Avenue Midrise: A building-integrated photovoltaic system distinguishes the tower from surrounding structures visually and economically, signifying advanced energy performance.



The box window, a type of double-skin façade, contains the southeast facades of the tower and functions to improve energy performance. All windows are prefabricated modules and are designed to fit over the precast concrete panels on the facade quickly and precisely. The surface attachment of the box window module to the face of the precast assembly mitigates heat transfer through the edge of the slab. The exterior dogtrot spaces are fabricated with thermal breaks along exterior walls, and lightweight concrete is used as filler between post-tensioned connections formed during assembly. These thermal breaks exist throughout the building and area reflected in the energy model. Daylighting strategies are a component of the box window. The system of integrated louvered panels allows for the modulation of daylight through the windows, blinds and light shelves. Each module has a cavity between their outer glazing and inner glazing which provides a thermal buffer zone in cold weather and mediates solar heat gain in hot weather.

FIGURE 8. Brady Avenue Midrise: Box window section.



CASE STUDY 3: HOUSING ALONG THE ATLANTA BELTLINE: DEMOGRAPHICS AND TYPOLOGY

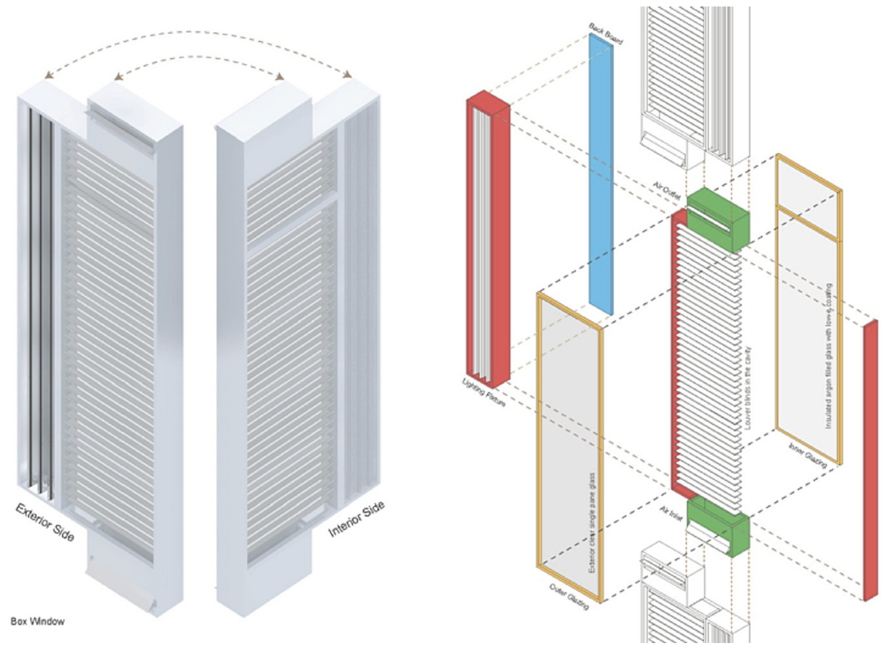
Madona Cumar, Miguel Otero Fuentes, Jennifer Ingram, Kaitlyn Pahel, Victor Renteria-Valdez, Bunny Tucker

The Atlanta BeltLine[x] is the most comprehensive sustainable redevelopment effort ever undertaken in the City of Atlanta and among the largest infrastructure reclamation projects currently underway in the United States. The creation of housing and public space along this 22-mile railroad corridor circling downtown will connect 45 in-town neighborhoods, provide first and last mile connectivity for regional transportation initiatives, and put Atlanta on a path to 21st century economic growth and sustainability. Energy demand and consumption patterns were investigated throughout the exercise, though in this case the initial focus was on two additional and highly relevant areas: demographic and site research as a means to help define what future "efficient" housing can become.

