Jury Narratives

Jury Narrative: Architecture

GRoW

GARDEN RELAX OR WORK

Architecture Jury Narrative

GRoW
GARDEN RELAX OR WORK

GRoW Philosophy

The GRoW Home embraces a broader conception of residential energy. It fundamentally considers its energy footprint to include the operations of the house, and the energy to supply food to building occupants. Further, the GRoW Home asserts that a new way of living is possible, which can truly move the needle on energy consumption. A pattern of engagement with the house and the food growing within it will keep the occupant in tune with the outside environment. This regular engagement of the user leads to new customs of resource stewardship.

Through innovative design, inventive spatial programing, and a fresh take on the user's interaction with architecture, we argue that one can live in rich, varied, and beautiful spaces while still producing more energy than is consumed.

This project poses several questions:

- What if we lived smaller, in flexible spaces that could transform to meet changing needs?
- What if we lived differently with the changing weather, if we opened our houses up when the weather was fine, and pulled back and snugged in during cold seasons?
- What if we used the sun not only to make electricity with solar panels, but also to warm our spaces, and to grow vegetables to eat? What if we made this space for heating and growing so fantastic that we got to live there too?

Place specificity + Target Market

Buffalo, NY is a city on the cusp of reinvention, full of history but bursting with new energy and creativity. The GRoW Home is inspired by and designed for Buffalo. While known for its long and intense winters, the city is less well known for its mild swing seasons and gorgeous summers.

Buffalo is also home to the first ever city-wide park and parkway system in the US, designed by Frederick Law Olmsted. Contemporary Buffalo is home to green at the individual and neighborhood level too. The city boasts the nation's largest garden walk, and has dozens of community farms, gardens, and community supported agriculture cooperatives. Citizens have time and again reinvigorated neglected neighborhoods from the "eyes on the street" of people outside, gardening.

Buffalo has a portfolio of historic buildings from a host of internationally acclaimed designers, including Louis Sullivan, H.H. Richardson, the Saarinens, Frank Lloyd Wright, and Louise Bethune, the first female member of the American Institute of Architects. The architect-less concrete grain elevators along Buffalo's working waterfront inspired the earliest European modernists to eschew ornament for function-based form.

Long a site of energy innovation, the "City of Lights" had the first electric street lights in the country, and the first electric streetcar system in the US. The first ever AC transmission system was adopted in the "Battle of the Currents" pitting Nikola Tesla and George Westinghouse against Thomas Edison, and the hydropower plant at Niagara Falls was the largest in the western world at the time of its construction. Today, the western world's largest solar panel manufacturing plant is under construction in Buffalo.

As described in the narrative to follow, the GRoW Home draws from each of these. It reflects the ability be outside, or in mildly tempered spaces through many months of the year. It celebrates gardening and local food production. It recalls iconic, beautifully functional architectural form. And it uses the latest innovations in electricity production.

The GRoW Home is designed for an active, urban gardening couple who want to be part of something new and inventive in Buffalo. They are "cultural creatives": active, engaged, inquisitive, and conscientious. They want to know that their actions can make a difference locally and globally.

Key organizing ideas

Four key concepts have informed the GRoW Home design decisions from overall organization to system selection to material detailing. These four are the DNA of the project; the implementation of each will be discussed further in subsequent pages.

1. Recognize energy hierarchy: Consider passive design first, conserve energy next, and contribute power last.
2. Live with nature: Evoke the qualities of the outdoors with plants, light, air, material, color, and connections.
3. Think functional flexibility: Design for a longer life with a looser fit.
4. Nurture active stewardship: Empower the occupant to steward resources by engaging with energy and material use.

Theoretical basis

The GRoW design team has drawn from the thinking of several architects

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and theoreticians. Reyner Banham recognized in *The Architecture of the Well-Tempered Environment* that advanced space conditioning systems led to a decoupling of architecture from the responsivity to climate. The GRoW Home reasserts the duty of the architect to inflect spatial design based on the climate resources available in a particular place. From Phillippe Rahm's conceptual work, such as "Convective Apartments" and "School, Neuveville, Switzerland" we draw the ideas that spaces can be programmed based on their thermal characteristics, so that diversity, rather than homogeneity is celebrated. From the current work of Lacaton & Vassal, such as the Latapie House, we observe that flexible, indeterminately programed spaces can be beautiful and inspiring, yet made from the most straightforward of materials.

Compositional design

The GRoW Home is composed of four elements:

Deck: The raised ground plane of the deck establishes the extents of the home. The deck is subdivided on a 12'-8" grid, and zoned from south to north in bands of circulation, vegetation, habitation, and utility. Program is organized along these bands.

Canopy: The elevated plane of the canopy further defines the extents of the project, while keeping view and access open on all sides. Columns are located on the 12'8" module.

Modules: The "wet" and "dry" modules are inserted within columns between the deck and canopy, yet pull back slightly from the grid to read as distinct elements.

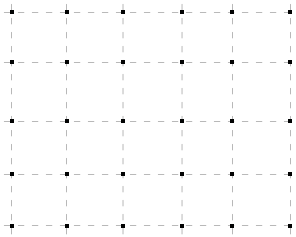
GRoWlarium: The glassy GRoWlarium nestles between the modules, crystalizing the spatial overlaps between the two.

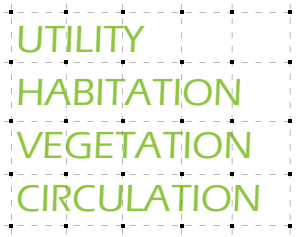
The spatial sequence from outside, to under canopy, to within growlarium, to inside modules makes a fluid transition from outdoors to indoors. When it is very warm or very cold, this sequence is heightened by a shift in thermal experience as one moves from distinctly outside to distinctly inside.

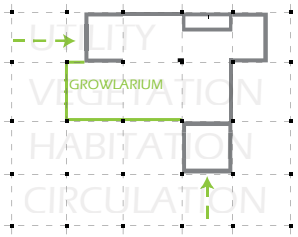
The interior of the modules is composed of two pairs of programs bookending more indeterminate space. The "wet" module bookends of kitchen and bathroom are articulated with paired concave forms delineated with glossy white cabinetry and white tile. The "dry" module bookends of mechanical room and bedroom are articulated with paired masses of birch plywood. In between these bookends usage is less strictly defined ("work area" and "relaxation area"), where both space and program overlap between the modules and the GRoWlarium. These areas have great permeability to the outdoors: folding glass doors along one side, and ventilators along the other.

