SOLAR DECATHLON MIDDLE EAST 2018

Team Virginia Tech
In recent years, innovations in digital technologies, such as smartphones, computers and robotics have revolutionized the way we live, work and build. The presence of technology in everyday life has become so ingrained that it would be impossible to function today without it. We have fully embraced the expectation of convenience that high performance technology offers. Cutting-edge technology has quickly been integrated into the design and manufacturing of high-performance products like aircrafts and automobiles. The construction industry by contrast, has been slow if not resistant to change its operations. With FutureHAUS Dubai, our team is challenging the construction industry by demonstrating the utilization of advanced manufacturing processes to prototype an energy positive, solar-powered smart home.

Our research focus is twofold as we explore:

- **A new way to build.** We challenge the construction industry to adapt by looking toward innovative prefabrication and manufacturing concepts that allow for the incorporation of the smart technologies and improve the construction process.

- **A new way to live.** Now that we have a delivery method for technology in the home, we can propose new ways to introduce technology in our lifestyles. In FutureHAUS Dubai, we explore wide ranging digital technologies that allow seamless integration into our architecture. We can greatly improve our standard of living by offering aging-in-place and universally accessible design.

The 940 square foot home is configured from a suite of nine structural cartridges. A center spine is the main circulation corridor, dividing the home into two halves: service and served. A perimeter garden and stainless steel shade wall surround the home.

**A NEW WAY TO BUILD - PREFABRICATION AND INDUSTRIALIZATION**

By looking toward the automotive and aircraft manufacturing, we have discovered that the production of a home should employ similar attitudes and methods of construction. The factory process brings many advantages.
Benefits include:
1. Efficient material use and less waste.
3. Automation and CNC technology.
4. An environment to optimize quality control.
5. Accurate scheduling, timeline and pricing.
6. Minimal site disruption and pollution.
7. Controlled, safe environment
8. Production can be expanded to 3 daily shifts.

By contrast, conventional construction methods remain archaic, revolving around weather, time, contractors and sub-contractors schedules, and permits – almost always resulting in inefficiency, waste, lack of predictability and poorly finished products. We believe that the use of advanced prefabrication processes is the way of the future, will ultimately be the vehicle to provide our architecture of the future.

FutureHAUS Dubai utilizes fully digital fabrication tools and processes including CNC routing, 3D printing and BIM management to develop construction processes suitable for factory built homes. The careful integration of complex smart home technologies allow for monitoring and optimizing the building’s net-positive energy performance. This lean and sustainable industrialized process will guarantee both the highest level of quality control and a high-performance home.

**THE CARTRIDGE CONCEPT**

Designed to be a part of a compact, spatially efficient plan, prefabricated modules or “cartridges” deliver strong details and technology to the site. Our system is unique: not panelized wall construction or big-box modular, but a series of transportable, compact smart modules that are plug-and-play. With our concept, we propose to ship technology to the site, not space. With the efficient delivery of precision, pre-built components, the on-site assembly is fast, highly improving the quality of the final product and ultimately reducing cost through industrial efficiency. At its core, FutureHAUS is about industrializing the process of house construction. The process is in demand with future needs for the production of smarter, more efficient and more affordable housing.

**A NEW WAY TO LIVE- INTEGRATED TECHNOLOGY**

A significant part of FutureHAUS research has been to explore the best ways to integrate new digital technologies into the home. The greatest discovery has been the ability to integrate concepts of aging-in-place and universal accessibility through vertical adjustability and multi-modal controls. Whether child or adult, short or tall, disabled or not disabled, the home adjusts to fit the need of the user. The home can autonomously recognize the user through voice, height, or gait recognition so when an individual enters a room...
or performs a task, the room or item adjusts itself for that user. The home uses artificial intelligence to save user profiles and adjust to their settings every time. The technology remains intuitive with one complete home interface and manual controls of touch, gesture or voice.

FutureHAUS Dubai is composed of the following cartridges:

**Entry Cartridge**
The entry cartridge is designed for the Middle East; doubling as an airlock separating the conditioned home from the desert environment. The powder room to the right of the entry door includes an automated foot washing station for prayer preparation. The closet incorporates the mailbox of the future: a drone delivery roof hatch that opens to receive packages from incoming drones.

**Kitchen Cartridge**
The kitchen incorporates many smart features for cooking, inventory management, and user preferences. Adjustable upper and lower cabinet banks raise and lower for complete accessibility. Fixtures and appliances like the kitchen faucet and induction cooktop are integrated, maximizing work space. Additional features include: voice control volume specific water dispensing, electronic mixing valves to regulate kitchen faucet water temperature and self-cleaning appliances. The Virtual Window backsplash features three touch display screens to monitor cooking activities and performance. The island or “social table” compliments the kitchen cartridge. With its integrated, interactive display, users have access to the whole house interface, instructional cooking videos and interactive media to entertain users and guests.

**The Bathroom Cartridge**
The bathroom combines two separate cartridges, one with program for bathing and showering and the other for the toilet, vanity and user interface mirror. The room is designed to accommodate any user and is focused on user comfort and experience. The touch control smart mirror allows interaction with all bathroom functions and features, the NUMI toilet and vanity are both height adjustable. A 3D-printed sink explores the capability of utilizing additive manufacturing to produce complete products. The sink allows for autonomous use by providing motion activated, location specific delivery of hot, warm and cool water. It also incorporates water supply and drainage piping and integrated sensors.
and controls for water flow. A load cell integrated floor detects slips and falls and provides user weight on the smart mirror. The shower incorporates water sensor technologies that allows recycling of clean water, greatly reducing water consumption by as much as 90%.

The Living Room, Bedroom and Home Office – Flex Space (REF: AR-115)
The concept of Flex Space is demonstrated by two automated wall cartridges that reposition to adjust to three program spaces throughout the day. The home transforms to an office by day, expanded living room at dusk and an full bedroom by night. The purpose of this feature is to allow for maximum usage of a smaller footprint house - resulting in lower energy costs and efficient use of valuable real estate.

Power is distributed to these walls through a Direct Current (DC) powered rail allowing for less energy usage and simple energy distribution for the moving walls. The rotating AV wall TV screen allows the user to share the television and audio visual technology between the living room or home office modes thereby reinforcing the concept of flex space and by sharing AV equipment. The bedroom incorporates a mechanically stow-able Murphy style bed which, when stowed, converts to a smart mirror with an autonomous RFID wardrobe database connected to the closet cartridge. When the bed is deployed, the user has access to a smart bed with integrated head and foot adjustability and multiple smart technologies that track sleep patterns to help the user sleep better.

SPINE CARTRIDGE
The spine is the central nervous system of the home, connecting the dry mechanical room to the primary cartridge elements. The 33-foot long cartridge sits over the central hallway and contains all home-run electrical and communication lines as well as all ductwork for the HVAC system. It is this critical component that makes the home installation simple, organized, and fast.

DRY MECHANICAL CARTRIDGE
The Dry Mechanical or electrical room contains all electrical systems including the main breaker panel, the solar inverter, charge controllers, HVAC equipment and systems controls and communications. This compact, complex pre-wired component marries to the spine for effective power, communications, and HVAC distribution.

Wet Mechanical Cartridge
The Wet Mechanical cartridge contains the water distribution components for the home including the solar thermal integrated domestic hot water tank, heat exchanger, distribution pumps, and laundry room.

Door Cartridges
Three major door cartridges provide plug and play automated door systems. Each doorway opening of the home has three automated layers; one clear glass insulated door for enclosure; one frosted insulated glass door for privacy and sun control (when needed) and a third bug-screen to allow passive house operation - weather permitting. Each cartridge includes a gorilla glass wall integrated touch interface for control.

SOLAR CARTRIDGES AND THE ROOF CANOPY
(REF ST-202) The roof of the home is its own architectural element. An interstitial space between the PV’s and roof panels allows for ventilation. Five structural, modular, light gauge steel frames hold a 3KW Photovoltaic array each. These cartridges become the core of the solar canopy element for the home. They not only entirely shade the roof of the home, but collect the output of the desert sun and convert it to energy for the house needs. Eighteen prefabricated shading canopies attach to the outer band of the five solar trays completing the roof canopy.
These shade elements are made of lightweight aluminum structure and clad with silver Alucobond which has a high heat capacity. The solar canopy is functional and aesthetic, power-generating and shading.

SMART TECHNOLOGY; ADJUSTABILITY, FURNITURE, FIXTURES AND LIGHTING
FutureHAUS Dubai responds to the needs of individuals throughout their lifespan, from childhood through late life. From easy to use, multi-modal ways to interact with appliances and fixtures to adjustable surfaces, cabinets and toilets that can automatically adjust to individuals of different heights, the components and interfaces are seamlessly integrated in the home.

An energy efficient LED lighting system can respond to users specific needs using smart controls and pre-programmed scenes. Modes include reading, cleaning, waking, or entertaining.

SMART SURFACES
Complex technology requires space for equipment and electrical wiring. To accommodate this, the prefinished panelized wall and ceiling system allows for the utilization of wall cavities and ceiling plenums with easy removal. The "snap-on" removable glass panels can feature digital interfaces and the prefinished MDF panels can be easily demounted and repainted for renovations. For long term use, the individual modular cartridges can also be removed, retrofitted and replaced for renovations or upgrades.

RESPONSIVE TO REGION
Responsive to place, our design incorporates designs that relate to the culture and religion of the Middle East.

The shade wall surrounds the perimeter of the garden, shading the house and providing privacy. The petal is inspired by mashrabiyyah patterns found in Middle Eastern architecture. The house includes a majlis, indoors privacy screens that separate the living room from the kitchen, and a room for prayer preparation. Materials and shading features were selected or designed in response to the local climate.

LANDSCAPE
In the deserts of Dubai, net-positive water and energy systems create an oasis for user that extends beyond the walls of their home to the private gardens. Species were selected for their suitability to the climate, with an emphasis on culturally important and native plants species. The north gardens are the vernacular gardens serving day-to-day needs such as the provision of kitchen herbs and drying clothes outdoors. Accessible via the master bedroom as well as the main living area, the South garden is an outdoor extension of the luxury and flexibility of the home. The FutureHAUS model demonstrates a leap forward in responsive design that makes sustainable necessities and comforts available for all.

SCALABILITY AND CUSTOMIZATION
With the rapidly expanding world population, the FutureHAUS concept provides a vehicle for production of single family homes and communities, and is also usable for medium to high density housing solutions. By employing an industrialized prefabrication concept that can address large scale demands while at the same time incorporating technologies of the future, the FutureHAUS can revolutionize the housing industry, not just in the Middle East, but at a world scale. The mass-customizable manufacturing process will allow for use-specific construction assemblies to be employed – thereby accommodating the global locations that site-specific design demands. This will allow harmonization with natural resources, accommodate the climate variations of the region, and utilize the fabrication specifics that are available in unique regions. This concept fits with our universal concept of responsive design - where the home can make adjustments for changing weather conditions to suit different global environments.
CONCEPT, TESTED
Our team has explored the use of cartridges to build a speculative house, to renovate a kitchen and to prototype a disaster relief home. All have proven the concept to have true merit.

