THE URBAN GARDEN; INDUSTRIALIZED NET-ZERO ENERGY HOUSING

JOSEPH WHEELER
Virginia Tech

ROBERT DUNAY
Virginia Tech

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The promise of factory built housing has risen and receded each decade over the past century, yet has failed to become part of mainstream construction. Economy of scale, lower cost, higher quality and faster production are predicted attributes that are now overlaid with concerns of sustainability and energy use. This project proposes a re-examination of industrialized processes and its applicability to high-density living. By integrating architecture and technology, the goal is to make dwelling sustainable and beautiful.

VT CENTER FOR DESIGN RESEARCH

Over the past decade, students and faculty at Virginia Tech have designed and constructed three net-zero energy houses for the Department of Energy Solar Decathlon Competition. These research initiatives have resulted in considerable expertise in sustainable construction and energy efficient dwellings. All three houses were not only top ranking in the architecture and innovation categories, but also were top performers in energy production and energy efficiency. As a detached single family dwelling, the most recent of the three houses, the LUMENHAUS, has fulfilled its challenge with regard to competition and dissemination of information to the public. However, considering the larger issue of the nation's energy security and use, new strategies are required to address systemic issues of higher density living and scalable communities. Energy consumption in residential and commercial buildings accounts for 40 percent of our nation's energy budget. Buildings typically operate at less than 50 percent overall efficiency. The housing industry has been reticent to experiment with new techniques that could make buildings less energy intensive. Houses constructed by small, local trades have not changed their construction techniques in decades. The panelized housing industry and prefabricated factory built processes represent some improvement in speed and waste reduction, but overall the results are conservative and energy saving is minimal.

This research is an initial attempt to apply lessons learned from previous work to crack open new ideas regarding residential, high-density construction and the use of energy in buildings. The goal is to develop and optimize an industrialized building system for low and mid-rise residential units. The initial tactic researches the feasibility and viability of a prefabricated building module. The intention is to merge sustainability, energy optimization, mass production and conservation with market demands and trends.

THE PROJECT

Through corporate partnership and research collaboration with the office of Skidmore Owings and Merrill (SOM), the Virginia Tech Center for Design Research (VT/CDR), is proposing a mixed use project on a site in south Chicago providing medium and high density housing for one city block. The project is designed to be factory-built-industrialized dwellings utilizing energy efficient and sustainability practices including passive heating and cooling design strategies and water conservation. The goal for the proposed development in south Chicago is to reach net zero status by utilizing self-generated clean energy and large-scale environmentally sustainable and renewable practices. The following paper will detail this research endeavor which proposes off site construction to be an ideal project delivery method, providing an energy efficient, sustainable and market viable product to the construction industry.

An underlying theme for this research is the development of one city block of Chicago's "Lakeside," a new development master planned by the Chicago SOM office. The site, which was previously occupied by the U.S. Steel *Southworks* mill, located approximately 10 miles south of Downtown Chicago. Once proposed as the location for an Olympic village, the now vacant site is planned to be an innovative, sustainable community that addresses the challenge of energy optimization in building. It is a joint effort between the developer/land owner, SOM and the city of Chicago to build a near net-zero energy development that receives its power from clean energy sources, mostly renewables, and consists of energy efficient structures, environmentally sustainable in production and operation.

As a mixed use, high-density community, it has the potential to be a model demonstration of sustainable development at the urban scale and will establish new residential, commercial, institutional and recreational amenities for Southside residents, as well as for the Chicago and Northwest Indiana commuting workforce. This 100+ acre waterfront site is comparable to "the Loop" in Downtown

Chicago and is one of the largest undeveloped sites in the city. What was once the site of a major steel manufacturing facility has the potential to become the greenest urban development in the United States. All energy consumed in the development will be from clean sources ranging from wind and solar power. Methane from landfills will be used to supply district scale fuel cells and geothermal systems will supplement energy efficient heating and cooling systems. Sustainability practices will be employed at the city scale to provide an environmentally responsible example of what a future city should be.

Figure 1. SOM's Chicago Lakeside Master Plan

PROSPECTIVE RESIDENTS

With the world population on the rise, urban areas are expected to be the most impacted and the demand for higher density development is projected. For the lakeside project, a target market of two demographic strata is proposed. The first are young urban couples with beginning double incomes, seeking an upscale residence that provides a place for entertaining a small group of friends year round. They want to be part of the city when they choose, but have access to a detached private sphere. This group is considering starting a family and has the possibility to move up to a larger unit.

The second group consists of empty nesters, wanting to downsize from their large residence to an in-town neighborhood. They are seeking an alternative lifestyle, based on conservation and energy awareness, yet have a sensibility to finer materials and details, seeking living accommodations with clear design aspirations. They are willing to pay a premium for an environment based on sustainability and alternative energy generation. They are interested in reshaping the competitive housing landscape from the vantage point of more sustainable energy dwelling.