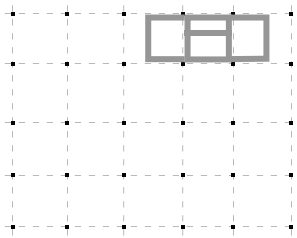
Explication of key organizing ideas

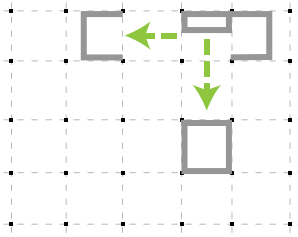
As mentioned above, four key ideas have informed design decisions throughout a GRoW Home design process lasting many months and involving many dozens of people.











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Recognize energy hierarchy
Consider first, conserve next, and contribute last.

Consider:
To design a truly ultra-efficient home, it is critical first to reduce the energy loads the homeowner (or society) incurs. For the GRoW Home, this means a small conditioned area (770sf) enclosed with a superinsulated, tight envelope of structurally insulated panels (SIPs) with twice the code-required R-value. Windows are triple paned, argon-gas filled, and low-e coated, and located to distribute reflected sunlight off adjacent walls. Ample daylight is always provided from at least two sides in each room, and this design was verified with daylight simulation. Dedicated ventilators sized for the cooling load on a Buffalo summer day are located high on the lee-ward sides of the house to exhaust by cross and stack ventilation air brought in through the GRoWlarium. The separation of window and ventilator allows the wall to optimize light, view, and air flow. Passive solar gain through south-facing folding glass doors is retained in the dark tile floors, which are protected from summer sun by rolling shades on the GRoWlarium walls and roof. The house itself is sheltered with shadecloth on the overhead canopy, further reducing cooling loads.
The embodied energy of materials is reduced by using locally manufactured SIPs, regionally harvested wood finishes, and locally fabricated metals. Energy from fossil-fuel-intensive food systems is reduced by growing nearly all of the produce required for the two house occupants in the home and landscape.

Conserve:
Some energy is required to run a home, but the GRoW Home has carefully selected equipment and appliances to minimize this use. LED lighting is used throughout, selected for a high color rendering index and low color temperature to be pleasant and complement incoming daylight. The exterior lights are generally dark sky compliant, so that energy is used to provide light only where desired. The appliances are best-in-class performers, including an induction stove and heat-pump clothes dryer. The mechanical system serves four zones independently, so heating and cooling is only delivered where needed, and is provided with a high performance heat pump and air handler. Fresh air is supplied with an energy recovery ventilator.

Contribute:
The energy that the house does consume is more than offset through production of electricity and hot water from the sun.

Live with nature
Evoke the qualities of the outdoors with plants, light, air, material, color, and connections.

The GRoW Home uniquely puts the occupants into regular contact with nature and the outdoors in various ways. The interior spaces are directly connected to the outsides through glass doors opening into the expansive all-glass GRoWlarium, which flows seamlessly onto the covered deck and out to the landscape beyond. The outside conditions are readily perceived within the home, whether through the play of light and shadow from the overhead structure or the sight of snow drifting overhead while sipping a hot beverage in the GRoWlarium in winter. Nature is brought directly into the home through the easily moveable GRoW tables, which nurture seedlings through winter, and larger plants when conditions allow. These share the flexible living space of the GRoWlarium. Plantings within the deck and landscape further the biophilia. Wood interior finishes and cladding, and a nature-inspired color palette throughout recall the tones of the outdoors.

Think flexible functionality
Design for a longer life with a looser fit.

While designed for a life enriched by rituals of tending home and garden, the GRoW Home is designed to be flexible beyond the extents of the current programming. The main spaces are designed to open up easily to one another, creating overlaps which can be appropriated to serve new or changing programs. The materials are designed for functionality, but with wide bounds on the function they serve. The dark tile on the floor of the "wet" module allows the floor to absorb winter sun, but also allows GRoW tables to readily roll in when plants are ready for processing, and can be easily mopped afterward. The tiled walls and glossy laminate cabinet fronts allow messes to be easily cleaned. The wood flooring and walls of the "dry" module are warm to the eye and touch, and suggest a more relaxed program.

The canopy provides a flexible infrastructure for a range of functions. It holds photovoltaic and solar thermal systems, shading devices, and lighting. It also readily supports various planters, outdoor movie screens, tool storage,

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hanging outdoor furniture and any number of uses the occupants might put to it.

Custom furniture pieces designed for the home each serve multiple purposes. The entertainment center can either divide or open the bedroom and living space, and contains a TV which swivels to serve either room. The kitchen table easily rolls from inside to outside, and has a rotating top with a wood surface for eating, and a stainless steel top for food processing. The outdoor benches can be stood up and opened to reveal a glazed box for drying vegetables in the sun before putting them in storage.

The LED track lighting can be adjusted and controlled zonally to suit preferences and use, and can easily be updated over time with new or different fixture heads.

Nurture active stewardship

Empower the occupant to steward resources by engaging with energy and material use.

The GRoW Home owners engage with the architecture and environment by managing the house like a captain would a sailboat, riding the waves of solar, wind, and thermal forces. To use another metaphor, the house is tended like a garden, where the industry of the activity is the source of joy. This home suggests a new set of domestic tasks related to climate and environment, similar in some ways to the installing stormwindows each fall, or spring cleaning. In the GRoW home, the owners put up the canopy shades in spring, and takes them down each fall; on a daily cycle they rolls the shades in the GRoWlarium up or down to suit. The owner removes ventilator insulation plugs when the spring gets warm, and replaces them when the fall gets cold; to modulate temperature on a daily basis, they open or close ventilator doors. The GRoWlarium has two large double doors to open the south façade of the house to fresh breezes, and roof and clerestory vents can be opened to exhaust heat.

A web-enabled monitoring system tracks electrical consumption and production, as well as outside weather conditions. The occupant tracks and views this information from a handheld device or computer, giving her further agency over energy usage in the house. The GRoW occupant is a "smart user", making savvy, informed decisions about consumption. In other homes these might be left to "smart systems", which could generate high performance, but insulate the user from full knowledge about the impact of decisions.

Conclusion

The GRoW Home proposes a new lifestyle, where the user, the architecture, and the environment engage with one another, seeking to change the conversation on residential energy.