INNOVATIVE FEATURES
- **Cartridge Construction:** A concept reinventing the process for building homes
- **Solar Shade Canopy:** Collects sunlight while shading home
- **Glass Rain Screen:** Shading and ventilating
- **Decorative Shade Wall:** Protects the house from east and west direct gain + privacy screen
- **Flex Space:** Reducing footprint without compromising program (with low voltage power rail)
- **Integrated Technology:** A new way to live; IOT, autonomous and automated systems
- **Smart Surfaces:** Touch screen interfaces incorporated in panelized glass wall surfaces
- **Energy Management:** Optimizing energy production and distribution for Net+ goal
- **Responsive Walls and Windows:** Systems for passive and active performance
- **3d Printing:** Additive Manufacturing for systems in the bathroom vanity
- **Interactive VR modeling:** A virtual showroom for designing, marketing and cost-estimating.
- **Innovative Closed Loop Water Recycling Systems**
- **The Fully Accessibility Home:** Adjustable cabinets and fixtures to accommodate all
- **Lighting:** Addressable network of LEDs controllable by smart house network
- **Future Mail:** Drone Deliveries
- **User Interface App:** Universal Graphical Interface for multiple devices, integrated and mobile.

CONCLUSION
At the inaugural Solar Decathlon Middle East, the Virginia Tech team is debuting our latest prototype, the FutureHAUS Dubai. As a testament to its innovative design, the majority of the smart home, consisting of eight cartridges, will be assembled within just a two-day period. The prototype will also demonstrate many smart home features made capable by the innovative construction delivery process. As we enter the digital revolution, we as a design and construction industry must be ready to develop suitable processes to meet the challenging demand.
ENGINEERING AND CONSTRUCTION
Engineering and Construction

FutureHAUS Dubai is the latest prototype from a decade of research at Virginia Tech. The project explores the utilization of smart construction techniques and digital smart technologies and develops a universal model for the future of housing. The project demonstrates the following:

**A NEW WAY TO BUILD — THE CARTRIDGE CONCEPT**

As the Internet of Things technologies become more prevalent and as we experience higher demand for smarter, energy efficient, affordable housing, the building industry must look to better ways to build with technology. With a projected population of 9.8 billion people in 2050 and a concentration of over the half the population in cities, the need for smart, energy efficient and affordable housing is evident. FutureHAUS Dubai proposes a new approach to the construction of buildings that is faster, more sustainable, and allows for complex systems integration.

Conventional modular methods of construction are unsustainable. Whether big-box modular or panelized walls, the systems present problems in either shipping or in a lack of sophistication. FutureHAUS advances prefabricated modular construction to the future by subdividing a home into plug-and-play volumetric modules large enough to contain prewired cabinets, fixtures and technology, but small enough to still be delivered and assembled on site efficiently.

The home is made of a suite of twelve “cartridges”, prefabricated modular structures that are constructed separately and assembled on site (REF: AR-004) The cartridges: entry, kitchen, bathroom, office, AV wall, closet, dry and wet mechanical, master bedroom and spine cartridge--are pre-wired, pre-plumbed and pre-finished. The assembly method is plug-and-play: each cartridge contains its own electrical sub-panel for simple on-site hook-up. The cartridges are designed to be produced in a factory, transported on a truck and placed with a forklift or crane. They are sized to be 4’ wide and 10’ tall modular measure so they nest efficiently and legally on standard 8’ wide flatbed trailers. The suite of cartridges ship on just five trailers. Once on site, the cartridges are unloaded from the truck and set on the modular prefabricated foundation.
Composed of CNC-cut Structural Insulated Panels (SIPs), the cartridge frames are dimensionally stable, highly insulated and structural. Once assembled, the cartridge structures serve as vessels for the home technologies. Because they are structural, the cartridges can be stacked allowing for multi-level capability. The cartridges are fireproofed on the interior and waterproofed on the exterior and once assembled ensure a very tight envelope system.

While this system has many advantages for its unique cartridge strategy, the process brings with it the many additional advantages that prefabrication processes bring over conventional construction methods.

Benefits include:
1. Efficient material use and less waste.
3. Automation and CNC technology.
4. An environment to optimize quality control.
5. Accurate scheduling, timeline and pricing.
6. Minimal site disruption and pollution.
7. Controlled, safe environment
8. Production can be expanded to 3 daily shifts.

The FutureHAUS is ideal for a wide range of building types including single-family homes and multi-family, medium, and high-density housing. The cartridge concept provides an optimal system for addressing the future global housing shortages as urban population continues to grow.

The individual cartridges encapsulate the program and the technology of the individual rooms of the home. Once on site, they efficiently join together to support a rich house program. Below is a list of FutureHAUS Dubai cartridges and a brief description of their innovative features (REF: AR-004):

**Spine Cartridge**
As the central nervous system of the home, this linear module sits atop the long hallway of the house connecting the sub-panel of each cartridge back to the main breaker panel. HVAC ducting and communications lines are also distributed.

**Dry Mechanical Cartridge**
The cartridge contains the main electrical panel, solar inverter, charge controllers, HVAC outdoor unit and air handler, energy-recovery ventilator, batteries and all building control components. The cartridge construction method is the optimal setting due to the complexity of the systems and density of the installations.

**Wet Mechanical Cartridge**
The cartridge contains the home’s central water system components, including the domestic hot water tank,
plumbing manifolds, water filters, plate heat exchanger loops, and circulation pumps. The hallway facing wall of the cartridge contains the clothes washer and dryer.

**Kitchen Cartridge**
The kitchen is enriched with sensors, actuators and interactive displays to fully integrate technology into the most central room of the home. The components are integrated in the house information system to control functionality and to optimize energy performance of all kitchen tasks. Features include automated temperature control, water measuring/dispensing technology and real time inventory monitoring.

**Bathroom Cartridges**
Two cartridges make up the master bathroom. The first contains the smart mirror interface, the height adjustable toilet and vanity, and the 3D-printed sink and countertop. The print was produced using a process called additive manufacturing, a type of 3D printing that involves layering and integrating multiple materials and systems to make a complex object within a single print. The hybrid sink and countertop was printed as one piece with integrated water piping and sensors, eliminating complex plumbing and allowing for touchless controls. The second cartridge contains the bathtub and shower. The tub demonstrates the future of bathing with multiple smart features providing an exciting user experience. Decorative finishes are also innovative, waterproof, CNC carved Corian.

**The Living Room, Bedroom and Home Office Cartridges – Flex Space**
The concept of Flex Space is demonstrated in the house’s three primary living spaces (REF: AR-032). Two automated cartridges positioned between two exterior fixed cartridges can be repositioned through the home interface to adjust the three program spaces: a home office, a living room and a bedroom. Adjustments can be made to accommodate the different programs during different times of day. The resulting benefit is a reduction of footprint size without losing program functionality, a reduction in the HVAC load and lower real estate costs. Power is distributed to these walls through a DC powered rail which consumes less energy and allows for simple energy distribution for the moving walls.

**Door Cartridges**
The three door cartridges carry the preinstalled sliding door systems. Each door assembly has three layers: A vision glass door for thermal enclosure and views, a frosted glass door for privacy and sun control, and an insect screen for passive natural ventilation. Each insulated glass unit boasts an R-8 insulation value (U 0.125). When both door panels are closed, the effective insulation value is R-16 (U 0.0625). All doors are electronically automated and can be controlled with digital interfaces or by the home automation system.

**Solar Cartridges**
Built with lightweight steel, five structural frames are prefabricated, fitted, and pre-wired offsite each with 3 kW solar arrays. The units nest together above the house roof surface to make up our entire 15 kW array, composing the main platform of our shading canopy strategy. Each mini array has a partner charge controller in the Dry Mechanical room, making plug and play installation simple. The five structural frames form the core of the Solar Shading Canopy (REF: ST-202)

**THE SHADING CANOPY**
The BIPV canopy, much like a tree, shades the house and processes the energy from the sun, turning what would be a liability in Dubai into a great asset. The five solar cartridges and 18 prefabricated projecting overhangs make up a wide, parasol-like shading canopy. The system with the 5 foot projecting overhangs essentially eliminates the direct solar gain on the house roof and envelope reducing the energy load by 51% in mid-day sun. Materials are durable galvanized light-gauge structural steel frames with factory finished, reflective composite panels. Much
research has been invested in cleaning technology, which will use a robotic vacuum cleaning system. The aerodynamic roof design diverts wind loads from the house, is self cooling, the projecting canopy with its partnering shade walls also provide shade for the outdoor living spaces below.

**SHADE WALLS**
Inspired by the mashrabiyyah shade screens, our shade walls (REF: ST-205) provide privacy for the home and protect the walls of the home from direct sun exposure, especially from harsh lower west and east direct sunlight. The stainless steel panels are durable and reflective and partner with the shade canopy to divert strong winds from sandstorms.

**RAIN SCREEN**
A 2.25” cavity between the glass siding of the house and the waterproof exterior wall creates a passive wall cooling system called a rain-screen. The glass also shades the insulated house envelope wall from direct sunlight further improving performance. The glass facade is durable and, like the rest of the house, is an easy to install, modular system.

**HVAC ZONE CONTROL**
Our building cooling strategy begins with minimizing thermal loads through full house shading, a high R-value envelope, rain screen wall venting, and responsive, tight, insulated, windows and doors.

The house then provide a essential ventilation using an energy recovery ventilator to minimize the impact of hot, humid outdoor air. With the cooling load minimized, a Mitsubishi mini-split heat pump conditions the spaces with a high coefficient of performance. Five wirelessly controlled Honeywell zone dampers, informed by occupancy sensors, can channel air to specific locations in the home based on real time demand.

**PHASE CHANGE LOAD SHIFTING**
A ceiling cavity is lined with a 71°F Phase Change Material (PCM) for the purposes of load shifting and balancing energy supply and demand. A dedicated HVAC zone for this interstitial space allows us to pre-charge (freeze) the material during periods of excess energy production, which then can be harvested for cooling purposes during non-solar production times – e.g. in the evenings when exterior temperatures still exceed the interior set-point temperatures.

**SMART TECHNOLOGY + ENERGY MANAGEMENT**
With the goal to achieve a net-positive energy balance in the FutureHAUS, an advanced power electronics system comprising state-of-the-art equipment is installed. It comprises five solar arrays, aggregately contributing close to 14 kW of peak power. Each solar array features its own dedicated charge controller for increased reliability as well as for independent, per
The installed 14 kWh battery is currently the safest and least polluting rechargeable battery on the market, built with very high environmental standards, and safe to be stored indoors with no need for venting or cooling. Furthermore, the efficient and contemporary 8 kW power inverter interfaces Photovoltaics and batteries with the utility grid, and is serving as a main generator of the clean energy utterly minimizing, if not eliminating, utility grid dependence.

In addition to the above described renewable energy system, FutureHAUS Dubai boasts an information infrastructure and an advanced, decision-making, energy management algorithm that goes beyond the traditional residential system control. For instance, if instantaneous harvested power from the PV is higher than what house loads demand at that instant in time, an algorithm sends the command to the inverter to sell the excess power back to the grid (net-positive mode). As this algorithm also has access to the weather forecast (short and long term), it will make a decision whether it is better to sell all excess energy or reroute some percentage to charge the battery (e.g., if the rain will start soon majority of that energy will go into the battery). If however power from the PV is lower than what house loads demand, an algorithm switches to the net-zero energy balance mode.