The site is located on the Eastside Beltline trail, southeast of Atlanta's Piedmont Park and directly south of the Midtown Arts Cinema. This area, quickly coined as "a great location, but a terrible place to be," was riddled with connectivity and pedestrian issues but was nested in an oasis of amenities – perfect for both the young Atlantan desiring Midtown living, as well as the empty nester wanting the ease of efficient living alongside existing neighborhoods and shops. Because of the site selection, the urban analysis led the team through a process of rethinking roads and pedestrian right-of-ways in a manner that would promote connectivity from the neighborhoods, to the commercial district, to the site, etc. At the heart of the intervention is a public park directly connected to the Beltline trail, providing pedestrian and bike access to the trail in an area that's currently completely severed.

Demographic research directed the group towards two important user groups: 25-35 year old mostly single professionals and adults who wished to downsize post-kids or post-suburban

FIGURE 9. Brady Avenue Midrise: Box window axonometric study.



living. According to the 2010 census, Atlanta has one of the highest percentages of single living alone households at 44%, a number belonging to the total non-family households at 56%, and a growing number of dual-income no-kid, or empty nest households, ages 44-64, at 14%. In each case, the convenience of urban, not sub or exurban living is preferred. The rise of the creative class and creative economy is likewise driving significant change to settlement patterns. Thus was born the driving theme of the "neighborhood" scheme, a housing project with shared social spaces that would draw a host of ages and demographics.

FIGURE 10. Atlanta Beltline Mixed Use Housing: Demographic and household size diagrams, 1950 to 2013.

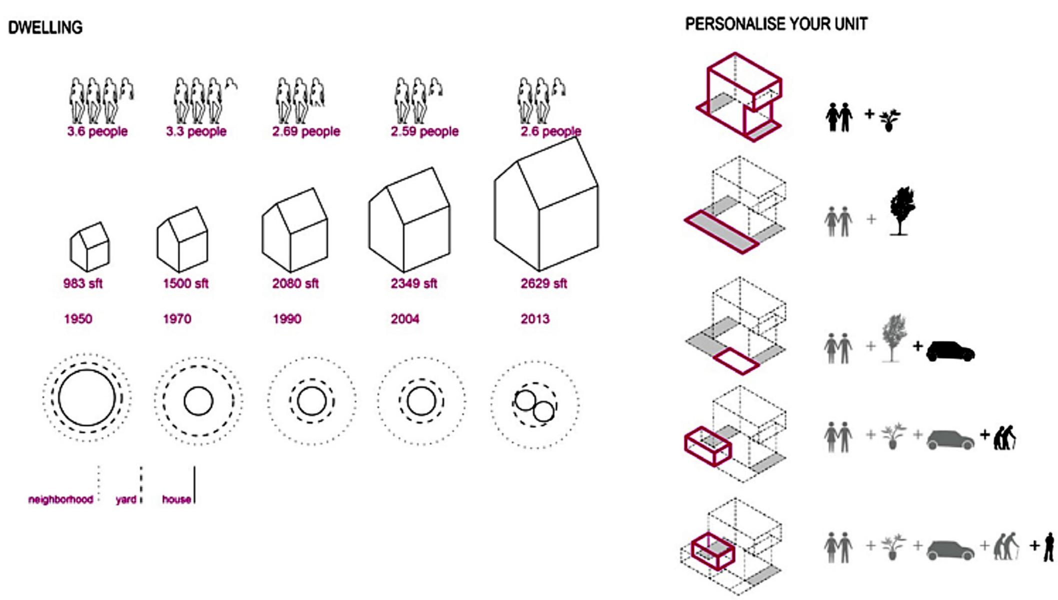


FIGURE 11. Atlanta Beltline Mixed Use Housing: Lifestyle Study, User Narrative/Demographic Driven Apartment Types.