[i] Banham, Reyner. Architecture of the Well-Tempered Environment. Chicago: Architectural Press. 1969.
[ii] "Convective Apartments." Phillippe Rahm architects, accessed August 2015. http://www.philipperahm.com/data/projects/convectiveapartments/index.html
[iii] "Thermal Conductivity." Phillippe Rahm architects, accessed August 2015. http://www.philipperahm.com/data/projects/thermalconductivity2/index.html
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Jury Narrative: Market Appeal

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Introduction
The GRoW Home is designed for a young and active "cultural creative" couple ready and eager to be a part of the new Buffalo. This home is unique, but springs from its context, presenting something both state-of-the-art and of its place. It offers a chance to live with nature inside and outside the home. It is flexible and fundamentally functional. It offers a chance to carve out a new lifestyle for an owner ready to make a change in the world. And it does all of this while producing more energy than it consumes.

House Specs
- Conditioned square footage: 770sf
- Additional tempered square footage: 290 sf
- Additional covered square footage: 815 sf
- Construction: Structurally insulated panels with galvanized steel canopy
- Equipment: Highest performing appliances and mechanical equipment, 6.72 kW solar array and solar thermal system
- One bedroom / One bathroom

Buffalo context
Buffalo is a richly historical city. It has the first park and parkway system in the nation, designed by Frederick Law Olmsted. It was the "City of Light" during the Pan American Exposition, and was home to the first electric streetlights and streetcars. It has world renowned architectural work from Frank Lloyd Wright, Louis Sullivan, H.H. Richardson, Eero and Eliel Saarinen, Daniel Burnham, and Louise Bethune. Like many rust belt cities, Buffalo has had its share of struggle and blight. Buffalo has seen its population fall from its 1950 peak of 580,132 to its current 258,959. As industry departed, previously strong communities watched their populations dwindle and incomes plummet, leaving neighborhoods pockmarked with empty lots.

But Buffalo is a legacy city on the rise. Median household income rose 32% from $24,536 in 2000 to $32,392 in 2013. Median house value rose 16.5% from $58,800 in 2000 to $68,500 in 2013. Despite this, population has not returned to peak levels, and empty lots are still commonplace. These spaces are opportunities to non-profits like Grassroots Gardens, which helps neighborhoods create and sustain gardens on vacant lots, or PUSH Buffalo's Green Development Zone, which supports a community based economy on Buffalo's west side, or the Massachusetts Avenue Project , which strives for a diverse and equitable local food system. These three groups alone have transformed over 90 lots within the city, and several other groups are also transforming parcels through urban farming, gardening, and place-making.

Buffalo is a gardening city. GardenWalk Buffalo, the largest garden tour in America, has for twenty years brought together gardening enthusiasts by the thousands each July. But here gardening is not just a hobby of the moneyed. Co-op garden centers, such as Urban Roots, provide affordable gardening tools and materials. Non-profits like the University Heights Tool Library create an affordable way for people to borrow the equipment they need, but cannot afford, to maintain homes and gardens. Buffalo's west side is home to communities of refugees from Burma, Bhutan, and Somalia; there community gardens help make ends meet for families in a new country, and provide a locus of collaboration.

GRoW Home Target Market
The GRoW Home creates a competitively-priced, contemporary and sustainable design for active, community-minded "cultural creative" couples for whom sustainable energy and fresh local food production are important.

Target Client
- A first time home-buying couple
- Aged 26 to 40
- Working professionals with a combined salary of $66,700
- College educated, community oriented, sustainably minded
- "Cultural creative" market segment

The cultural creatives were identified by Paul Ray and Sherry Ruth Anderson as sharing a

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number of characteristics which resonate with the potential owners of the GRoW home. This group makes up roughly a third of the US population. Cultural creatives are interested in ecology and the environment, prefer reading to watching TV, and rebel against anything lacking in authenticity. They are an active group, and are willing to pay more for goods if that money went to improving the environment. They are skeptical of big business and the ecological and social impact it has. They like things that are different. They are optimistic, and want to be involved in creating a new and better life.

Since 2008's Great Recession, Buffalo has seen an influx of cultural creatives, particularly those returning home from New York city for Buffalo's lower cost of living and tight-knit neighborhoods. These are the target market for GRoW Home.

The GRoW Home is an offering in a currently overlooked home ownership segment. The majority of homes in Buffalo are of older stock sized to accommodate families, whereas most residences for singles or couples are rentals. Only recently have examples of newly built compact dwellings appeared, and there is more demand than the market can satisfy.

Based upon Buffalo census statistics, the combined annual household income for a young couple such as our target client, is $66,700. The GRoW Home has an estimated Buffalo construction cost of $275,000. Under the Buffalo Homestead Act, one can buy a plot of land in certain neighborhoods for a dollar if one intends to build a home. Assuming a 20% down payment, the remaining $220,000 could be financed for $1,481/month with a thirty year mortgage at a 4% interest rate, a Buffalo tax rate of 1.88% and a .5% Private Mortgage Insurance rate. Today many desirable Buffalo neighborhoods, especially those with the influx of young cultural creatives, are seeing average monthly rental costs over $1,000 , and electricity and heating costs averaging $119/month. Comparing $1,119/month in rental costs to the $1,481/month mortgage, means that for less than $400 more per month, a couple can own a solar powered house, rather than rent a conventionally powered apartment. Given that the GRoW Home produces more energy than it consumes, this difference would be reduced further through energy export. Once the mortgage is paid off, the couple would own outright a tangible asset, which will likely continue to appreciate, given the historic steady strength of the Buffalo housing market.

GRoW Home Design

The GRoW Home is fundamentally designed and named for Gardening, Relaxing, or Working. The key design attributes discussed below support this.

Design for gardening

The GRoW Home embraces the idea of the home as a place of food production. As the core of the home, it facilitates indoor gardening throughout the year. Plants can be started in winter, and protected within the buffered zone. Food can be raised for several months before and after planting outdoors is possible. When sited on a double lot in Buffalo, food production in the GRoWlarium and landscape is sufficient to supply all produce needed for the two occupants annually. The bathroom has a door to the private east deck, and doubles as a mudroom. When finished gardening outside, one can clean up and even toss muddy clothes right into the laundry before entering the main home.

The custom-designed GRoW tables easily move in or out of the GRoWlarium, around the expansive outdoor deck, and into the kitchen space for plant harvesting. The roof of the modules is designed to drain rainwater into barrels on the north and east sides of the home for use in irrigating plants indoors or in the landscape.

Design for relaxing

The GRoWlarium is the heart and soul of the house. This light, airy,

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and expansive space makes the house feel 50% larger than its 770 sf, and allows one to comfortably live in regular communion with the outdoors. Outside conditions are readily perceived within the home, whether through the play of light and shadow from the overhead structure or the sight of snow drifting overhead while sipping a hot beverage in the GRoWlarium in winter. Ample daylight is provided to the space through the folding glass doors, even when the space is closed off for warmth.