**SMART BUILT ENVIRONMENTS**

A Smart Built Environment (SBE) incorporates smart objects, devices and sensors that observes the built environment and interacts with the inhabitants in novel ways. The Internet of Things (IoT) provides sensing, communication, computing, and actuation infrastructure for ubiquitous interactions and pervasive services. The result is an adaptive environment that responds to a range of real-time needs or changing environmental conditions. For security purposes, the infrastructure is self-contained and does not need access to the outside network to function.

**THE DC POWERED HOME**

Inspired by the recent trends of power distribution where contemporary loads process energy through power electronic converters and use direct current (DC) as the primary source, our FutureHAUS team has implemented a low-voltage DC power distribution in a rail that seamlessly delivers power to the flex-space walls as they move from end to end. In order to comply with the competition rules this rail is still powered by the alternating current (AC) but uses high-quality rectifiers to supply the rails directly with DC and hence demonstrate a glimpse of this technology. The main motivation to demonstrate this concept comes from the fact that none of the contemporary home appliances ranging from portable electronics and laptops to induction cooktops and air conditioners use AC supply directly in its original form. All of them first rectify the alternating input to DC before supplying their internal circuitry for operation, hence completely unnecessary imposing the energy loss for this AC-DC conversion.

**ADJUSTABLE SYSTEMS**

FutureHAUS has numerous design and technological features that are responsive to the needs of individuals across the lifespan, from childhood through late life. From easy to use, multi-modal ways to interact with appliances and fixtures to adjustable cabinets and toilets that can automatically adjust to individuals of different heights, the components and interfaces are seamlessly integrated in the home and easily accessed by all. The dynamic aspect is of particular value since the home can simultaneously respond to a range of users with different user preferences.

**SMART WALL SURFACES**

Complex technology requires space for equipment and electrical wiring. To accommodate this, the prefinished panelized wall and ceiling system allows for the utilization of wall cavities and ceiling plenums with easy removal. The “snap-on” removable glass panels...
can feature digital interfaces and the prefinished MDF panels can be easily demounted and repainted for renovations. For long term use, the individual modular cartridges can also be removed, retrofitted and replaced for renovations or upgrades.

**SOLAR THERMAL AND WATER CONSERVATION**

Water heating accounts for 17% of the energy consumption in homes in the United States, making it the third largest energy draw. A solar thermal water heater in FutureHAUS Dubai eliminates that load. This is critical to energy positive performance since it allows optimized use of solar electric energy for house and car functions. The closed loop rooftop solar flat-plate thermal system (REF: SW-001) heats 120 gallons of Domestic Hot Water which is distributed through the house. In order to be able to reuse shower and laundry water without contaminating the DHW in the tank, The 120 degree DHW is piped through two separate flat plate heat exchangers for those two heating-on-demand systems. The shower employs the Orbital System, a water recycling technology that measures real-time water quality with an opacity sensor and recycles clean water back into the shower loop after additional UV and chemical filtration, reducing water consumption by 90% and energy consumption by 80%. (REF: PL-221)

For laundry water recycling, we utilize a compact subsurface wetlands filtration system that passes waste laundry water through an aerobic/anaerobic filtration process then UV and chemical filtration for ultimate reuse as supply laundry water.

A rainwater collection system collects water from the roof and channels it into an under house bladder collection tank. Of the 500 gallons of water we are expected to use during the two-week long competition, we anticipate recycling 475 of those gallons.

**VIRTUAL AND MIXED REALITY (VR/MR)**

Interactive virtual and mixed reality models enable the use of newest VR/MR technology. The model allows the user to interact with rooms of the home and interchange different materials, colors, appliances or furnishings in the model. In the future, we see these models to be virtual showrooms ideal for real-time marketing and pricing tools. This functionality directly translates to the production process, allowing the user to have feedback on design changes and the fabrication schedule, bringing the client into the assembly process.

**INNOVATIVE FEATURES:**

**Prefab Modular:** To provide a new way to build in the digital age, with modular, factory-built components.

**Solar Shade Canopy:** A Photovoltaic array and framework as a shading component for a home, eliminating direct solar gain on house surfaces, greatly reducing HVAC loads.

**Shade Wall:** CNC fabricated ornamental walls for sun shade, privacy, and lighting system.

**Rain Screen:** Ventilated wall cavity for distances heat from wall assembly.

**Flex Space:** Automated walls arranged to accommodate program needs.

**DC Home exploration:**

**The Smart Home:** The integration a wide range of functions and technology in the home to enhance user experience, improve performance.

**Adjustability:** Automated counters, desks, and fixtures to accommodate people of all ages and abilities.

**Energy Management Algorithm:** Optimization of power distribution to ensure energy positive operation.

**Water Dispensing and Temperature Controls**

**3D Printed Sink:** Additive manufacturing technology, integrated systems.


**Interactive Virtual Reality Model:** New VR concept for design, marketing, and costing.

**Phase Change Material (PCM)**
FutureHAUS
SUSTAINABILITY
Sustainability

Throughout the design and construction stages of FutureHAUS Dubai, our team respected the three overriding sustainability principles:

1) to design a house that is energy and resource efficient in both performance and during construction
2) to build a house that incorporates environmentally friendly building materials, and
3) to space plan a house that utilizes space efficiently.

In the following narrative, we will detail our sustainable features and practices within these three categories. With FutureHAUS Dubai, sustainability was considered as integral to design and not just applied as an afterthought, that is why, in our home the sustainable features are seamless and well integrated, just as are much of the new digital technologies and features.

SUSTAINABLE MATERIALS

The most desirable materials to use in a sustainable project are those that are recyclable, renewable and that require the least energy to manufacture. Our focus in this report are our four predominant materials which make up over 90% of the material use in our house; glass, SIPs panels steel and wood.

Glass

Glass is not only one of the most affordable and durable building materials, but also one of the most sustainable. It is a resource efficient material made from raw materials that are abundant, primarily sand and recycled glass or cullets. Glass is also fully recyclable. In manufacturing, since glass has a low melting point, it uses very little energy (11 MJ/kg) to produce. Glass is also an inert material, sanitary and easy to clean and doesn’t off-gas. Overall the material contributes to a safe interior environment. For passive design, the glass in our windows and doors not only contributes to an effective natural daylighting strategy, it simultaneously is saving considerable energy by utilizing new insulated glass unit (IGU) technology that replaces gasses with a vacuum resulting in a thin profile and high insulation values.

Finally, the beautiful, reflective, white glass as a material contributes to our modern aesthetic for the house of the future. The material projects a futuristic look that allows your imagination to “fill in the blanks” to what the future will be. It contributes to a pristine modern look and feel when combined with technology such as integrated touch screen technology, video displays, and tune-able LED lighting systems.

Structural Insulated Panels (SIPS)

The sustainable advantages to using SIPS seem to be endless. The insulated foam and wood sandwich panels provide high insulation values and a tight, water and vapor resistant building enclosure while also incorporating structural integrity for both vertical bearing and lateral loads. In our case, the SIPS panels are effective in providing modular cartridge frames for the modular strategy of our home. For us, one unique advantage to using SIPS is the fact that they are manufactured in a factory and can be precisely precut with CNC technology, a very important criteria for our factory built home. The two materials that comprise our SIP panel is PUR foam and OSB sheathing. Both materials are described below:

PUR Closed Cell Foam. A closed cell insulation product delivers very high insulation values per inch. A typical energy efficient residential framed wall with BATT or open cell insulation is R-3.5 per inch as opposed to PUR technology which doubles that. Our effective walls are R-27 and floors and ceilings are R-41, contributing significantly to the performance of our home. PUR foam also has great structural characteristics, significantly stronger than eps alternatives. PUR is also fireproof will not burn, smoke or melt.

SIPs technology allows for optional sheathing choices.
Since the manufacturing process involves the high pressure foam being injected in a press between two outer sheathing panels, resulting in a monolithic structural sandwich panel, having a range of sheathing material selection is possible. In the Middle East, we would prefer to use concrete fiberboard, however, since our home was built in the US and will eventually reside in the US, we selected to use oriented strand board, made from locally harvested, sustainable wood products for our panels.

**Steel and Aluminum**

Steel and Aluminum each have their own individual benefits in terms of sustainability, however both are very strong in recycled content (40% in current supply) and recyclability. Steel have much lower embodied energy (32 MJ/kg) than Aluminum (200 MJ/kg). The big difference characteristic difference between the two is that aluminum has significantly lower density (2.7 kg/m³) compared to steel (7.8 kg/m³) a determining factor when material decisions are made for production. The FutureHAUS project utilizes both materials based on the constraints for each use. For example, canopy overhangs need to be strong but lightweight therefore utilize aluminum framing and composite aluminum skins for their strength to weight benefits. The structural solar trays by contrast utilize light gauge steel beams with integrated rebar reinforcement to achieve long spans with significant live load impact. As a manufactured product, material choices now do not need to be necessarily all or none. Specific choices are made based on performance and structural constraints. Our team tries to make educated choices always when choosing between steel and aluminum with regards to sustainability.

**Wood and MDF**

In contrast to Dubai and the Middle East, Wood is a local and sustainable resource for us in the United States. It also acts as a carbon sink during its lifetime and can be down-cycled or composted at the end of life. We therefore do not restrain from using the material in the FutureHAUS prototype however consider the use of alternate, locally sourced materials when fabrication happens in different regions. There are two companies that source our wood product, both are extremely responsible in regards to environmental sustainability with their products, Weyerhaeuser and Columbia Forest. Both practice responsible forest management and certify their wood as such, both consider embodies energy in material processing and manufacturing including clean manufacturing and limiting waste and both utilize environmentally responsible chemical materials to manufacture composite products.

Industrialized wood products or "engineered wood” not only eliminates waste, but provides a stable, straight, strong and durable product - ideal for our constraints for industrialized production. Another wood panelized product is medium density fiberboard (MDF) which is now produced with more sustainable adhesives such as MDI glues which eliminate the human health risks associated with formaldehyde-based adhesives. Utilization of this adhesive minimizes VOCs making the product more sustainable.

**ENERGY AND RESOURCE EFFICIENCY**

By nature, we expect that all of the entries in the Solar Decathlon Middle East will be energy and resource efficient, however, it has been our goal to push this constraint to the limit. We do this with the following energy efficient strategies of our home:
FULLY SHADED - WELL-INSULATED ENVELOPE
Our solar roof shade canopy with projecting overhangs in conjunction with our vertical, ornamental shade screens keep the FutureHAUS in the shade during daytime hours. A breathable, glass rain-screen façade serves as additional solar protection. Our entire thermal envelope is therefore protected 24 hours a day, 360 days a year from direct solar gain. Our airtight insulated ceiling walls and floors additionally protect the home from extreme Dubai ambient temperatures.

LEAN MANUFACTURING PROCESS
The primary FutureHAUS concept is about industrializing the process of house construction. Taking the process away from the site and into the factory where lean manufacturing processes can be employed. The many sustainability benefits of off-site production include the following:
- It uses the material efficiently and limits waste.
- It utilizes production software in CNC fabrication which economizes material use
- Minimizes site disruption and pollution.
- Factory waste is recycled
- Benefits from economy of scale
- Results in a precise and energy efficient final product
- Decreases commuting time for factory workers
- Lowers embodied energy due to factory efficiency and construction speed
- Guarantees sustainable material selection
- Reduces construction time

SMART BUILDING CONTROLS, ENERGY MONITORING AND OPTIMIZATION
The use of smart building systems benefits sustainability in many ways. It allows for optimized use of energy through both high performance systems operation and by managing real-time energy use based on occupancy/vacancy sensing. Giving homeowners access to energy use is also a very useful. Knowing how their daily living habits effect their energy use helps them determine ways to curb their energy use.