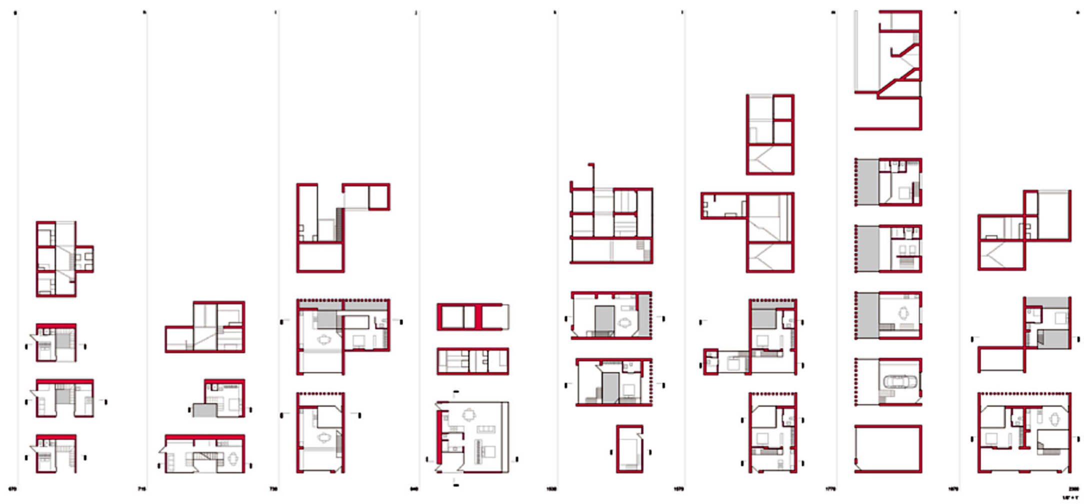


Figure 11 demonstrates the palette of housing types that emerged out of the neighborhood, demographic, and user needs study. The unit development of the schemes provided a direct connection to family structure, and income levels, and needs – exploring the possibilities of different unit types for each lifestyle narrative. Whether the aging bachelor or the young nature enthusiast, the team explored units in a variety of sizes. In all, we concluded with 15 different unit types, varying from the micro unit to the townhome strategy and from 230 to 2,600 square feet. The unit types were distributed into three combined housing typologies. The first block, lining the edge of the park and the Beltline trail was elevated above the ground in a way that would allow a free threshold between the Beltline and the park, encouraging pedestrian movement between the two. The second block, situated at the current retaining wall separating the Midtown Arts and Home Depot parking lots, sat in the ground to retain lighting into the park as well as to offer units with parking opportunities for some users. The last prototypical scheme operated between the existing Lakeview drive neighborhood and the parking lot of Home Depot, Whole Foods, et al. These units would offer an opportunity to connect to neighborhood living while leveraging the sectional qualities to enhance the commercial level below. These building schemes were developed most fully through rigorous modeling and group investigation. As seen in the following pictures, the groups worked constantly across a variety of scales, with the goal that each bar would respond appropriately to its site. Every decision was questioned fully by the members of the team in a collaborative and exciting way.

Interior Design

Next, the typology proposals were investigated as interior environments. Each member of the studio was asked to hone in on a specific user and design around that narrative, all within the overarching goal of the existing housing project. Each of the four members of this team during this spring semester focused on a very different user, including an individual with physical disability, a "nomad" resident, an individual with a severe visual impairment, and an "empty nester". Specifically, the following two illustrated projects showcase the unit for a wheelchair

FIGURE 12. Atlanta Beltline Mixed Use Housing: Interior view of apartment for wheelchair user.

FIGURE 13. Atlanta Beltline Mixed Use Housing: Apartment for Empty Nesters.

user, which sits within block 2, and the unit for the empty nester, who lives in the modern townhome style unit situated between Lakeview Dr and the commercial district in block 3.