The "dry" module has the living and sleeping spaces, designed for relaxation. The main living space opens directly into the GRoWlarium, and can flow into the sleeping space as well. These areas have wood floors and walls, a material soft on the eye and warm to the touch. Colors recall a natural material palette. The custom designed entertainment center only suggests a boundary; it can either separate or connect the bedroom and living spaces, and contains a TV which can swivel to serve either room.

Design for working

The GRoW home proposes that the owners not only grow plants, but process them for food throughout the year. Whether through canning, drying, or freezing, the home is designed to facilitate a lifestyle of greater independence from large scale food systems. The kitchen area is designed for durability and easy cleanup, well suited to a home where food production and preservation are a way of life. The custom-designed kitchen table has a wooden surface for eating, but flips over to a stainless steel top ideal for large scale food preparation.

The dark tile on the floor of the work space allows the floor to absorb winter sun, lets the GRoW tables readily roll in when plants are ready for processing, and can be easily mopped afterward. The tiled walls and glossy laminate cabinet fronts allow messes to be easily cleaned.

As with the other spaces in the home, the work space is bathed in balanced daylight so electric light is rarely needed during the day.

Design for flexibility

The entire home, along with the specially designed furniture inside, allows the space to function for a long time, given the loose fit to program. The GRoWlarium shifts from extension of living space to greenhouse. The GRoW Tables can all be reconfigured with changing uses, seasons, or weather. The furniture pieces, such as the dryer box, canning table, dining table, and entertainment center, all promote multiple uses and the option for reconfiguration to fit owner need.

The canopy provides a flexible infrastructure for a range of functions. It holds photovoltaic and solar thermal systems, shading devices, and lighting for the GRoWlarium. It can also readily support various types of planters, an outdoor movie screen, tool storage, hanging outdoor furniture and any number of uses the occupants might put to it.

Design for an energy-savvy owner

The GRoW home uses far less energy than a conventional home through smart design. The home is first a compact 700sf. It is enclosed by a superinsulated, tight envelope of structurally insulated panels (SIPs) with twice the R-value required by code. Windows are triple paned, argon-gas filled, and low-e coated, and are located to reflect sunlight off adjacent walls and improve daylight distribution. Abundant light is always provided from at least two sides in each room. Dedicated ventilators on the lee-ward sides of the house exhaust fresh air brought in through the GRoWlarium. Passive solar heat gain through the south-facing folding glass doors is absorbed in the dark tile floors, which are protected from summer sun by rolling shades on the GRoWlarium walls and roof. The house itself is sheltered with shadecloth on the overhead canopy, further reducing cooling loads.

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Some energy is certainly required to run a home, but the GRoW Home has carefully selected equipment and appliances. The LED lighting used throughout has a high color rendering index to be pleasant and complement daylight when needed. The exterior lights are generally dark sky compliant, so that energy is used to provide light only where desired. The appliances are best-in-class performers, including an induction stove and heat-pump clothes dryer. The mechanical system serves four zones independently, so heating and cooling is only delivered where needed, and is provided with a high performance heat pump and air handler. Fresh air is supplied with an energy recovery ventilator.

The energy that the house does consume is more than offset through production of electricity from a 6.72 kW solar array and solar hot water system. The panels are a cutting edge, high-voltage design with power optimizers, so energy production is not compromised with any incidental shading.

A web-enabled monitoring system tracks electrical consumption and production, and outside conditions. This information can be tracked and viewed from a handheld device or computer, giving the occupant further agency over energy usage in the house. The GRoW occupant is a "smart user", making the savvy, informed decisions about consumption.

Conclusion

Overall, the GRoW Home embodies the desired lifestyle of many cultural creatives: an affordable, sustainable, urban living. It not only appeals to the logic of owning an affordable and sustainable home, it appeals to a desire to be a part of something big. The GRoW home suggests a change in lifestyle, not simply living with less impact, but giving back food and energy to the community. The home's design strategies benefit the resident and the city. Through innovative, sustainable urban living, the residents contribute to Buffalo's renaissance. Overall, living in the GRoW home ensures that the homeowners' ideas, influence, impact grow.

[i] Buffalo Census Data. Unites States Census Bureau. Accessed August 2015. http://quickfacts.census.gov/qfd/states/36/3611000.html

[ii] Buffalo Data. Accessed August 2015. http://www.city-data.com/city/Buffalo-New-York.html

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[iv] Gillespie, Gina. "The Cultural Creatives Crowd." Southam Newspapers Real Estate Guide, February 28, 2002, p. E8.

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[vi] Buffalo Census Data. Unites States Census Bureau. Accessed August 2015. http://quickfacts.census.gov/qfd/states/36/3611000.html

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Engineering Jury Narrative

Introduction

We believe that natural flows of sun, wind, and light can provide much of the energy we need to operate the GRoW Home; only after we utilize these "free" resources should we utilize conventional mechanical and electrical systems to provide space conditioning and lighting. These "passive" systems used to be the norm in building systems design; large windows facing south, natural ventilation, and light colored interior finishes all served to condition the indoor environment and distribute light evenly without relying on imported sources of energy.

This "passive first, active second" approach to engineered systems aligns with our architectural design goals and the general philosophy of the urban gardening movement, the theoretical underpinning of our house design. Urban farming is a grassroots effort to provide local food wherever possible before importing products from outside the region. Urban gardening/farming also connects people to the land, reduces an individual's ecological footprint, and encourages them to be active stewards of the natural environment.

The following document outlines the design of the mechanical, electrical, plumbing (MEP), and structural systems for the University at Buffalo GRoW Home. After a brief introduction to each of these systems, five subsequent sections outline our climate analysis, the energy balance analysis, how we sized systems, the design/testing of unique technologies, and our expected house performance.

Mechanical Systems Design

As discussed in the introduction we attempted to reduce energy usage wherever possible by relying first on passive systems like the GRoWlarium to capture heat in winter for use in the conditioned portions of the house. We then proceeded to identifying and sizing mechanical systems, using an iterative approach that balanced architectural design goals with energy efficiency and the constraints of the competition format.

To begin our mechanical systems design, we first evaluated potential system types. Initially we considered four systems: (1) ductless mini-split heat pumps, (2) a variable refrigerant flow system, (3) a ground source water-to-air heat pump system, and (4) an air-to-air heat pump system. We quickly eliminated the ductless mini-split systems because the indoor fan units did not integrate with the desired aesthetic for the interior. We dropped the variable refrigerant flow system from consideration because of a high first cost and perceived difficulty in extending refrigerant lines across the connection between the "Wet" and "Dry" modules of the house.