Energy Positive Performance
With a clear goal to achieve a net-positive energy balance in FutureHAUS Dubai, our Electrical Engineering students have developed an advanced power electronics system comprising state-of-the-art equipment is installed. It comprises five solar arrays, aggregately contributing close to 14 kW of peak power. Each solar array features its own dedicated charge controller for increased reliability as well as for independent, per string, maximum power point tracking. The installed 14 kWh battery is currently the safest and least polluting rechargeable battery on the market, built with very high environmental standards, and safe to be stored indoors with no need for venting or cooling. Furthermore, the efficient and contemporary 8 kW power inverter interfaces photovoltaics and batteries with the utility grid, and is serving as a main generator of the clean energy utterly minimizing, if not eliminating, utility grid dependence.
In addition to above described renewable energy system, the FutureHAUS boasts an information infrastructure and an advanced, decision-making, energy management algorithm that goes beyond the traditional residential system control. For instance, if instantaneous harvested power from the PV is higher than what house loads demand at that instant in time, an algorithm sends the command to the inverter to sell the excess power back to the grid (net-positive mode). As this algorithm also has access to the weather forecast (short and long term), it will make a decision whether it is better to sell all excess energy or reroute some percentage to charge the battery (e.g. if the rain will start soon majority of that energy will go into the battery). If however power from the PV is lower than what house loads demand, an algorithm switches to the net-zero energy balance mode.

Other renewable systems and energy efficient systems include a solar thermal for domestic hot water with heat exchanger loops circuits to heat shower and laundry water, a highly efficiency Mitsubishi heat pump system with smart controls and electronic zone control, an ERV and programmable LED lighting systems.

**Subsurface Wetlands**

This system receives waste laundry water, rejects water from the Orbital system and bathroom sink and filters it through an aerobic/anaerobic gravel filter bed. This system also uses a reheat heat exchanger and UV filtration as water returns for reuse in the laundry system.

**Orbital Shower System**

A closed loop shower water recycling system that incorporates a water opacity sensor for detecting clean vs contaminated water, allowing clean water to be diverted back into the shower loop after running through heat exchanger reheating and UV filtration. The water sensor tests the water quality 0x per second. With this system, we are able to use 90% less water and 80% less energy than a standard shower.

**Solar Thermal Towel Drying**

Because the ultimate location for the FutureHAUS will be in the US with winter season freezing implications, we have shied away from the use of a thermo-siphon solar thermal system and opted for a closed-loop collector. Since our selected system may have a chance for overheating during extreme Dubai days, we have installed a heating dump bypass manifold that can double as a radiator for fast towel drying. (REF: SW-001)
FLEX SPACE
With smarter space planning and smaller footprints, energy loads can be reduced. Life cycle environmental impacts scale with the size of the building so efficient space use reduces embodied energy. Our concept of Flex Space is demonstrated in the three primary rooms of the FutureHAUS where two automated wall modules that double as a closet and an AV wall, can be mechanically repositioned to adjust the three program spaces between the walls. Adjustments can be made to accommodate different programs during different times of day: an expanded office by day, expanded living room at dusk and an expanded bedroom by night. This feature allows for maximum usage of a smaller footprint house - resulting in lower energy costs and efficient use of valuable real estate. Power is distributed to these walls through a DC rail allowing for less energy usage and simple energy distribution for the moving walls.

MATERIAL CHOICES AND CONSTRUCTION METHODS
Much of the overall energy that goes into this project will be produced during the manufacturing stages of the materials. Tally® LCA software was integrated into the Autodesk Revit model to environmental impacts of the entire FutureHAUS design using Life Cycle Assessment (LCA) techniques. By using life cycles assessments (LCA’s) we are able to analyze and study each material component and breakdown their individual environmental impacts across all life cycle phases – manufacturing, transportation, maintenance, and end-of-life. We are able to see analyze breakdowns for each material, and the overall building as shown above, emissions equivalents, usage, transportation impact. This has become a design tool for us allowing us to compare material choices for more informed decisions.

In all environmental aspects that were analyzed (energy, global warming, smog formation, acidification, and eutrophication), manufacturing is the project phase that has the highest environmental effects. For example, approximately 50% of the embodied energy in this project are due to metals, mostly due in part to the large quantity of metals being used in the project in comparison to other materials. To minimize its carbon footprint and other associated environmental impacts, we will focus on sourcing metals from manufacturers using <90% recycled steel when possible.
LANDSCAPE

In the deserts of Dubai, the landscape channels the harsh elements to power habitation. Net positive water and energy systems create an oasis for the residents that extends beyond the walls of their home to the private gardens. The primary irrigation source is Air conditioning condensate, which is collected and stored in bladders beneath the deck. These collection systems are plumbed to the home’s gutters, allowing for storage and slow release of the rare rain event.

TRANSPORTATION

FutureHAUS cartridges are sized to be easily transported. The entire FutureHAUS Dubai house fits on five 43-foot long trailers with no wasted space on each trailer. The innovative cartridge construction allows us to ship technology rather than space, reducing carbon footprint.

Sustainability has always been an essential prerequisite for the existence of architecture, from the first pitched roof engineered to provide shelter and shed rainwater to the gutter system today that harvests the water for recycling. FutureHAUS Dubai, though full of materials and technologies that make up a long list of sustainable features, as a whole, is ultimately a work of architecture with seamless integration of these many sustainable characteristics.

INNOVATIVE FEATURES:

Prefabrication Strategy and Efficient Production
Flex Space: Efficient use of space
Solar Shading Strategy
Closed Loop Shower System – Orbital Shower System
Closed Loop Water System – Subsurface Wetlands
Recycling
Energy Positive Inverter Optimization
Smart HVAC Zone Control – Electronic Dampers
Spacia High Performance Glass
Solar Thermal Towel Drying
Solar Thermal Heat Dump
Water-saving bathroom fixtures
3D printed sink
Transportation
Water-conscious landscape
Spacia Door Assembly
ENERGY EFFICIENCY MEASURES
Energy Efficiency Measures

FutureHAUS Dubai reaches its energy positive status primarily by utilizing a combination of passive strategies, to greatly reduce the overall energy demand, with smart building controls, to optimize energy use. The following paragraphs will identify these and other strategies used to optimize its energy and water efficiency.

PASSIVE DESIGN: THE SHADE CANOPY
(REF: AR-301)
In designing a home for Dubai, common sense calls to immediately shade the home from intense direct sunlight. Our passive design incorporates a roof shade structure, composed of solar array cartridges and prefabricated roof overhangs that together work like a parasol, hovering 12” above the roof of the home. By isolating the direct sun from the roof surface, we radically reduce the solar heat gain of the home while at the same time, we harvest and store the sun energy for later use. To prove the impact of the shading, we have calculated a 51% reduction of heat gain through the ceiling during a typical November day.

SHADE SCREEN (REF: ST-205)
For mornings and afternoons, when the direct sun is not blocked by the overhangs, our mashrabiya inspired shade screen take on the task of shading the home. The screen also doubles as a privacy screen and nighttime lighting system. The beautiful, Arabic inspired dynamic patterns of the screen walls become the identity of FutureHAUS Dubai.

SIP ENVELOPE AND RAIN SCREEN
Cartridges are constructed with Structural Insulated Panels (SIPs) with high density polyurethane foam, giving both a tight envelope and high insulation values. In a SIPs panel, the structural and insulation components joined as one, eliminating breaks and gaps in insulation. Chases for electrical wiring are hollowed into the foam core which provides a continuous layer of insulation. The walls have an R-value of 27, the floor has a value of 41 and the roof has a value of 56. SIPs-constructed homes use 50% less energy than stick-built homes to heat and cool. Glass rain-screen paneling protects the exterior walls from direct sun but also sets up a ventilation channel between the wall and the glass. The 2” air cavity has a significant reduction on the cooling load of the house. Metal supports for attaching the glass rain screen to the exterior also double as downspouts for rainwater harvesting.
SMALL SPACE – FLEX SPACE (REF: AR -004)
The concept of Flex Space is demonstrated in the primary space of FutureHAUS where two automated wall modules can be mechanically repositioned to adjust the three program spaces: a home office, a living room and a bedroom. Each room can be expanded on demand depending on need. The purpose of this feature is to allow for maximum usage of a smaller footprint. FutureHAUS Dubai consolidates three unique and vital rooms into one, thus greatly reducing the load. The flex-space walls are powered by DC through the conductive rail seamlessly integrated into the house central spine. This also significantly simplifies the power distribution infrastructure, which is particularly challenging when supplying the moving structures using conservative means of power delivery.

The rotating AV wall allows the user to share the television and audio visual technology between the living room or home office modes reinforcing the concept of flex space and sharing AV equipment. Instead of separate screens in each room, a simple modification to the wall allows one screen to be shared.

HVAC ZONE CONTROL (REF: ME-231)
Our building cooling strategy begins with minimizing thermal loads through full house shading, a high R-value envelope, rain screen wall venting, and responsive, tight, insulated, windows and doors. We then provide essential ventilation using an energy recovery ventilator to minimize the impact of hot, humid outdoor air. With the cooling load minimized, a Mitsubishi mini-split heat pump conditions the spaces with a high coefficient of performance. To further our efficiency, five wirelessly controlled Honeywell zone dampers, informed by occupancy sensors, can channel air to specific locations in the home based on real time demand.

PHASE CHANGE LOAD SHIFTING
A ceiling cavity is lined with a 71°F Phase Change Material (PCM) for the purposes of load shifting and

Spacia Glass Door Assembly
balancing energy supply and demand. When conditions allow a dedicated HVAC zone for this interstitial space allows us to pre-charge (freeze) the material during periods of excess energy production, which then can be harvested for cooling purposes during non-solar production times – e.g. in the evenings when exterior temperatures still exceed the interior set point temperatures.

ENERGY MANAGEMENT AND MONITORING
FutureHAUS Dubai features its own nanogrid, comprised of 50 Photovoltaic panels, batteries, and a power electronics converter as a core electrical system. The nanogrid is supervised via a high-level energy management system constantly scanning large appliance power demand and assuring positive energy balance.

SOLAR THERMAL (REF: SW-001)
Two Solar flat plate collectors provide heating for the domestic hot water, thus allowing more expensive energy sources such as solar PV to be used exclusively for equipment such as cooling, lighting, and electronics. Energy from the flat plate heat exchangers is stored in a hot water tank at a relatively high temperature that fluctuates during the day. Hot water from the tank is used through a mixing valve to supply domestic hot water at a constant, safe temperature. In addition, the mixing valve supplies hot water to heat exchangers located in two closed loop water recycling systems, one for laundry and the other for the shower. The solar thermal loop, in the case of overheating is equipped with a radiator type heat dump which can also be utilized as a laundry drying rack for energy free towel drying.