CITY BLOCK PLAN

From SOM's master plan, one city block was selected by our research group to propose the research concept. This mixed-use city block provides a range of building types, which make the Lakeside development an active 24-hour urban neighborhood. The city street is lined with two levels of retail and service buildings, mid blocks from the third to the eighth level will be Chicago flat style town homes with a mix of one, two, and three bedroom units. City blocks are flanked by fifteen story towers with a range of unit types. An internal courtyard becomes a public garden oasis. Under the elevated garden plaza are two levels of parking.

Figure 2. VT's rendering of the proposed city block illustrating the massing for industrialized high and medium density housing.

The mid-block, mid-rise units are oriented north south and stretch the full depth of the row with arrangement of balconies strategically located integrating inside and outside to maximize summer and winter use. It is a different type of domestic experience centering on urban gardens. The south walls of the living spaces open as a garden in summer and close down as greenhouses in winter. The north balcony gardens provide a refuge from the hot summer sun. Natural cross ventilation, particularly across the living and dining module and passive heating collected from the south sun help optimize energy use.

The tower units located on the short sides of the block are articulated toward the east with the cores situated to the west. Each unit has views of the lake. Single loaded units take advantage of sunlight, passive gain and cross ventilation. The towers are articulated to allow a view of the lake from the mid-rise units and to maximize sun exposure to the center of site.

Parking is a two-story podium ringed by retail, service and office space. The block is cut by a small road providing access to the parking. Above this parking deck is a common garden terrace for the living units.

ENERGY CONCEPTS

The Lakeside community is planned to be a near-to net-zero energy development. This is accomplished through both clean energy outside sources and through high performance energy efficient building systems design. To increase energy efficient performance, many buildings utilize passive heating and cooling strategies when possible. Building performance is also optimized with the use of electronic smart building control technology for control of both active and passive systems.

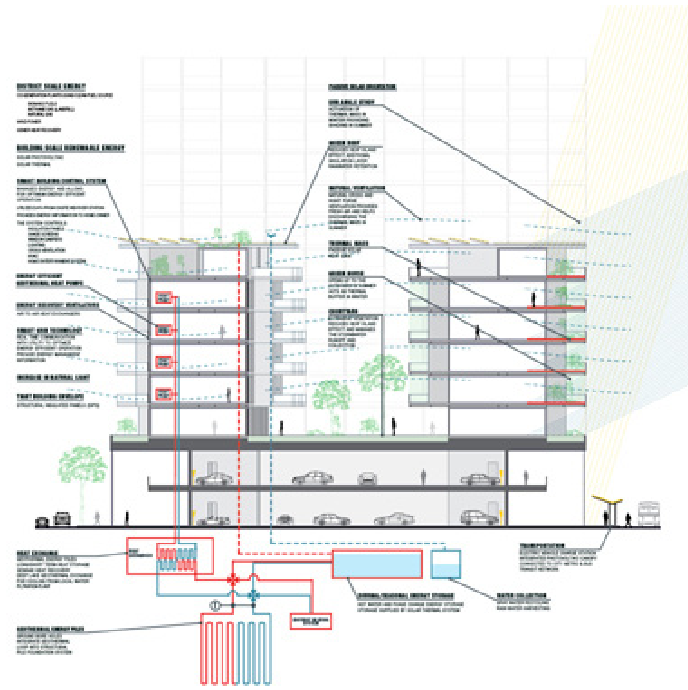
Clean energy will be provided through wind turbines located on Lake Michigan, from clean methane gas derived from a local landfill, and from Biomass fuel sources. On site photovoltaic arrays provide a moderate percentage of the electric power generation.

Building performance is optimized with the assistance of several forms of geothermal heat exchange. The nearby water filtration plant feeds the domestic water supply to the city of Chicago from deep, cold water collection from lake Michigan, a heat exchanger installed in the water filtration plant provides the means to provide district cooling to the entire development throughout the summer season. For heating, sewage heat recovery is also utilized by providing heat exchangers in the local sewage collection system.

Geothermal loops are integrated into the building structural pile foundation systems assisting local HVAC heat pump operation within the development. The geothermal loops are also integrated into sidewalks and paved surfaces providing an energy efficient means to provide snowmelt in wintertime. This geothermal system is also supplemented by hot water collected by rooftop solar thermal collectors and through heat collected from paved surfaces.