CASE STUDY 4: PAULK RESIDENCE, SCALY MOUNTAIN NORTH CAROLINA THE LUXURY SINGLE FAMILY HOUSE MODEL

Gamble + Gamble Architects, Atlanta, with Russell Gentry, P.E., Garnier and Kim, Mechanical Consultants, Maing Consulting Engineers, Façade and Terrabonne, Inc. Landscape Architects

The Paulk house is a private residence located on a steeply sloped, 57 acre wooded lot in Highland Gap, North Carolina. A small creek cuts though the northern edge of the site and flows to the Ocoee River, less than 1/2 mile away. The clients are a retirement age couple who wish to downsize from a larger home, and require a simple but highly specific building

FIGURE 14. Paulk Residence: Exterior view.

program including a small music room, library, gym, modest guest quarters, and outdoor pool for exercise and relaxing. The clients specifically requested a vertically oriented scheme that would create a series of segregated public and private zones, encourage exercise via the stairs, and offer a variety of views across the landscape. The programmatic strategy was ultimately defined as eccentrically zoned and compactly vertical. The formal strategy for the house was influenced first and foremost by maximum solar exposure derived from a carefully calibrated building geometry as well as air flow as expressed through controlled exterior windows and apertures, the interior stair, and operable interior openings that encourage air movement. The plan geometry is also derived from the existing site geometry – a series of center points generated by the natural placement of trees across the site.

Hot Side/Cool Side

Of particular importance to the clients and the design team is what was termed the "hot side/cool side" strategy related to site orientation and systems operation. The upper windward side of the house faces uphill and directly south. An array of framed solar louvers wrap the so called "hot" side of the house, generating enough electricity on an average daily basis to balance the energy required to power the house. The stair serves as a vertical ventilation shaft using the hot side of the house to magnify thermal movement on warm days during the swing season. The louvered solar wall allows air to move freely up the interchangeable pressurized panel system. The lower windward side of the house faces a small creek with the view extending towards a river basin. Air current in the mountains is marginally predictable, but the orientation captures cool air traveling up the hill. Windows serve as soft articulated apertures to emphasize air flow across smooth ceilings and through unobstructed openings.

The energy generating kit operates with positive energy generation over a 12 month cycle and includes monocrystalline BIPV which are moderately ventilated and southerly oriented with an inclination of 45° on the southern, louvered wall and 0.12 -0.18 Kpk KW/m^2 with a minimum package density of 80%. The cooling/heating system is multi-split with COP = 2.9. Heat pump + radiant floors, estimated conservatively at COP = 1, mechanical supply and exhaust of air @ 0.35 ACH. Other features include:

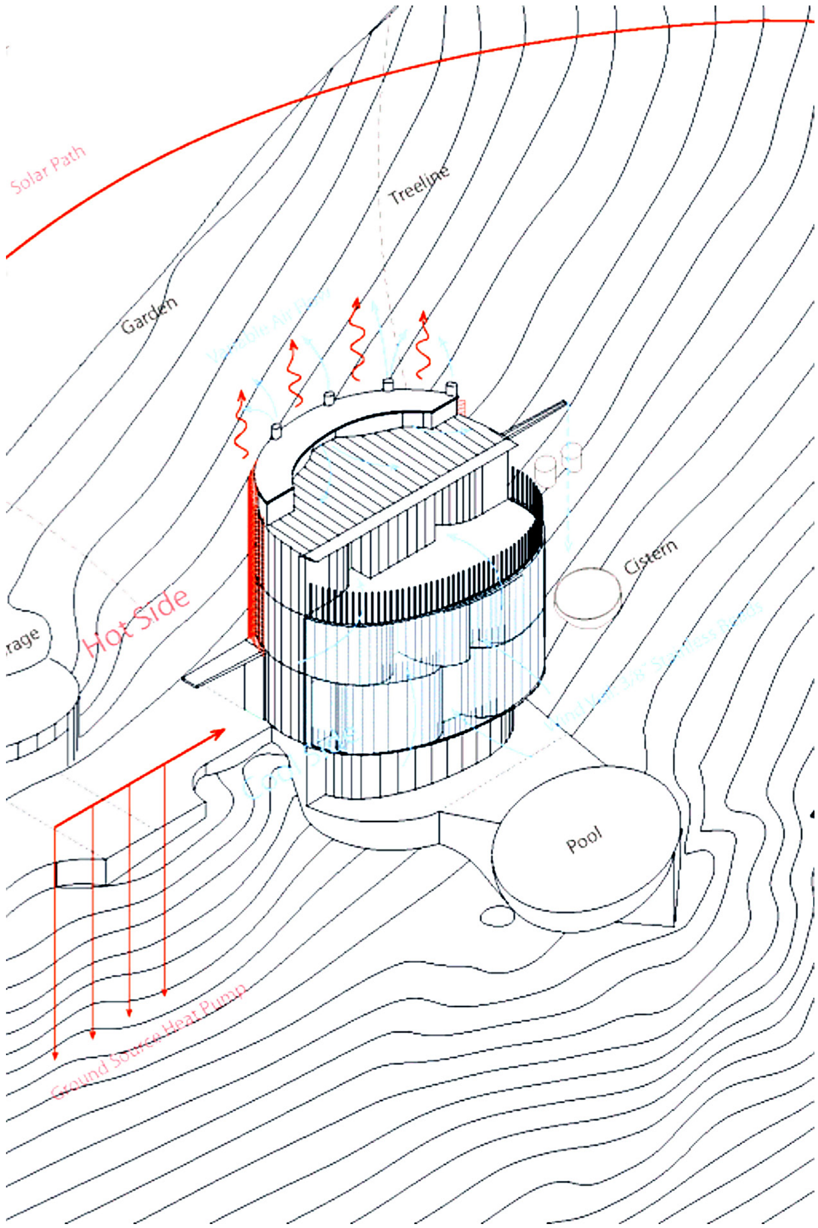
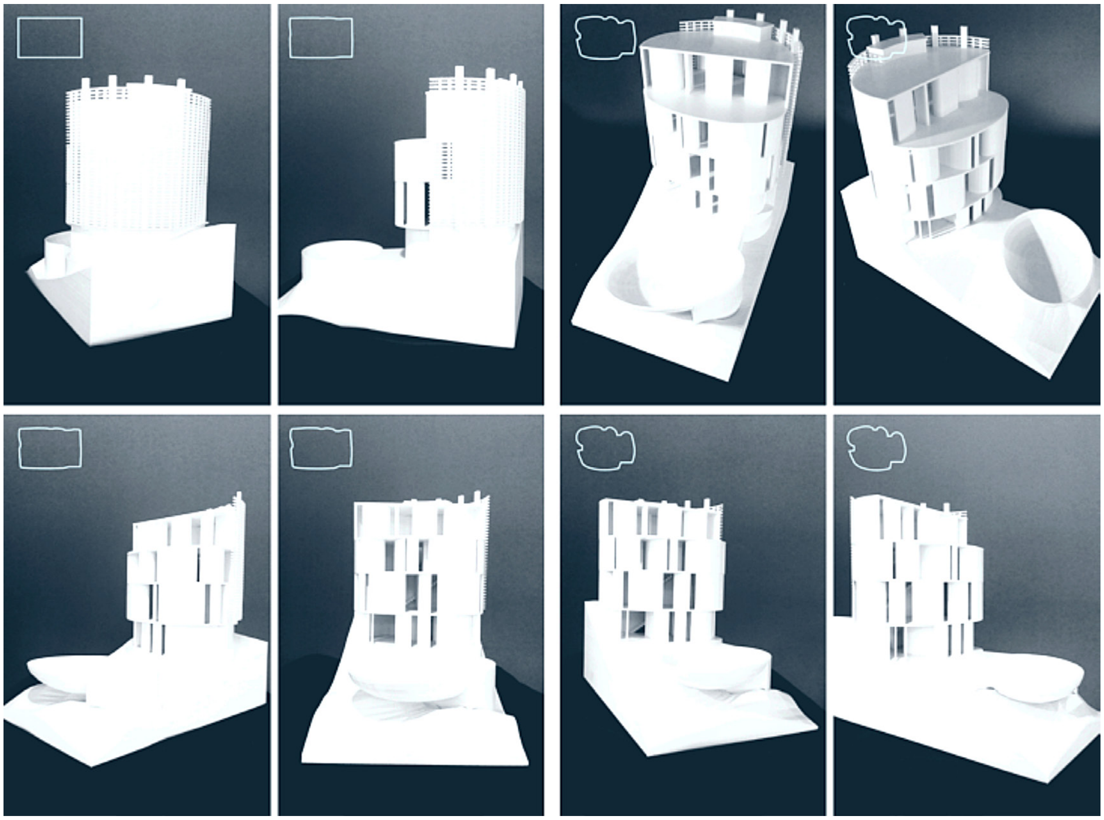


FIGURE 15. Paulk Residence: Energy concept diagram demonstrating hot side/cool side strategy.