WATER CONSERVATION AND RECOVERY
The Orbital water recycling system (REF: PL-221) utilizes a water opacity sensor to differentiate clean from contaminated water. If the sensor detects clean water in its drain, it diverts the water back to the shower head. If it detects contaminated water, it rejects it and allows it to pass into the drain where it can be diverted to the Subsurface Wetlands system for filtration. (REF: PL-211) The recycled shower water saves energy by recovering and reusing preheated water. The Orbital system saves 90% of the shower water and 80% of the heat energy. The Subsurface Wetlands system recycles all of its incoming grey water less water lost through evaporation.

APPLIANCES
All appliances have been carefully selected and thoroughly tested to be energy efficient. For further energy optimization, energy management system informs the homeowner when to run each specific appliance.
LIGHTING
To fit the narrative of smart home and energy efficiency, our lighting system is fully tunable. As a 12” x 12” grid network of addressable LEDs, smart lighting can respond to user’s specific needs for light throughout the day or can be digitally programmed as required. With this selective, localized, lighting strategy, much energy is conserved.

INTERFACE
A home interface present in every room of the house allows the user to understand and monitor energy production and consumption. The interface also gives the user the power to control appliances, lighting, temperature and door openings, allowing each item to be shut off quickly and more easily, using less energy.

TRANSPORTATION
FutureHAUS cartridges are sized to be easily transported. The entire FutureHAUS Dubai house fits on five 43-foot long trailers with no wasted space on each trailer. The innovative cartridge construction allows us to ship technology rather than space, reducing energy consumption.

INNOVATIVE FEATURES:
Flex Space: Reduced footprint, expanded space.
Solar Shade Canopy: Eliminate direct solar gain.
Vertical Shade Walls: For privacy, shade and wind protection.
Glass Rain Screen: Shades and vents wall cavity
SIPs Cartridge Construction: High insulation values.
Smart Home Interface: Gives user control of consumption and provides user awareness.
Smart Building Systems: Optimize energy use, autonomous operation.
Strategic HVAC Zone Control: Occupancy and vacancy based cooling.
Phase Change (PCM): Balancing energy supply.
Spacia Glass Doorway Cartridge: Automated and tunable network of insulated doors.
Solar Thermal Towel Dryer: Doubles as a heat dump for overheating protection.
Flat Plate Heat Exchangers: On-demand heating for closed loop water systems.
Water Reuse: Orbital systems and subsurface wetlands.
LED Lighting and Controls: Energy efficient with addressable control.
Lighting Controls
Home Interface

Left: The dynamic LED lighting in the bedroom. Right: The main navigation screen of the home interface.
Communications Strategy and Plan

You've just stepped into 2030—

Where drones deliver groceries, a touch of the button changes the layout of a whole room, and the mirror on the wall is your new best friend.

Welcome to the home of the future: a prefabricated house that’s less expensive, safer, energy-efficient, and higher quality than the houses of today. Virginia Tech’s FutureHAUS research proposes an alternative to conventional construction, and new, innovative ways to market a Haus.

FutureHAUS Dubai is more than just house of the future—it is a symbol of innovation and resilience. When entering the Solar Decathlon in the fall of 2017, a few bumps along the road were expected. However, nothing could have prepared the team for the fire that engulfed the house and destroyed five years of work. It felt as if the reality of our vision vanished with the flames.

But this was not the end of FutureHAUS™. We rose from the ashes, more determined than ever, picking up the pieces and shaking off the dust. The build began again, and the house grew, better than ever. FutureHAUS Dubai is our nexus of all the past research and prototyping that was lost. This was our second chance to create something that mattered for the future to come and share a story our audience would never forget.

Welcome back to 2018. Here stands the culmination of creativity, hard work, adversity, and the future. Here stands FutureHAUS.
PRISM, an award-winning, student-run advertising agency at Virginia Tech, was selected as a strategic partner by the FutureHAUS leadership team in January of 2017. The agency’s interdisciplinary team of marketers, designers, writers, analysts and videographers has spearheaded the FutureHAUS marketing strategy, execution plan and analytic assessments. Through an integrated marketing communications approach, PRISM shaped FutureHAUS’ brand voice and ensured that all outgoing social media posts have effectively conveyed that the team is resilient, tenacious, adaptive and proud. Using the brand voice as a guiding principle, PRISM created engaging narratives and videos of compelling stories, reflecting the strategy behind every step. PRISM helped the FutureHAUS team directly engage with their audience through branded events, while facilitating engaging digital content through virtual reality and live-streaming. The end result showcased the intelligence and breadth of the entire team and effectively conveyed how the state of the art FutureHAUS will positively impact generations to come.

TARGET AUDIENCE
With such a dynamic house, our team initially struggled with identifying the ideal audience to promote FutureHAUS. How can we arrive at one identity if FutureHAUS is designed to respond to every user and their needs? We quickly realized that this was our biggest opportunity: to make the home accessible and approachable to each demographic. We presented the house to five-year-olds just starting school, eighteen-year-olds entering college, and eighty-year-olds in our community.

TYPES OF MARKETING
Three types of marketing were implemented in the team’s communication strategy:

1. Community response marketing:
We tapped into the Virginia Tech community to gain support and understanding of the project, mainly through university-related social media posts and events that were held at Virginia Tech.

2. Strategic immersion and activation marketing:
Rather than traditional marketing, we took on a new approach and engaged with our audience in social media.
campaigns that featured immersive strategies like virtual reality and Facebook live videos. A virtual 3D model of the house brought our audience into our house when they couldn’t physically be there. The model featured gesture controls in which users can adjust finishes to the cartridges to design and visualize their own FutureHAUS.

3. Experiential marketing:
The best way to understand the house is to see the house. To do this, we hosted events like “Lights on at the LumenHAUS” and the “FutureHAUS Open-HAUS” to bring the house to life. This allowed us to interact with our audience face-to-face and give the Virginia Tech community an opportunity to gain a better understanding of the project.

OUR PROCESS
A strategic marketing plan is the backbone of our communications strategy. Through this plan, we determined our brand voice, target audiences, key performance indicators, goals, and metrics we will use to track our success. These factors drive every decision we make.

CONTENT CALENDAR
We use a content calendar to plan how our message and campaigns will be displayed on social media. This allows us to plan weeks in advance what we will be posting and what channels the posts will appear on. In-depth research and analytics determine how captions will be phrased, which posts should continue into a series, and which posts should be boosted to reach a larger audience. Once we finalize this calendar, the posts are scheduled in the social media management program Hootsuite, which automatically publishes them on the selected days and times.
INTEGRATION
Our team strategically utilizes the multiplier effect to conserve resources and increase the effectiveness of our communications efforts. Social media is used to facilitate two-way communication, which encourages our audience to not only view our process, but to become a part of it. Tools such as Facebook Live and 360 degree photos allow our audience to step into each moment with us.

MEASUREMENT
The utilization of a variety of channels requires our team to use multiple methods to measure the effectiveness of our communication efforts so every choice we make is purposeful and successful. Analytics tools like Cyfe, Google Analytics, Hootsuite Social Media Analytics, Google Scholar, and Qualtrics allow us to record and track audience engagement and feedback. We utilize key performance indicators (KPIs) to assess what metrics we should use to gain an understanding of how our goals are being met.

CROWDFUNDING
From September 30 to November 14, 2017, the FutureHAUS team launched a campaign on JUMP, Virginia Tech’s crowdfunding platform, to increase support and donations for our project. Curated stories that personified the FutureHAUS brand encouraged donors to take action. We demonstrated how the team has remained resilient in the face of adversity and was able to rise from the ashes—literally and figuratively—and rebuild after the fire. We then moved into the personal stories of the students who are involved in the project and showcased areas that they created within the FutureHAUS. The hashtag #powerthisVTHAUS amplified the conversation and reach of the campaign and created a call to action for our supporters to help rebuild the house. The campaign exceeded its goal by 110% before the end date.
12 DAYS OF FUTUREHAUS CAMPAIGN

The main goal of our “12 Days of FutureHAUS” campaign was to use the holiday season as a means of engaging with our audience and showing the human aspect of the project. We highlighted select students and faculty members and shared their favorite holiday memories and traditions, which allowed us to humanize the FutureHAUS brand and give our audience a more personal look at our team. We included narrative captions that boosted levels of engagements on our social channels.

DIGITAL NATIVES

To demonstrate how FutureHAUS will help inspire and support generations to come, the FutureHAUS multimedia team created a four-part video series, “Digital Natives,” where children were asked to imagine what their future homes will look like. Their answers included many features that FutureHAUS is implementing, which reflects the team’s commitment to creating a shared vision of the future.

LIGHTS ON AT THE LUMENHAUS

On the last day of the crowdfunding campaign in Fall 2017, the team hosted a public event called “Lights on at the LumenHAUS” to celebrate the upcoming competition and provide educational tours of our winning Solar Decathlon house from 2010 and a sneak peak of the current project plans to the general public. The FutureHAUS multimedia team handled all aspects of the event, from advertising to catering. The event was an overwhelming success and it effectively made the project accessible and exciting for students and the general public.

FUTUREHAUS DUBAI OPEN HAUS

The FutureHAUS Open HAUS on August 30, 2018 allowed the Virginia Tech community and corporate sponsors to exclusively visit and experience the house before it left for Dubai. The event was planned and hosted by the Virginia Tech College of Architecture and Urban Studies and our marketing team strategically planned posts to boost engagement and attendance to the event. Our strategy for the posts included sharing the Facebook event page every other day of the week and directing traffic toward the location and details of the event. Overall, the event was incredibly successful, with an attendance rate of 400 people. We also saw an increase of 22,159 impressions on our Facebook and gained a significant amount of followers on all channels.

SPONSOR HIGHLIGHTS, COUNTDOWN GRAPHICS, AND FUTUREHAUS FUN FACTS

Throughout the process of designing and constructing the house, we highlighted the specific sponsors that provided us with supplies and essentials used in the house, provided our audience with a countdown to the competition so they can be on this journey with us, and shared “FutureHAUS fun facts” to educate the public on unique aspects of our project. The content we chose for social media is curated to represent our brand voice and is thoughtfully planned based on the strong engagement we have seen on prior posts and through research.
Virginia Tech Hokie Pride

As the only team representing Virginia Tech in the competition, we wanted to demonstrate our school spirit and engage with the university. To do this, we tapped into one of Virginia Tech’s beloved traditions: football. Our marketing team created graphics and photos supporting our football team on the FutureHAUS social media channels. These posts reiterated how FutureHAUS is proud to be a part of the Hokie Nation and is honored to represent the university in Dubai.

VR/AR

We implemented cutting-edge VR/AR with the Hololens and Oculus Rift. A 3D model of the house built in Unreal Engine allows the public to visualize the house beyond just FutureHAUS Dubai. The user can use gesture controls to walk through and interact with the house and then select individual cartridges and configure them to their needs. The user can change colors and finishes as well as build floor plans and understand furniture arrangements. This allows the FutureHAUS method to be scaled from affordable to luxury. This replaces the standard showroom and design method that we are accustomed to and greatly expedites the process. It also empowers the user to design their home and walk through a hyper-realistic model before purchasing.