Additional sustainable systems for the City Block section include:

- Green roofs, rooftop gardens and integrated landscapes for processing rainwater and insulation.
- Greenhouses on balconies and terraces provide solar protection and green facades.
- Access to public transit for smart transportation strategies/ photovoltaic bus shelters.
- Community shared electric cars and electric charging stations.
- Smart grid technology for energy management and efficiency
- Public courtyards and green space for rainwater management and thermal control
- Rainwater, grey water collection and recycling.



UNIT PLAN ENERGY STRATEGIES

Maximum energy efficiency with uncompromised, comfortable living conditions is provided in each individual living unit by incorporating the following design implementations:

- Passive heating and cooling systems
- Whole-house cross ventilation
- Energy efficiency heat pumps incorporate geothermal loops to provide HVAC and hot water to units.
- Smart Technologies (Building Controls to ensure energy efficient operation)
- Water conserving and energy efficient fixtures and appliances throughout.
- High natural light values and views
- *Urban Garden* greenhouses providing thermal insulation, cross ventilation, solar protection and green facades.

THE URBAN GARDEN

One of the drawbacks to living in a dense urban area, particularly a tall building, is the lack of connection to the outdoors. Moving from the suburbs to the city often leaves regret for loss of private landscapes, and the additive attachment of balconies does not integrally support the inhabitants' lifestyle. The urban garden is intended to be a spatial and physical destination that brings the closeness of the ground to the dwelling. With a limiting physical presence, it evokes a psychological connection to nature. The built landscape reads as an essence, not an object. The materiality of the Urban Garden establishes its presence as an integral yet separate entity. It is sometimes subtly present; other times an active, real garden.

To accomplish the urban garden concept, each modular unit assembly comes equipped with two large balcony terraces integrated within the prefabricated structural frames. Every unit therefore has an urban garden on each end of the major living space. During moderate weather, these gardens become open extensions of the interior living spaces and make possible full cross ventilation across the entire unit. During extreme winter conditions, balconies may be enclosed with a retractable glass walls creating an urban greenhouse. This creates a thermal buffer space for energy efficient wintertime operation, protecting the garden plants from freezing throughout the wintertime. Geothermal loops will be activated during freezing conditions to temper the garden space and protect plants from freezing during the harsh Chicago winter season.

CROSS VENTILATION

Full cross ventilation for living spaces provide an ideal passive cooling strategy for moderate weather. For more optimal performance, automated building control systems can operate facade dampers, which can be orientated towards prevailing wind directions to create effective pressure differentials that drive natural ventilation. In windless conditions when humidity is not too high and when outdoor temperatures are within the comfort range, fresh air will be mechanically drawn into the unit via the central exhaust fans. By taking advantage of comfortable outdoor conditions, operational hours of the higher energy mechanical systems are therefore reduced to a minimum resulting in saved energy.

INDUSTRIALIZED PRODUCTION; THE IDEAL BUILDING DELIVERY METHOD

Off-site modular construction consists of factory manufactured volumetric components of a building, which are then transported to the site, and assembled as single units to compose a finished building.

For a complex building such as the Urban Garden project, the process of off site delivery is a perfect fit for the construction of this project and accommodates the many complex constraints of the high performance design. The following list details the benefits of going off-site for the production of the urban garden design:

- **Economy** - Approximately 15% construction cost savings and 50% construction time savings. For large-scale housing projects, an on-site factory eliminates major shipping costs. The process guarantees cost certainty, risk reduction, reduced financing and lower insurance expense.
- **Quality Control** - An enclosed and organized work environment with predictable inventory and fabrication can guarantee a product of higher quality. As in automobile production, the factory provides a platform for fully installing and testing systems before the project is delivered to the site.For the high performance building type we are proposing, quality control during systems installation is critical.
- **Efficiency** - On time delivery of materials, an enclosed work environment, around the clock production, safer construction conditions, a tight envelope, quality control, sustainable materials and limited waste make the fabrication and construction process as efficient as possible.
- **Safety** - regulated shifts and quality supervision are better achieved in a factory; assistance of computer numerical controlled (CNC) processes makes assembly more precise and reduces the chance of accidents.
- **Sustainability** - significant waste reduction, sustainable products and efficient assembly techniques. Green Building delivery methods reduce waste and guarantee the use of certified sustainable products and materials.

MODULAR UNIT

This research into industrialized housing takes an existing manufactured module as a starting point of study. Measuring 14' wide, 11' high and a variable length up to 32', the structure is steel with a concrete floor. The units are engineered to allow stacking up to 28 stories.