- Heat exchange plates and/or pipes, 20% exhaust air recirculation, with a tight envelope @ 0.4 ACH
- Sensor controlled lighting deployed throughout the residence with a lighting intensity = 5 W/m^2
- Evacuated tube solar collectors with direct flow system (hot water) 30 m^2, facing south @ 30º inclination on the roof

Water conservation strategy includes two 1000 gallon cisterns located at east and west side of house. The building structure is composed of reinforced cast-in-place concrete with tube steel bracing at pressurized wall system with interchangeable pressurized panel system Aluminum Clad.

FIGURE 16. Paulk Residence: Serial photo of 3-D printed model.



CONCLUSION

We've outlined specific examples from our teaching and research at Georgia Tech that explore new approaches of incorporating the physics and technologies of buildings into the design studio while encouraging students to develop inventive and original architectural strategies while specifically considering and engaging urban demographics, residential design, building performance, and sustainability.

US based, sustained efforts in the area of market rate, carbon neutral, ultra-low energy consuming market rate urban housing will lead to:

- advances in interdisciplinary educational models
- community engagement and debate around 21st century and housing
- advances in what constitutes the public realm in urban areas with increasing density
- inquiry into innovative materials and construction methods
- advances in dialogues around design and energy delivery

Our intent with the development and implementation of these courses is to enhance the learning experiences of architecture and engineering students at various points within program curricula in order to extend the dialogue to include technical expertise, design and representational virtuosity, and energy management as an essential part of any design project.

ACKNOWLEDGEMENTS

Many thanks to the students at Georgia Tech for all of the effort and dedication to realizing the full potential of these courses in relation to our design curriculum; the support of Alcoa Aluminum and Resource Furniture; the guidance and good spirit of everyone at Southface Energy Institute; and our friends at Architecture for Humanity. Editing by Samuel Maddox.

REFERENCES

i. For a complete list of faculty and students participating in this effort, please go to www.zedhstudio.com

ii. There are a number of recent or forthcoming publications which examine the conceptual and instrumental dimensions of thermodynamics in architecture, and elaborate in various ways on this larger shift in general architectural education to include deeper thinking on the subject in the design studio, not just lecture and seminars.

iii. Opening Remarks to the Graduate Student of Architecture 2009" George B. Johnston, Ph.D., R.A. Director, Graduate Program in Architecture, also published on the Program's website.

iv. Minjung Maing, architect, educator and engineer, contributed to the general idea for this essay, and is working in a related field at the Chinese University, Hong Kong. We are working to combine forces in coming years with students from both Universities working on the same problem.

v. The work is generously supported by grants from the Alcoa Foundation, and a gift from Resource Furniture. The College of Architecture at Georgia Tech continues to put considerable resources into overhead and travel. We've benefitted from assistance from the now defunct Architecture for Humanity and continue to receive support from Southface Energy Institute.

vi. http://makingroomnyc.com

vii. http://sweetauburn.us/intro.htm

viii. At this stage, energy performance is calculated based on building energy demand induced by occupancy: people, appliances, lighting, and weather. This does not include energy required to run the HVAC systems, only energy needed to be put into or extracted out of the building in order to keep the scheduled temperature set points.

ix. This value falls well within the recommended EMC (Equilibrium Moisture Content) according to Table 13.1, and recommended average moisture content in Figure 13-1, Wood Handbook, US Dept. of Agriculture, Forest Service, Forest Products Laboratory, 2010 Centennial Edition.

x. http://beltline.org/about/the-atlanta-beltline-project/atlanta-beltline-overview/