Home Interface

Going beyond our marketing events and strategies, we developed a home interface with graphic design and computer science students. The interface eliminates the need for separate and confusing home remote controllers and screens, making the technology accessible to all. The user can also control security, lighting and appliances with pre-programmed setting. Additionally, the interface showcases energy production and consumption so that the user is able to understand their use and respond to it. Biometric data including weight, temperature and sleep patterns is displayed in the interface, connecting the home to the health of the user. The simple design with clear text and bright gradient graphics makes the home easy to understand and control. The interface is accessible via nine touchscreen tablets positioned in the home as well as a mobile app for 24/7 access.

Website

The home of the future requires the website of the future. A website designed specifically for mobile use allows the public to access the story behind the house at their fingertip. The website focuses on the research, the history, the cartridges and team behind the house. It also features all social media posts and articles in one place. We will use the website to update the public throughout the journey of the house and to drive home our narrative and educate the public on solar energy and the future of housing.
BUILDING INTEGRATED PHOTOVOLTAICS
SHADE CANOPY

The shade canopy design is the FutureHAUS’ most significant energy efficiency feature and is deeply rooted in the concept of building integrated Photovoltaics. The concept is to integrate a 15kW Photovoltaic array (50 – 60 cell monocrystalline silicone panels - LG 360-Q1C-A5) into the whole-house shading canopy. Similar to a canopy of a shade tree, leave both provide shade and photosynthesize. In this case, the roof system with integrated PV technology shades the house from the intense direct Dubai sun, eliminating the direct solar gain, and also harvesting energy for all of the FutureHAUS systems.

The shade canopy is composed of five prefabricated structural assemblies that each contain a 3kW photovoltaic array. The photovoltaic panels are factory installed on each of the modular structural frame, with each assembly lifted by crane onto the house structure and operationalized utilizing our simple, plug-and-play, approach. The modular assemblies were specifically designed to fit the FutureHAUS cartridge concept of prefabricated, factory built housing elements. Each of the frames measure 18” x 7’-6” x 28’, allowing transport from the factory by nesting side by side on a standard flatbed trailer. All dimensions are chosen so as not to exceed the maximum legal road transport width or height limit.

Once the five solar trays are installed over the entire house, an additional 18 prefabricated shade canopies are attached to the outer structural rim so as to extend the shade protection beyond the roof dimension and also shade the exterior walls.

The 12” separation between the solar canopy and the roof of the house allows passive natural ventilation for the evacuation of hot air under the Photovoltaic panels. This space also allows for access to the array for any servicing needs. The depth of the frames does allow for the possibility to actuate the mini arrays for solar tracking which would further economize the PV system by reducing array size and fit with the house narrative of responsive architecture.

The South Garden featuring the shade wall, rain screen, solar canopy and deck that doubles living space.
In contrast to conventional BIPV systems such as field applied solar shingles or amorphous membrane systems, which can involve much on site installation complexity, high long term maintenance costs, or limited efficiency, our prefabricated monocrystalline array not only simplifies installation but also greatly improves building performance with its shading and ventilation assets.

Different from a site installed rail installation, the Photovoltaics are installed as part of an architectural element of the home. Seamlessly integrated into the architecture of the home.
A second BIPV element is found incorporated into our entryway window since this is our only fixed window. This 48” x 48” insulated glass unit incorporates Pilkington’s Sun-Plus technology and provides 104 Wp with a g-.54 value. The monocrystalline technology is 8.8% efficient and is mounted on the #2 surface of a 1.25” IGU. For the purposes of the competition, which limit powering systems directly from DC and with inverter, limitations, the system will not be integrated in the power system, however, post competition it will be activated.

This synergistic methodology of the FutureHAUS demonstrates that BIPV elements can contribute both technologically and aesthetically to an architecturally whole solution.
INTERIOR CONCEPT
AND DESIGN
The design of the interior space of FutureHAUS Dubai is a direct complement to the house’s architectural strategies and beliefs. The interior is responsive to the user’s needs, reinforcing the connotation of creating a home that makes living not only easier, but contributes to well-being. As the cartridge system is in place, interior spaces become flexible spaces, allowing a user to control room size, mood, and function. The interior responds to current and future needs of the occupant, and addresses the rapid change of the built environment in the next fifty years.

OCCUPANT EXPERIENCE
As an occupant living in the space, the interior becomes a living organism that uses artificial intelligence to learn and adapt to personal preferences of each user. This allows the house to cater to different age demographics and people of different cultural backgrounds. Touch screens and multi-modal points of interaction allow the user to constantly communicate with the house.

FLEX SPACE
With FutureHAUS’ compact design, the house lends itself to creating flexible spaces. Flexible space becomes possible as rooms have the ability to reconfigure. Rooms have the capability of enlarging or shrinking based on the user’s required programmatic needs. The AV wall partition, shared by the living room and home office, can be shifted into the home office back wall to enlarge the living space during the day to cater to visiting guests. As the home office space can also expand by shifting the AV wall partition into the living space to provide ample working space.

The lines are blurred between exterior and interior living with a large deck garden space that surrounds the house on all sides and is enclosed by perforated metal panels. The exterior glass partitions of the living space act as windows to penetrate natural light into the space without overheating the interior, while also acting as moving wall partitions to extend the area of the space by using the outdoor deck as a living space continuation. The bedroom and walk-in closet become

The Bathroom of the Future featuring a 3D-printed sink, Orbital Shower, and glass floor with slip-fall detection.
interchangeable as the user can enlarge the bedroom/closet by shifting the shared wall into the living space, and can stow the bed to create more open space in the room. The transitions between rooms and spaces are effortless as different rooms share the same wall panels and same flooring, allowing rooms to blend into one another or serve multiple functions when the program requires it.

**UNIVERSAL DESIGN**

FutureHAUS Dubai believes design is for everyone, which is why universal design features have been implemented throughout the house. Catering to different user groups of all ages and capabilities allows this house to outlive its competitors since it will address a user’s current and future needs to come.

The house’s master bathroom uses universal design to provide maximum safety and protection in a space that has high risks. The 3D printed sink rests on the actuated vanity to raise for clear knee space below allowing a wheelchair user to roll up to the sink, and lower to allow young users to reach the sink. The faucets are sensor detecting allowing a user to turn the water on and off without having to physically operate a mechanism. The smart toilet fixture will be able to elevate to different heights as the fixture is mounted on an actuator that will allow the fixture to adhere to younger users as well as adult users. The toilet area will also have adjacent mounted grab bars to accommodate users with different mobility needs. The walk-in shower provides the user with hands-free fixtures as well as height-adjustable hand held fixtures to address users with different mobility needs. The transition between the shower and bathroom floor is seamless as a wheelchair user can easily enter the shower room without encountering any obstacles. The shower floor tapers to a drain allowing the water to remain contained without having multiple floor transitions. The overall glass flooring material is etched to be slip resistant and contains sensors that will detect user slippage or falls while automatically contacting emergency services. The lighting strategy incorporates amber lighting beneath all bathroom fixtures allowing a user to navigate at night without affecting his or her sleep cycle.

**AGING IN PLACE**

As homes begin to excel in user comfort, FutureHAUS Dubai strives to provide the same level of comfort to users of all ages and abilities. Features within the house have been modified to accommodate aging in place as rooms have become user-friendly and easier to control. The prefabricated cartridge construction method allows for the home to be expanded and downsized as the users age.

All entry ways within the house are barrier free allowing
users with different mobility needs easy access while eliminating threshold obstacles and tripping hazards. Both bathrooms in the house carry smart toilet fixtures, sinks with clear knee space, grab bars, and amber lighting beneath all fixtures.

The master bathroom is also fully equipped with fixtures adhering to universal design features, and provides a five foot turn radius as well as a walk-in shower room and tub. The master bedroom/walk-in closet are interchangeable as a user can easily move from a wheelchair into the bed with ease. All light fixtures are LED dimmable lights that can be controlled to follow a user’s circadian rhythm, while consuming lower levels of energy and taking advantage of natural light with daylight sensors in place.

The kitchen, like other rooms within the house, can also be controlled based on a user’s preference. The kitchen sink is hands-free allowing a user to turn the water on and off without handling a control mechanism. The storage drawers stowed beneath the sink can be pulled out to allow clear knee space for a wheelchair user. The top shelf of cabinets is placed on an automated tracking system that enables the shelves to come down to the lower shelving unit allowing users with limited mobility access to the cabinets. The dishwasher installed in the lower cabinet shelving is a drawer-type appliance allowing easier access to the washed items. The kitchen island features an induction cooktop with safe cooking technologies, as well as a touch screen interface that will allow the user to control kitchen features and access the web. A pull out table is stored within the kitchen island, that can be pulled out to use as a dining table or as an additional kitchen work surface.

Landscaped grounds around the house are accessible giving users the ability to maintain the gardens if needed, and visually enjoy the grounds when the weather is suitable.

MATERIAL PALETTE
The interior space focuses on creating a soothing atmosphere with predominant washes of bright white and light greys in response to the hot climate. These light colors will allow light to bounce off surfaces enhancing the presence of natural light in the house while maintaining a cooler interior space. The light palette also serves to visually increase the size of the living spaces as the open plan will allow more opportunities for natural light to enter the space.

White back painted glass surfaces allow sensors to be installed in order to detect user movement while adjusting room settings based on the user occupying the space. Rift cut white oak wood finishes serve to
warm up the interior, balancing the cooler tones of white and grey within the interior spaces. The oak wood finishing will allow the cabinets to be visually lightweight and provide contrast to other materials. All soft furnishings within the space are colored in order to liven the interior while representing the FutureHAUS branding and proposing the ability of the space to carry different color palettes once handed to different users. Sofas, bedding, pillows, throws, and rugs are called out in different shades of charcoal.

FURNITURE SELECTION
The furniture pieces selected for the house exhibit the house’s overall design intent, the ability to reconfigure, providing maximum flexibility and comfort. Renowned designer pieces were selected based on their product longevity, ergonomic design, comfort, sustainable production process, lightweight technology, and ability to stack or move with ease.

The FutureHAUS team selected furniture products that could grow with the house, maintain their original form and function over the years, and withstand the harsh climate conditions. Furniture pieces selected for the kitchen space will act as the main dining chairs that have the ability to stack, allowing the chairs to be stowed when not in use, and are suitable for outdoor use, allowing the users to easily shift the dining table outdoors without having to worry about the chairs being damaged. The living space furniture is lightweight, as this will allow the user to easily move pieces as per needed. Modular seat cushions are stowed into the living space credenza, allowing the user to create an additional seating bench out of the credenza when the extra space is needed.

LIGHTING
The FutureHAUS lighting scheme aims to provide sufficient interior lighting while also conserving energy along the process. The lighting strategy takes advantage of ceiling planes as opportunities to diffuse light. LED light panels float above each room within the house providing interior lighting that mimics daylight, while having the ability to control mood lighting, dimmable features, and activate daylight sensors. The lighting scheme promotes user health as the selected LED fixtures accommodate a user’s circadian rhythm. The lighting controls can be voice activated or controlled using the multiple interface screens located within the house. The
lighting scheme also plays into aging in place, as amber lights are placed beneath all bathroom fixtures, kitchen appliances, wall reveals, and under cabinets, in order to allow a user to easily navigate throughout the home during sleep hours.