We then proceeded with designing two mechanical systems in parallel, a ground source heat pump system, and an air-to-air heat pump system. We were drawn to the efficiency of the ground source water-to-air system for the extremes of Buffalo's climate; the ability to reject heat to the cool ground in summer and draw on the warmer earth in winter would improve the annual performance of the house. However, after an analysis of the system revealed that we would need more than 30,000 pounds (or roughly 3,500 gallons) of water in proxy ground loop tanks to be able to reject heat at the competition in Irvine, we decided to move toward an air-to-air system that would function in our cold Buffalo climate and perform well during the competition.

After considering systems from a number of manufacturers, we selected a Trane XV20i air-to-air heat pump system that had a variable speed heat pump, variable speed air handler, and ability to serve up to 4 zones individually. We felt that this system would mesh with the architectural idea of thermal zoning, each space could be conditioned to between 71 and 76 degrees Fahrenheit without overheating or overcooling any individual zone. Since it was a variable speed system, it can handle part load conditions better than a single speed system, and keeps air circulating throughout the house. This helps maintain positive pressure inside the house and circulates fresh air from the energy recovery ventilator (ERV). The Trane air handler also has a unique design that promotes easy replacement of filters and components and a controls system that is self-calibrating.

To provide good indoor air quality, we installed a Greenheck ERV. Rather than having the system operate continuously, which we felt would increase energy usage unnecessarily, we chose to have it controlled on demand using carbon dioxide as a proxy for occupancy. (This controls system is described in greater detail in the next section.) We also provided an override switch so that the homeowner

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could turn the ERV system off if they were naturally ventilating the home or away for extended periods of time to save energy.

To size and design the details of the system, we consulted Air Conditioning Contractors of America Association (ACCA) Manuals D and J, and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.2. When reviewing these documents, we realized that it is not recommended to put ductwork outside of the conditioned interior, and therefore developed a raised floor system to run all MEP inside the envelope.

eQuest and EnergyPlus were used to model the performance of the house during the competition in Irvine and annually in Buffalo. A simple model of the house was extracted from the architectural Revit model; weather data for our analysis was provided by Weather Analytics. Multiple runs were made varying the type of insulation and window construction to reach optimal annual energy performance while remaining within the cost parameters of the competition.

Electrical Systems

Like all of the Solar Decathlon houses, our home features a grid-tied photovoltaic (PV) system. However, our 6.72 kW PV system utilizes Silevo's Triex U-280 PV panels with a hybrid tunneling junction cell technology; this allows our system to out-perform traditional monocrystalline silicon solar panels by achieving a 16.9% efficiency. With this cell technology, the electrical generation system achieves a higher performance in hotter weather due to a lower temperature coefficient; the panels were also specified with an anti-reflective coating to allow them to perform better in low light conditions which occur during Buffalo winters. We also specified the Silevo panels because they are scheduled to be manufactured locally beginning in 2017; this is in line with our general desire to purchase local products wherever possible.

This PV system is balanced by SolarEdge's Central Inverter (SE-6000A-US) with a P-400 Power optimizer system. Power optimizers mount to each individual solar panel and help to manage mismatch losses brought on by partial shading; this occurs frequently in Buffalo due to snow or cloud cover. The SolarEdge system also features a rapid shutdown safety switch which allows for a quick shutdown in an emergency. Finally, the SolarEdge system has internet connectivity so that the user can view solar power generation in real time. This would allow the homeowners to engage with their energy production and potentially to troubleshoot any issues that may arise like a panel partially obstructed by snow or ice.

To understand energy system performance in the house, the homeowners will rely on a PowerWise energy monitoring system. This system allows the user to monitor the electrical usage, outside weather conditions, interior, exterior, and GRoWlarium temperature/humidity, interior carbon dioxide levels, and allows for control of the Energy Recovery Ventilator (ERV). All of this information is displayed in an online dashboard. Different from many "smart" homes, the monitoring system does not automatically adjust all of the systems in the house; it instead relies on the homeowners to view the data and then make their own decision on how to adjust system performance. This controls approach aligns with our overall idea of an active occupant; the system nurtures stewardship of resources rather than relying on an algorithm.

With regard to lighting, the GRoW home comes fully equipped with an energy efficient LED lighting system that will supplement the daylight coming in through the windows and doors, and fully illuminate the house at night. This system is integrated with the architecture of the house using an elegant, embedded track lighting system. This system allows the homeowner to decide to add or remove lighting in the interior, or to reconfigure lighting in spaces based on function. One of the track lighting heads was also manufactured locally by SORAA.

The exterior of the house features an under-guardrail LED tape lighting system. This system extends into the GRoWlarium, illuminating the area of the home used for urban agriculture and outdoor living. This further blurs the line between indoors and outdoors, keeping with the architectural concept for a house that blends indoor and outdoor living. In addition, this system has been fully integrated with the steel canopy; the canopy design is described in detail in the architectural narrative and the structural systems portion of this document.

In terms of appliances, the

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homeowners can help reduce their power consumption by utilizing the most energy efficient technologies to support their daily lives. Our house features all Energy Star rated appliances including an induction cooktop, a state of the art heat pump clothes dryer, a dishwasher, and a clothes washer. All of these appliances were manufactured by the Whirlpool Corporation within 500 miles of our construction site.

Plumbing Systems

The plumbing system maximizes spatial and pumping energy efficiency through a simple, well-organized distribution network of piping in the home. The programs within the GRoW Home are positioned into the either the "Wet Module" or "Dry Module" based on their need to access running water. Acting as a hub, the mechanical room is positioned at the intersection of these two modules, extending a plumbing supply branch east to the bathroom, and another branch west to the kitchen. Since we lack water pressure at the competition site, this system is pressurized by an Armstrong Series 4700-VMS-03:03 pump. This pump was selected for its efficiency and because it was manufactured within five miles of our construction site.

To distribute potable water, the GRoW Home uses ½" cross-linked polyethylene (PEX) piping to simplify the construction process, to reduce the overall weight of the home during shipping, and to facilitate easy repairs of the system in the future. If we had chosen a copper pipe system in the floor, it would require taking up the raised floor system to repair leaks. With PEX piping, we can pull a new pipe to a fixture because it is seamless along its entire length.

To generate hot water for the GRoW Home, an Apricus AP-30 evacuated tube solar collector is positioned directly above the mechanical room. The system utilizes a steam back design with a pressurized tank in the event the glycol becomes overheated. Pressure regulation is controlled by an Apricus APS-KIT-DOM-CL closed loop pump station.