Several floor plans were developed to accommodate the planning needs for the medium and high density components of the city block which includes one, two and three bedroom units. A typical unit consists of three module types as illustrated below**:**

- **Living Module**
  The living and dining areas are completely open to allow for expansive views out each end to the city. At each end of the module, there are integrated patios or "urban gardens."
- **Service "Smart" Module**
  This technology module contains the mechanical, electrical, plumbing and electronic systems of the house consisting of a full kitchen, an audio visual closet, a laundry room, an HVAC closet and all unit bathrooms. This unit remains fixed in plan in relation to above and below units to ensure vertical chase alignment. The completed module includes energy star appliances, low energy lighting, an integrated smart building control system, a hot water system, water efficient fixtures, a geothermal integrated heat pump system, air-to-air heat exchangers and integrated duct work.
- **Bedroom Module**
  The bedroom module houses the bedrooms and additional patio space. This module can have multiple bedrooms, an office, or an extended garden depending on configuration and family needs.

A fourth type accommodates the vertical circulation and entry. These core elements also accommodate lateral bracing in both directions for the low and mid-rise building types. The research group is currently investigating the possibility of fabricating these core elements out of concrete modular components.

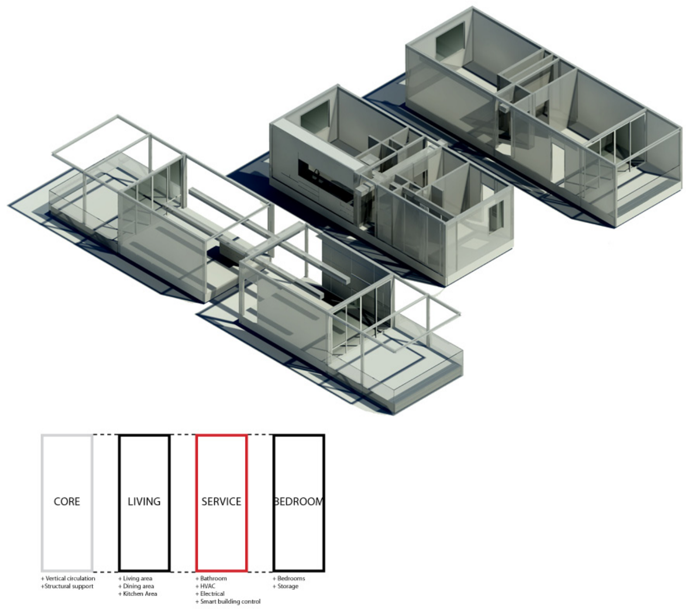


Figure 3. Three unit types make up a unit plan. The center unit is the “smart module” incorporating most of the buiding systems.

ONE-TO-ONE SCALE: TESTING THE URBAN GARDEN CONCEPT

This fall, the VT Center for Design Research will begin the fabrication of a prototype which will include the nesting and stacking of at least six prefabricated modules. The goal is to further develop an industrialized housing protocol. Details will be tested for structural stacking connections, for enclosure integrity, weatherproofing details, and for integrated systems coordination including mechanical, plumbing and electrical, and for interior partition systems and finishes. The litmus test for our research is that all work must be fabricated utilizing assembly-line-ready technologies. In the Virginia tech research laboratories, the VT/CDR team will employ a wide range of CNC equipment to insure “hands-off” fabrication. This requirement will insure that the design of the prototype is in line with the processes of optimized prefabricated construction.

One example of a non-compatible product is drywall. Though the material is a construction industry standard for interior finishing and a convenient product for achieving required fire ratings, it is not an assembly line friendly product. The process of installing sheetrock is messy, labor intensive and time intensive. If an alternative means for providing fire ratings can be introduced, a better assembly line ready and aesthetically appropriate “panelized” system can be utilized.

An additional constraint for the prototype is to establish the urban garden as a central architectural and performance feature of a mid to high-density dwelling complex. The structural frame design of the prefabricated units allows for the integration of the cantilevered balconies which are of utmost importance not only for performance of but also for the architectural significance of and marketing strategy of the sustainable dwellings.

Figure 4. VT rendering of a mid-rise unit interior featuring the double height space of a top floor penthouse scheme.

CONCLUSION

In today’s age of electronic technologies and advancements in robotics and industrialized fabrication, it is time to embrace the process of off site construction as an appropriate and economically viable method for delivering residential architecture. At present, the most inhibiting influences for utilizing such methods of construction are; one, the negative stigma attached to modular construction due to its association with low cost housing and, two, the lack of precedent for the transition from conventional to industrialized construction. This conversion to industrialization involves significant investment and experiences great resistance from established industry, code enforcement and organized labor unions.

With demands for high performance, sustainable practices, and the need for more integrated electronic technologies, buildings are reaching a production standard similar to that of an automobile. The Virginia Tech Center for Design Research, in collaboration with our industry and developer partners, through the production of a market viable prototype, is set to prove that off-site method of production is the appropriate means for the delivery of an affordable, environmentally sustainable, high performance home for the twenty first century. This is the challenge.