**Cultural Context**

The powder room located directly adjacent to the main entrance addresses Dubai’s cultural context as the compact space is designed to accommodate the Muslim Wuḍū process. The Wuḍū process involves cleansing certain body parts, including: the hands, mouth, nose, face, arms, head, and feet, before prayer. The faucet at the sink will be a touchless hands-free faucet allowing the user performing Wuḍū easier manipulation of the water as it will turn the faucet on and off based on sensor detection. Along with water conservation, the sink provided in the powder room will have a separate drain mechanism placed underneath the basin that will detect a user’s foot and release a small fountain of water, allowing the user to easily cleanse his or her feet before ending Wuḍū. The separate fountain/drain will release just the right amount of water in order to cleanse the feet while ensuring the water returns directly into the drain. Both the sink and toilet fixture are mounted on motor-track wall systems that allow the fixtures to rise or lower based on the user’s preference. The smart toilet also has a built in bidet which addresses the Middle Eastern preference of using a wash wand. A separate seat will unfold above the toilet that will address users with limited mobility when performing the Wuḍū process.

The living room space demonstrates a modernized reinterpretation of the “Majlis”. The living room will have the ability to accommodate smaller groups of occupants with the provided furniture, but can also provide seating for a larger group of occupants, as the credenza attached to the AV wall partition will double as a linear bench with modular seat cushions stowed in the credenza cabinets. This will allow the user to change the room setting based on the number of people using the room.
1. Office and Living Room Flex Space with rotating AV Wall
2. Expanded office during day allows for conferencing
3. 3D Printed sink
4. The master bedroom compressed to dressing room.
INNOVATIVE SPECIAL AWARD REPORT
INNOVATIVE SPECIAL AWARD REPORT VIRGINIA TECH FUTUREHAUS DUBAI

The FutureHAUS Dubai is a prototype that explores the utilization of smart construction techniques and digital smart technologies and develops a universal model for the future of housing. The project demonstrates two scales of innovation; the architectural scale that proposes “a new way to build,” and a product development scale that proposes “a new way to live.”

A NEW WAY TO BUILD — THE “CARTRIDGE” CONCEPT

As the Internet of Things (IoT) technologies become more prevalent and as we experience higher demand for smarter, energy efficient, affordable housing, the building industry must look to better ways to integrate newer technology. With a projected population of 9.8 billion people in 2050 and a concentration of over half the population in cities, the need for smart, energy efficient and affordable housing is evident. FutureHAUS Dubai proposes a new approach to the construction of buildings that is faster, more sustainable, and allows for complex systems integration.

Conventional modular methods of construction are unsustainable. Whether big-box modular or panelized walls, the systems present problems in either shipping or in a lack of sophistication. FutureHAUS advances prefabricated modular construction to the future by subdividing a home into plug-and-play volumetric modules large enough to contain prewired cabinets, fixtures and technology, but small enough to still be delivered and assembled on site efficiently.

The FutureHAUS is made of a suite of twelve “cartridges”, prefabricated modular structures that are constructed separately and assembled on site. The cartridges: Entry, Kitchen, Bathroom, Office, AV wall, Closet, Dry and Wet Mechanical, Master Bedroom and Spine cartridge--are pre-wired, pre-plumbed and pre-finished. The assembly method is plug-and-play: each cartridge contains its own electrical sub-panel for simple onsite hook-up. The cartridges are designed to be produced in a factory, transported on a truck and placed with a forklift or crane. They are sized to be a maximum of 4’ wide and 10’ tall modular measure so they nest efficiently and legally on standard 8’ wide flatbed trailers. Once on site, the cartridges are unloaded from the truck and set on a foundation.

Composed of CNC-cut structural insulated panels (SIPs), the cartridge frames are dimensionally stable, highly insulated and structural. Once assembled, the cartridge structures serve as vessels for the home technologies. Because they are structural, the cartridges can be stacked allowing for multi-level capability. The frames are fireproofed on the interior and waterproofed on the exterior and once assembled ensure a very tight envelope system. While this system has many advantages for its unique cartridge strategy, the process brings with it the many additional advantages that prefabrication processes bring over conventional construction methods.

Benefits include:
• Efficient material use produces less waste.
• Opportunity for Mass-customization.
• Automation and CNC technology.
• An environment to optimize quality control.
• Accurate scheduling, timeline and pricing.
• Minimal site disruption and pollution.
• Controlled, safe environment for construction.
• Production can be expanded to 3 daily shifts.

The FutureHAUS is ideal for a wide range of building types including single-family homes and multi-family, medium, and high density housing. The cartridge concept provides an optimal system for addressing the future global housing shortages as urban population continues to grow.

The individual cartridges encapsulate the program and the technology of the individual rooms of the home. Once on site, they efficiently join together to support a rich house program. Below is a list of FutureHAUS Dubai cartridges and a brief description of their innovative features.
- The Spine Cartridge. The central nervous system of the home, this linear module sits atop the long hallway of the house connecting HVAC ductwork, communications and main panel to sub-panel electrical.
- The Dry Mechanical Cartridge. Main electrical panel, solar inverter, charge controllers, HVAC outdoor unit and air handler, energy-recovery ventilator, batteries and all building control components.
- The Wet Mechanical Cartridge. All wet systems including hot water tanks, plumbing manifolds, heat exchangers, solar thermal controls and laundry.
- The Kitchen Cartridge. All smart kitchen appliances and cabinets, integrated digital screens and interfaces and smart plumbing fixtures.
- The Bathroom Cartridges. The first cartridge contains the smart mirror, toilet, and vanity with a 3D-printed sink/countertop. The second cartridge contains the bathtub and shower with water conservation technology and CNC waterproof surfaces.
- The Living Room/Home Office. Integrated desks and dynamic audio visual wall
- The Bedroom Cartridge. Integrated automated Murphy bed for space saving
- Closet Cartridge. Integrated smart wardrobe management with flex space technology
- The Door Cartridges - Preinstalled automated sliding door systems with flex space technology
- Photovoltaic Cartridges. Carry 5 prefabricated photovoltaic arrays

Proofs of Concept
As a testament to the viability and merit of the FutureHAUS modular concept, our team has explored the use of cartridges to physically build several prototypes. We envision FutureHAUS Dubai to be the project to transfer the concept into mainstream production. Three of these proofs of concept include:

- **The Willow House** is a 2200 square foot house built in Charlottesville, Virginia and assembled with 12 prefabricated cartridges, SIP roofs, and floors. The cartridges were built by our research team in one month in a controlled environment, assembled into a house in one day with a crane, and completed the finishes 4 months later. The home sold at asking market price for profit and proved the viability of the concept for affordable, market rate projects. See this article: Builder Magazine

- **Kitchen Renovation**. A full size kitchen was renovated by the FutureHAUS team in one weekend using a prebuilt kitchen cartridge. 3D scans mapped the as-built window openings and plumbing/electrical locations and a custom cartridge was built off-site to perfectly fit the new site. The wall cartridge was divided into an upper and a lower section so the components could fit through the front door of the house. See this video: FutureHAUS Renovate

- **FEMA Disaster Relief Prototype** In a compact, prefabricated "core," our team pre-plumbed and pre-wired a full kitchen and bathroom with walls and floors that unfold to create the living space around them. The folded shippable unit is 8’ x 12’, but when unfolded onsite it becomes a 300 sf dwelling. This prototype demonstrates an ideal concept for delivering low cost, prefabricated, emergency housing. Each house can be fully assembled in less than 2 hours with 1 forklift and 2 installers. See this video for more info: Disaster Relief Home.

Recent excitement and communications blasts from this FutureHAUS Dubai project has caught the attention of two entrepreneurs who are considering this method of building and will be working with our team in the coming months to move this forward. The projects are described below:

- **Pharrell Williams** famous musician, actor and fashion designer, (with his financial backer, LOWE’S) wants to develop a 35-acre site in Virginia Beach, Virginia to provide affordable, but exciting new housing models for young homebuyers. This spring, our team will be working with the developers to design the cartridges and the manufacturers who are capable of building at this scale. Construction of a model prototype will begin this spring.
Dominion Energy, one of the largest energy providers of the United States, wants to team up with the FutureHAUS team to develop a micro-grid community in Southern Virginia using cartridge homes. Charrettes and financial models are currently being proposed by our team for the innovative project.

A NEW WAY TO LIVE - PRODUCT DEVELOPMENT & CORPORATE PARTNERSHIPS

Smart Fixtures KOHLER Corp.
The FutureHAUS Dubai team has been closely collaborating with the R+D teams at KOHLER, our primary financial and in-kind SDME sponsor, to explore the modification of their off the shelf products to fit IoT integration. This work includes adding electronic control to water valves to adjust both flow and temperature. The water dispensing from the kitchen faucets can now be controlled with multi-modal digital interfaces that integrate seamlessly with current smart home systems. Additional research with Kohler includes integrating height adjustability to the toilets and vanities for universal accessibility (in collaboration with the LINAK company) and the production of a 3D printed sink. This sink demonstrates the use of cutting edge, additive manufacturing processes to print utilizing multiple print-heads to build an all in one sink/vanity top that incorporates plumbing piping, water supply tubing, integrated sensing, and finished countertop surfaces.

Smart Envelope - DuPont-Dow, Pilkington Glass, Insolcorp
With the partnership of DuPont and Dow, the FutureHAUS team is prototyping the high-performance building envelope. The walls are composed of a glass rain-screen, vapor barriers, and structural insulated panels with PUR insulation. The highly insulated, sensor integrated wall provides real time performance data to the smart home. Pilkington’s (NSG) Spacia insulated glass units uses a vacuum in lieu of gas to obtain high insulation (R8 per panel) within 3/8” thickens. The HVAC-linked building control system has access to all of the automated door/window openings to guarantee optimal performance and comfort year round. Sensors also monitor the temperature of Insolcorp’s ceiling mounted phase change material (PCM). A separate HVAC zone activates the PCMs for the purposes of energy load shifting from peak to non-peak energy periods. In the spirit of mass-customization, the FutureHAUS team has been exploring material and technology options for the wall assembly so wall systems can be custom “tuned” for different climactic regions.

Smart Technology + Energy Management Osisoft and Outback
With a clear goal to achieve a net-positive energy balance in the FutureHAUS, an advanced power electronics system comprising state-of-the-art equipment is installed. It comprises five, 3kW solar arrays (14 kW peak). Each solar array features its own dedicated charge controller for increased reliability as well as for independent, per string, maximum power point tracking. The efficient and contemporary 8 kW power inverter interfaces photovoltaics and batteries (14kW) with the utility grid, and serves as a main generator of clean energy utterly minimizing, if not eliminating, utility grid dependence. In addition, FutureHAUS Dubai boasts an information infrastructure and an advanced, decision-making, energy management algorithm that goes beyond the traditional residential system control. For instance, if instantaneous harvested power from the PV is higher than what house loads demand at that instant in time, an algorithm sends the command to the inverter to sell the excess power back to the grid (net-positive mode). As this algorithm also has access to the weather forecast (short and long term), it will make a decision whether it is better to sell all excess energy or reroute some percentage to charge the battery (e.g. if the rain will start soon majority of that energy will go into the battery). If however power from the PV is lower than what house loads demand, an algorithm switches to the net-zero energy balance mode.