This system uses an indirect circulation system charged with glycol to offer freeze protection in winter. Based on an analysis of available systems (e.g., batch solar collector, heat pump water heater, etc.) the evacuated tube system is expected to be the best performer in overcast Buffalo winters because the vacuum-sealed tubes will still achieve design temperatures on the coldest days. In the event that the system does not provide enough heat for hot water production, an electric resistance heater can be switched on by the occupant.

The fire suppression system for the GRoW Home is the only water system to extend into the "Dry Module." Because the house separates at the intersection of the "Wet Module" and the "Dry Module," a break-away coupling was designed to allow for attachment/detachment of the system during assembly, and also to allow for movement in the event of an earthquake in Irvine. To keep the system pressurized, two Series E19.2 ci pumps manufactured by Armstrong are located in the mechanical room.

Structural Systems

The structural system of the GRoW Home was designed to withstand the strong winds and lake effect snow produced by Lake Erie. The home must also be strong enough to endure the roughly 5,200 mile round trip journey between Buffalo and Irvine, and designed to withstand a possible earthquake in California. When taken together, these unique constraints result in a house that is over-structured for any one location.

The "Wet Module" and "Dry Module" sit on a steel chassis designed for transportation and rigging. This system uses W12x30 structural steel sections in the long direction of the modules, and W4x13 ASTM structural steel sections running in the perpendicular direction at 4 feet on center. Being utilized for their weight to strength ratio, and their high performing insulating value, structural insulated panels (SIPs) manufactured in Buffalo by Thermal Foams make up the exterior walls. Inside the conditioned space, the raised floor system is constructed using 2x6 lumber to conceal mechanical, electrical, and plumbing distribution branches.

For ease of construction and architectural unity, the exterior and site design for the home is organized into a single comprehensive grid. To simplify the construction of the foundation, the columns for the canopy are spaced evenly in a 12' 6" by 12' 6" grid with the deck modules and conditioned space fitting within the grid. The canopy, deck modules, and conditioned spaces are all supported by adjustable structural support columns manufactured by Ellis Manufacturing Company. Finally,

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the steel canopy super structure has been designed to exceed the 32 pounds per square foot requirement for Buffalo snow loads utilizing TS 5x2 ridge beams, TS 4x2 rafters, W5x16 beams, W4x13 columns, and 2" angle X-bracing for lateral wind resistance.

Team Climate Analysis

The GRoW Home has been designed to sustain comfortable conditions in the cold winters and mild to warm summers of Western New York. Located at 42.93°N Latitude on the easternmost edge of Lake Erie, Buffalo, New York is defined as having a moist continental mid-latitude climate. Between May and September, temperatures are tempered by Lake Erie and Lake Ontario, but these bodies of water can produce heavy lake effect snows in winter. For example, in the fall of 2014 the City of Buffalo experienced what is now called "Snowvember" where in some places over 70" of snow fell in the span of four days. As the shallowest and warmest of the five Great Lakes, lake effect snow is produced when cold air (averaging 21.5°F as the average low temperature during winter) moves over the warm lake water, collecting water vapor which then freezes in the atmosphere and drops as heavy snow. On the other hand, the summer months in Buffalo are pleasant and temperate (averaging 76°F as the average high temperature during Buffalo summers). Fortunately for our design for the competition, the average high temperature in Buffalo, New York is nearly equal to the average high temperature in Irvine, California during the month of October (79°F average high). This means that during the Solar Decathlon competition, visitors will be experiencing the GRoW home in what approximates an average Buffalo summer. This is where similarities between Irvine and Buffalo's climates end; as summarized in the following table.

Table 1: Heating and Cooling Data for Irvine, CA and Buffalo, NY

Location	Heating Dry Bulb Temperature (99%)	Cooling Dry Bulb (1%)	Mean Coincident Wet Bulb Temperature (1%)	Heating Degree Days	Cooling Degree Days
Irvine, CA	43.9°F	88.3°F	67.2°F	1142	1067
Buffalo, NY	7.4°F	83.9°F	70.1°F	6508	563

Note: Data from 2013 ASHRAE Handbook of Fundamentals, Chapter 14.

To respond to the harsh winter conditions and maintain thermal comfort, the GRoW Home must take advantage of the 3 to 4 kWh/m2/day of annual solar radiation, and produce approximately 4,902 annual hours of heating either through passive solar or mechanical heating. To retain the heat, the GRoW Home was designed to include a minimum of R-30 in the floor, a minimum of R-20 in the walls, and a minimum of R-38 in the ceiling. To reduce the dependence on mechanical systems, the GRoW Home also utilizes passive strategies such as a narrow floor plan with cross ventilation and exterior shading to combat the humid summers. These strategies were identified by reviewing typical meteorological data (TMY) using the software Climate Consultant produced by UCLA.

Energy Balance Analysis

In order to make our house as efficient as possible, extensive market research was conducted to find the most energy efficient appliances, lights, HVAC system, and electric car available. This was an iterative process that took into account design aesthetics, cost, reviews of the product, availability, and the possibility of a donation to our project. For example, in order to find the efficiency of appliances, data from the Energy Star program was utilized to find how much energy would be used by each appliance and electronic device. For HVAC equipment, extensive modeling was conducted, and our team also evaluated electric vehicles using data provided by the Department of Energy. With this research, a comprehensive set of estimates were compiled which outlined the amount of energy that would be used both during the competition and each year in Buffalo. These estimates are presented in Table 2 on next page.

The methodology behind the calculations varies. For example, the clothes washer is an Energy Star appliance with a 125 kWh per year rating. The Energy Star website states that this number assumes eight washes per week. For the competition we will also run the washing machine eight times. So if one takes the 125 kWh per year number and breaks it down into a per week value (125kWh/52 weeks) we get roughly 2.4kWh. A similar methodology was used for the rest of

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Table 2:
Estimated Energy Consumption during Competition and Annually in Buffalo, NY.

House Loads	Competition Energy Use (kWh)	Annual Energy Use (kWh)	Calculation Methodology
Car charger	64.01	2336.45	Department of Energy ratings (kWh/mile).
HVAC system	52.00	1898.00	eQuest/ EnergyPlus models.
Lighting	18.21	664.67	Power ratings multiplied by time.
Dryer	15.01	547.89	Energy Star numbers divided by length of competition.
Refrigerator	7.90	288.51	
Cooktop/Range	6.40	233.60	
Dishwasher	6.22	227.03	
Washer	2.39	125.00	
Solar Thermal Pump	1.30	47.45	Power ratings multiplied by time.
Television	0.97	35.31	
Main Water Pumps	0.86	31.39	
Router	0.84	30.68	
Nighttime Inverter	0.38	13.69	
Laptop	0.34	12.41	
ERV	0.10	3.65	
Fire Safety Pumps	0.09	3.29	
Blu-ray player	0.08	3.07	
Total	177.11	6464.40	

the appliances with Energy Star ratings including the dishwasher, refrigerator, and clothes dryer.