The Internet of Things (IoT) provides sensing, communication, computing, and actuation infrastructure for ubiquitous interactions and pervasive services. The result is an adaptive environment that responds to a range of real time needs or changing environmental conditions. For security purposes, the infrastructure is self-contained and does not need access to the outside network (cloud) to function.
**Flex Space & DC Powered Walls - Thompson Linear and KB Homes**

The concept of “flex-space” is demonstrated in the primary space of FutureHAUS where two automated wall modules can be mechanically repositioned to adjust the three program spaces, a home office, a living room and a bedroom. Each room can be expanded on demand depending on need. The purpose of this feature is to allow for maximum usage of a smaller footprint resulting in lower energy costs and efficient use of valuable real estate. The flex-space walls are powered by DC through the conductive rail seamlessly integrated into the house central spine. Not only that it is more energy efficient, this innovative concept also significantly simplifies the power distribution infrastructure, which is particularly challenging when supplying the moving structures using conservative means of power delivery. The rotating AV wall allows the user to share the AV technology between the living room or home office modes reinforcing the concept of flex space and sharing equipment. In the living room, furnishings are incorporated with the walls to allow ease of room conversion. The bedroom incorporates a mechanically stow-able “murphy” style bed which, when stowed, converts to a smart mirror with an autonomous RFID wardrobe database. When deployed, the user has access to the cutting edge Sleep Number 360 smart bed with integrated head and foot adjustability and multiple smart technologies that tracks sleep patterns, human biorhythms and snoring detection. The moving bedroom partition doubles as a closet and provides significant wardrobe storage for the room (or walk in closet when contracted.)

**Adjustable Systems; Linak Accuride Wood-Mode**

FutureHAUS Dubai has developed new ways to interact with your environment that allow for universal accessibility for all users and adjustability of home components as the user ages in place. Multi-modal interfaces are seamlessly integrated into the home and allow for interactions with appliances and fixtures as well as adjustability in the height of the toilets and cabinets to fit each user or task. This individual adjustability allows for the home to accommodate a multitude of user’s and simultaneously respond to a range of preferences for a dynamic living experience. Linak linear actuators and Accuride sliding hardware are composed into “dynamic lifting column” modular wall assemblies that flank cabinets and integrate IoT controls. Similar assemblies can raise and lower toilets as well. The team has several provisional patent applications on inventions related to this technology in the house. (see patent applications below). Our team has been working with our sponsor, WOODMODE (largest custom cabinetmaker in the US) to develop this tech into market-ready products.

**Smart Wall Surfaces; Corning Glass / Snap Partnership**

To fit the model of prefabrication for smart systems, all of the modular, FutureHAUS wall and ceiling panels are prefabricated/prefinished and removable. This capability allows for integration of the technologies within wall panels and within cavities of walls and chases. Select panels also incorporate smart touchscreen digital interfaces behind thin gorilla glass surfaces. These “plug-and-play” panels incorporate touch screen technology for whole house interfaces, sound transducers for integrated sound systems and can be back-painted or printed for interior finish options.

**Water Conservation; Orbital Systems and Critical Flow Partnership**

The shower employs the Orbital System, a water recycling technology that measures real-time water quality with an opacity sensor and recycles clean water back into the shower loop after additional UV and chemical filtration, reducing water consumption by 90% and energy consumption by 80%. Our computer science and power electronics team has integrated the software of this technology with our building monitoring and control software giving us better usability of the technology.

Working with Critical Flow LLC. (one of the original developers of “Living Machine”), our team is utilizing an innovative “closed loop,” compact subsurface wetlands filtration system that passes waste laundry water through an aerobic/anaerobic filtration process and a UV and filtration system for ultimate reuse as laundry water supply. Of the 500 gallons of water we are expected to use during the two-week long competition, we anticipate recycling 475 of those gallons.
Virtual And Mixed Reality (VR/MR) Spine 3d
Interactive virtual and mixed reality models enable the use of newest VR/MR technology. The model allows the user to interact with rooms of the home and interchange different materials, colors, appliances or furnishings in the model. These models are proposed as “virtual showrooms” ideal as real-time marketing and pricing tools. This functionality directly translates to the production process, allowing the user to have feedback on design changes and the fabrication schedule. Spine 3D is a top VR/MR developer in the US and a close research partner with the Virginia Tech team.

INTELLECTUAL PROPERTIES; PROVISIONAL PATENT APPLICATIONS:

• **Provisional Patent Application #1. Universal Automated - Murphy Bed Frame;** Save space by converting any size or weight bed into a murphy bed using motor assist. This dynamic frame can convert any full size bed and frame (smart beds included) into a “murphy” style bed. Unlike a traditional murphy bed which relies on springs and counterweights, this mechanism uses powered actuators to raise and lower the pivoting brackets. A bed can be lowered to the horizontal position when a bed is needed in the room or raised and stowed against a wall to free up space within the room. The frame width can be sized to fit many sizes and brands of mattresses and bases. The pair of actuators push on a lever to rotate the cantilevered frame around a pivot point. The two structural cantilevers are steel or aluminum brackets that are screwed or bolted to the bed frame. Actuators can be controlled with electronic switches or with hands free multimodal methods including voice or gesture control.

*Possible market: Sleep Number 360 or TempurPedic, Hafele, Resource Furniture etc.*

• **Provisional Patent Application #2.** a pair of wall partitions that integrate guide rails and lifting columns (actuators) that flank a base or wall cabinet allowing for fine tune height adjustment of those components. This concept is ideal for a kitchen or bathroom application to allow for users of differing heights (or ADA accessibility constraints) to comfortably access countertops, cupboards, and vanities. Each of the two wall frames consists of a single or double vertical guide rail (for alignment) and a motorized actuator (for height adjustment). The lifting capacity of the actuators can be sized accordingly to carry a wide range of base, wall and vanity cabinets. A pair of dynamic columns can be integrated into the structural framing of a wall, floor or ceiling and can be installed in both new construction or retrofits. The actuators are controlled with either electronic switches or with hands-free multimodal methods including voice or gesture control. *Possible market: IKEA, BLUM, Accuride, Stanley Hardware, Garage Door Opening companies.*

• **Provisional Patent Application #3. Toilet Pedestal;** This floor mounted (recessed) toilet Base allows for height adjustment of toilets for purposes of ADA accessibility, elderly assistance, or child potty training. The toilet is mounted to this actuated base that sits within the floor structure. The base can be raised and lowered using one or two platform actuators between two support surfaces. Toilet drainage uses a sealed slip drain gasket to guarantee safe black-water septic drainage. Actuators can be controlled with electronic switches or with hands free multimodal methods including voice or gesture control. *Possible market: Major toilet manufacturers, Kohler, TOTO, American Standard.*

• **Provisional Patent Application #4. Electronic Door Portal;** This self-contained modular wall assembly incorporates a doorway opening with integrated automated sliding doors. This interior or exterior wall assembly contains pocket, motorized, sliding door systems. Meant for new construction or retrofit, the assembly provides all motors, sliding hardware, controls, thresholds and weatherproofing to make a weatherproof and secure doorway portal for a house or room. Walls can contain multiple automated door layers to provide privacy, view and screens for cross ventilation. The prewired, “plug and play” doorway portal is an ideal accessory for smart homes systems. Actuators can be controlled with electronic switches or with hands free multimodal methods including voice or gesture control. Potential Market: IKEA, Stanley, Oldcastle, Marvin, KolbeKolbe, Dorma, Assa Abloy

• **Provisional Patent Application #5. Smart Wall Panel;** This back painted or back-printed “plug and play” glass wall panel incorporates a range of electronic components such as touch screen interfaces, sensors, and transducers for sound (music or intercom). Equipped with a Raspberry Pi (or small computer) and a touch capable LCD screen, this detachable interface or console can be integrated into the walls of a home, office, hotel, dorm, or hospital room to give the user access to all controllable
smart building components. The wall integrated assembly consists of touch capable thin glass (i.e. Corning’s gorilla glass or Willow Glass), touch sensor technology, and LCD display. The glass is laminated to a backer frame for mounting (mdf, plywood or composite) which allows for wall integration. The glass can be rear illuminated for lighting or contain a transducer which converts the surface to a speaker system. Panels can be decorative as well by back printing patterns or imagery onto the glass surface before laminating. Panels can be mounted with hardware to allow for detachment from walls for servicing purposes. *Potential Market: KB Homes, Toll Brothers, Amazon, Schools, Hotels, IKEA, Hospitals, Workplace conference rooms, Security systems, Wayfinding, Sound companies (Bose, Harmon Kardon group), Dynamic Wall Art, Dynamic Illumination.

• **Provisional Patent Application #6. Drone Hatch:** As drone package delivery (i.e. by carriers like UPS and FedEx) becomes more and more viable in the near future, solutions are needed to receive packages delivered from the sky. This invention combines a roof hatch, motorized actuator, rooftop motion sensor and lockable cabinet to make an automated, weather-tight, mailbox for secure drone deliveries. When a drone hovers over the hatch, the access sensor can activate an actuator that opens a roof hatch for safe, secure package delivery. A lockable closet inside keeps the home secure from outside intrusion (essentially a double door mailbox system) *Potential market: Door manufacturers, home builders, Smart Home Equipment suppliers

• **Provisional Patent Application #7. Wall Integrated Lifting Columns:** This system allows for a vanity, cabinet or desk to be cantilevered off of a wall by a wall concealed lifting column. This pair of lifting columns attach to vertical structural wall studs within a partition wall. The columns contain an actuator for movement, a vertical glide track for alignment, and a cantilevered bracket that supports the moveable wall cabinet. The system allows for motorized height adjustability of base and upper cabinets to satisfy ADA accessibility requirements or to accommodate people of varying heights. Actuators can be controlled with electronic switches or with hands free multimodal methods including voice or gesture control. *Possible market: Cabinet Makers, Hardware Manufacturers

• **Provisional Patent Application #8. Digital Backsplash:** An interactive digital backsplash behind a kitchen countertop for kitchen interactions, controls and backgrounds. Like an appliance, this console is plug and play and comes with a glass backsplash, a touch film, and three high definition TVs. The frame is 22” tall but can range in width depending on the countertop width. Ideally, as a product widths are sized in increments of 3” to fit with the kitchen base cabinet module. The two-part frame can be hinged down onto the kitchen countertop for servicing the back sides of the monitors and access power and electronics. The digital screen assembly can be used as a smart home interface to control appliances, countertop heights, and with an integrated camera can work to telecommunicate with two-way video and sound interaction. *Possible market: Best Buy, Panasonic, Samsung, etc.

• **Provisional Patent Application #9. Digital Tabletop & Island top:** The “Social Table” A modular tabletop that integrates touch screen technology into a functional kitchen work surface. The tabletop consists of an hd tv, a ¼” piece of clear tempered glass, back painted to mask out a window for the monitor, and glass applied touch film technology. The glass perimeter is mounted to an aluminum frame. The console can be added to any island or table top to make any surface smart. *Possible market: Best Buy, Samsung, etc.

• **Provisional Patent Application #10. Foot Washing Station** Foot washing is integral to the Muslim pre-prayer ritual. Up to this point, this has been accomplished with an additional spray nozzle attached to the wall, spreading water throughout the restroom and creating slipping hazards. The solution is to integrate the foot washing station within the floor surface. The invention incorporates a water pump located within the floor that dispenses clean water in a fountain-like manner to clean the user’s feet. The waste water flows through the perforations in the floor to a collection drain below the surface. *Possible market: Appliance Companies like KOHLER, American Standard