If the technology didn't have an Energy Star rating, a method of calculating the energy used was simply taken from rated wattage of the technology multiplied by the amount of time we expect to use it, converted into kWh. This method was used for the lighting, Blu-ray player, television, laptop, router, the pumps, and the ERV.

During the competition, the house will consume approximately 177.11 kWh. However, for full points during the competition, the house needs to consume less than 175 kWh. In order to achieve this number, some solutions are under development. This includes an electric car driving plan, reduction of dryer time using clothes lines, operating the refrigerator at the warmest permissible settings, and employing current transducer loggers to eliminate vampire loads.

System Sizing Analysis

The photovoltaic system was sized to meet and surpass the energy requirements for the competition and Buffalo's climate. For the competition, the GRoW home must consume less than 175 kWh for the 8 day competition. It must also produce more energy from the PV system than is consumed. Finally, the system must be cost effective in order to meet the affordability contest guidelines. With these three design goals in mind, a number of simulations were performed using the SolarEdge Site Designer Tool; see Table 3 below for the results.

For the competition, the house must produce more than 175kWh. In order to size our system, we used a 25% safety factor to get roughly 220 kWh as a minimum requirement for our system for the competition. Then by running multiple simulations with the SolarEdge site designer tool with different panels, angles, and number of panels, a system was specified that should produce approximately 238 kWh over the 8 day period in October, assuming ideal conditions. While this is a slightly higher safety factor (36%) than we wanted for our design, if we reduced the design by two PV panels the safety factor would be cut to less than 25%.

Table 3: Estimated Photovoltaic System

Month:	Buffalo, New York		Irvine, California	
	Annual Energy Production (kWh)	Average Daily Energy Production (kWh)	Annual Energy Production (kWh)	Average Daily Energy Production (kWh)
January	410	13.2	640	20.6
February	500	17.9	700	25.0
March	740	23.9	940	30.3
April	840	28.0	1,050	35.0
May	990	31.9	1,090	35.2
June	1,070	35.7	1,110	37.0
July	1,050	33.9	1,200	38.7
August	970	31.3	1,170	37.7
September	800	26.7	1,030	34.3
October	620	20.0	920	29.7
November	390	13.0	770	25.7
December	380	12.3	680	21.9
Total:	8,760	24.0	11,300	31.0

Note: Panel/inverter data from Silevo/SolarEdge. Calculated with SolarEdge Site Designer Tool.

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The mechanical system was sized using ACCA Manuals D & J, eQuest and EnergyPlus. The calculations were done first by hand in order to understand the heating and cooling load calculation methodology; this later helped with troubleshooting the computer models. The hand calculations and models indicated a peak cooling load of ~19,000Btu/hour in Irvine, California during a high heat event, and a peak heating load of ~19,000Btu/hour in Buffalo, New York on the coldest day. These numbers were based on TMY data. After adding in a 25% safety factor given that the peak cooling and heating conditions are typically higher than what is found in the TMY files, we settled on a ~24,000Btu/hour as being the peak system demand. We used this number to size the air-to-air heat pump system.

Design and Testing of any Unique Technologies

The GRoW home features a number of custom technologies that were developed to assist the homeowner in their daily routine while saving energy. These technologies include the GRoWlarium, ten heavy-duty growing tables, an energy saving food drying box that doubles as a bench, and ventilators that function in lieu of operable windows.

The GRoWlarium, a large greenhouse space immediately adjacent to the house, is an unconditioned greenhouse that serves as a buffer zone to temper the interior environment of the house in winter. It serves as the primary space to grow food. In summer, the space is covered with fabric shading to prevent it from overheating, it also extends the living area of the house. In winter, it captures sunlight, and during hours when it is warmer than the interior of the house, can be used to heat the home. This provides additional living space and reduces annual energy use in Buffalo. Initial sizing of the GRoWlarium was done with rule of thumb calculations, the final performance of the space was modeled using tools like Ecotect, eQuest, and EnergyPlus.

The ten GRoW tables are constructed of simple materials - pipe and aluminum sheet - yet are heavy duty enough to allow a homeowner to easily move vegetation from the GRoWlarium to the deck or the house interior. This gives the homeowner the opportunity to start plants in the spring and move them outside to raised beds in summer, or to bring plants into the house to assist with cooking or preservation activities like canning or drying. Development of these tables included structural calculations done by hand to confirm that they would be able to hold the weight of waterlogged soil. The engineering team also worked with a Buffalo manufacturer (Rigidized Metals) to test the strength and rigidity of the aluminum pans.

The food drying box was created to allow the user to either dry food grown in the garden or to dry their clothes using only solar radiation. Drying of food is typically done with high acid foods like grapes, tomatoes, or beans to save them through the winter; it is a preservation strategy that has been used for millennia. However, drying food in the sun has challenges including preventing the material from getting wet or insects spoiling the product. The drying box design solves both of these problems because it is fully enclosed; the box also doubles as a bench when it is not in use, saving space. We tested the performance of the drying racks using dataloggers; a recommended minimum temperature for food drying is 85°F. Our design regularly reached temperatures of 110°F, even on partly cloudy or cool days.

Finally, the GRoW home features custom ventilators that are stationed above every fixed window. These ventilators allow for passive airflow throughout the house in summer while maintaining the ability to tighten the house in the winter to reduce infiltration. The ventilators were placed by analyzing the average wind direction in the summer in Buffalo; they were sized using calculation procedures presented in The Green Studio Handbook. We expect these ventilators to cost less and perform better than standard operable windows because operable triple-glazed low-e windows are extremely expensive, the ventilators have less frame area that needs to be sealed and are also close to the ceiling to allow hot air to escape.

In addition to designing some of our own technologies, we also performed an energy use analysis on the appliances supplied by Whirlpool. These studies used current sensing equipment to calculate the power used by the refrigerator, clothes washer, and clothes dryer in order to find a more accurate energy consumption value for the competition. With this testing, the team can reduce the amount of

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energy used by these appliances both during the competition and when the house returns to Buffalo.

Expected House Performance Discussion

Based on our calculations and assumptions regarding the competition, we believe that we will consume approximately 177kWh during the competition. We are currently testing electric vehicles and appliances to reduce their consumption during the competition, we hope that the protocols we develop can also be used to reduce the annual energy use of the house when it returns to Buffalo.

[i] Grondzik, W. T., A. G. Kwok, B. Stein and J. S. Reynolds (2010). Mechanical and Electrical Equipment for Buildings. Hoboken, New Jersey, John Wiley & Sons, Inc.

[ii] Kwok, Alison G., and Walter T. Grondzik. The Green Studio Handbook: Environmental Strategies for Schematic Design. 2nd ed.. New York: Routledge. Architectural, 2011. 153-56.

[iii] Climate Consultant 6.0 is available from http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php

Jury Narrative Communications

GRoW

GARDEN RELAX OR WORK

Communication Jury Narrative

The GRoW team's communication efforts surround four main objectives. First, we hope to inspire our target audiences by presenting a unique model for sustainable living and urban gardening. Next, we seek to inform our target audience about smart energy consumption in the U.S., as profligate fossil fuel usage underpins our building, food, and transportation systems. Third, being one of twenty institutions selected to participate in the U.S. Department of Energy Solar Decathlon, we intend to raise the profile of the University at Buffalo (UB) as a premier, research-intensive public institution. Last but not least, we hope to fundraise for our project. Being able to aptly communicate the key elements and goals of the GRoW Home gives potential sponsors and donors a better sense of what they are investing in.

Our communication strategies target four groups. The first is college students. We want to empower fellow university students to make changes within their respective fields. Through peer-to-peer engagement in different forms, this audience is made aware that they can take on ambitious projects with world-changing goals. The next group is University at Buffalo's alumni. At 200,000 members strong, our alumni base is keen to follow the latest developments in UB research and projects and is engaged in the development of Buffalo's community. The third group is people in the Buffalo-Niagara community. Our communication efforts complement UB's core mission to bolster relationships with people and entities in the region. Finally, we aim to reach those interested in sustainable living and the environment, and to interact with people outside the region who are topically interested in our project.

There following are six key messages that we intend to relay to our target audiences via our communication strategies:

From our climate to the organizations that we partner with, the GRoW Home is a Buffalo-focused project. We observed trends such as the rise of community gardens and demand for renewable energy, and have partnered with over 55 entities in western New York on this project.

Solar is on the rise in Buffalo, long a city of electrical innovation. Solar housing is a feasible and practical option in Buffalo. This is affirmed by SolarCity's move to build a 1.2million-square-foot factory in Buffalo, the largest in the Western hemisphere. The growth of solar in New York State has increased more than 300 percent from 2011 to 2014, twice the rate of U.S. solar growth overall.

The GRoW Home proposes a lifestyle shift to achieve deeper sustainability. From awareness of seasonal changes to harvesting the best crops to planning one's energy consumption, the GRoW Home demonstrates how sustainable habits can be cultivated over time.

We are an interdisciplinary team of students and faculty members working together towards a common goal. Unique among student projects, the GRoW Home involves more than 240 students and faculty members from 14 different departments at UB.

UB is an elite institution. This project provides one-of-a-kind real world learning experience, and reinforces UB's reputation for sustainability. It complements recent university efforts including the 1+MWatt Solar Strand installation on campus, the formation of the RENEW (Research in Energy, the Environment, and Water) and the establishment of the UB Sustainability Academy.

GRoW Home intends to have a second life on campus. The team has been in conversations with the UB administration about bringing the house back to the campus after the U.S. Department of Energy Solar Decathlon as a proposed Multiscalar Energy Research and Education Center (MEREC)

To meet and convey our objectives and messages respectively, our communication plan encompasses the following:

Social media outreach involves regular and tactical updates on Facebook (FB), Twitter, Flickr and Instagram. We employ a unique hashtag (#UBGRoWHome) across all platforms, make use of pictures to intrigue and inform our audiences of construction and events, and repost external media coverage. As of August 2015, we have more than 800 likes on FB, and the number continues to increase as we build the buzz around our project.

Our official website contains detailed project content and contact information. We determine our website's success by the number of unique page views and time spent on our site, as measured by Google Analytics. The number of unique page

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views between March and mid-July 2015 was 1315, with an average of 1:47min spent on each page. As we added new content to our website, and conducted more fundraisers and community events, the number of unique page views between mid-July and mid-August rose to 1656, with an average of 2:06min spent on each page. To increase our web traffic during the competition in October, QR codes on our public exhibit materials will direct visitors to the site for more information.

We make use of the power of traditional media. Besides providing press releases to local, national, and regional media at key project milestones, we have been interviewed and featured in UB's internal (UB Reporter and Spectrum) and alumni publications, as well as external media outlets such as Time Warner Cable, The Buffalo News, and WKBW-TV.

From fundraising salons to community and college outreach, we interact personally with individuals and companies. We organized a crowd funding campaign in February this year and had 300 donors, approximately 2500 contacts and raised an estimated $30,000. We plan to have a second campaign in September to increase outreach and revenue.

Some additional events we have participated in include Solar Jam 2015 (300 attendees), Music is Art Festival 2014 (20 000 attendees) and tabling at Earth Week in UB's Student Union (700 attendees). For example, at PUSH Buffalo's Solar Jam 2015, many took the time to read our informational posters, ask questions, and engage in a hands-on activity that we organized.

As another form of community engagement, we intend to use the trucks that are transporting the GRoW Home from Buffalo to California for further broad communication. We have designed a large scale sign to affix to the side of truck for the journey, and ask anyone who spots the truck to post a picture of it on social media with the location and our hashtag. Besides gaining greater public attention, it will create a source of interest for our September crowdfunding campaign.

Four key concepts – Nurture Active Stewardship, Think Flexible Functionality, Live with Nature, and Recognize Energy Hierarchy – reflect the GRoW Home's philosophies and tie our public exhibit materials and website together. Due to their multiple appearances, our audiences would be able to easily identify these concepts alongside their respective icons, which will help them better understand the GRoW Home before, during and after the house tour. Our handout material begins as an informational leaflet that can be folded into a small planter for seeds. This furthers audience engagement and fulfills our objectives to inspire and inform.

[i] Robinson, 2015: http://www.buffalonews.com/business/solarcity-aims-to-create-1460-jobs-20150713

[ii] Robinson, 2015: http://www.buffalonews.com/business/prospectus/solar-energy-building-a-new-industry-in-wny-from-the-ground-up-20150123

[iii] Solar energy statistic in New York State: http://www.dec.ny.gov/energy/43231.html