THE NEXUSHAUS: GET CONNECTED IN CENTRAL AUSTIN

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INTRODUCTION

The NexusHaus is the entry for the U.S. Department of Energy Solar Decathlon 2015 competition of the cross-cultural team The University of Texas at Austin (UT) and Technische Universität München (TUM). It demonstrates a, solar-powered and zero-water capable home designed for Central Texas. Its innovations serve as catalysts for change, leading the residential housing industry toward more sustainable practices. NexusHaus offers homeowners the chance to directly participate in the energy economy, moving from energy consumers to becoming energy producers. This potential source of rental income can be used to defray increasing property taxes. The energy and water concepts in NexusHaus make the house more marketable for property owners to a growing group of ideologically motivated people, who want to have a low-impact lifestyle. The target resident is also less interested in the total square footage of the unit but places a premium on location in a city where access to recreation and downtown is increasingly important. NexusHaus was recently voted "Best What's Next in Austin Architecture" in this year's The Austin Chronicle Best of Austin.

KEYWORDS

affordable housing, energy-water nexus, modular design, urban home of production

AUSTIN: GREEN AND GROWING

The City of Austin was awarded a national Climate Leadership Award from the Environmental Protection Agency, and is the first city to receive an Organizational Leadership award for its response to climate change. As part of its Climate Protection Plan, Austin has set the following goals: (I) being carbon neutral by 2050; (II) 30% of all energy needs will come from renewable sources by 2020 including at least 100 MW of solar power; (III) all new single-family homes will be net-zero energy capable starting in 2015. Austin Energy as the municipally owned electric utility offers rebates on residential solar electric and solar thermal systems to meet these ambitious goals.

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FIGURE 1: The two modules of the Nexushaus with expanding interior spaces into fully shaded outdoor decks, the aquaponics system and the thermal storage rainwater tank. (Credit: Thomas Kelsey, U.S. Department of Energy)

The population of Texas is projected to double over the next 50 years. Austin has been growing more than any other city in the U.S. with 110 people moving to Austin and 70 cars added daily to its roads. This causes both stress on the urban residential market especially for affordable housing and on the municipal water supply. According to the Texas Water Development Board, the available water supply in Texas might decline by 10% by 2060 due to the population growth coupled with the multi-year drought.

NEXUSHAUS: URBAN HOME OF PRODUCTION

Our approach to reduce the stress placed on Austin's housing market and road infrastructure is to increase the urban density by adding Accessory Dwelling Units (ADU). According to the local zoning alley flats, granny flats or secondary dwellings can be placed along existing alleys. The Center for Sustainable Design at UT Austin in collaboration with the Austin Community Design and Development Center ACDDC identified more than 42,000 single-family residential lots throughout Central Austin that would fit to add ADUs. Many of these lots are located along existing public transportation ways and would allow residents to utilize public transit, helping to alleviate traffic and preserve quality of life for the nearly two million Austinites.

NexusHaus addresses the challenge of sustainable urban development in the context of energy and water resource constraints. The key factors driving the concept of the house are the following: urban infill strategy via ADU development, affordable green building design, energy-water nexus, space extension and smart technology. As a unit of production it can easily extend the existing neighborhood's infrastructure without increasing demand for energy and water. NexusHaus is able to offset the costs of its own utilization by harnessing natural and other available resources that would otherwise be considered as waste and a burden on the infrastructure. Furthermore, the impact on the environment and on the regional power generation, as well as water supply and water treatment is being reduced.

DESIGN: MODULAR AND FLEXIBLE

The NexusHaus is intended to become a prototype for a next generation modular home that could be reproduced en masse in Austin to provide an urban infill strategy with multiple environmental benefits that address the shortage of affordable housing. Until November 2015, the zoning requirements for secondary lots in Austin limit the maximum dwelling footprint to 850 square feet. To provide this modest dwelling with a spacious feeling, the design employs various spatial concepts: The indoor spaces are bright with an open indoor-outdoor connection. The "outdoor rooms" of the house are designed as much as the indoor ones, made suitable with shade in the subtropical climate of the Sunbelt region. Movement and views are extended along and across the modules through carefully positioned openings in the facade, connecting the interior with the exterior and providing generous amounts of daylighting to enhance the sense of spaciousness.

The building configuration consists of two 392 square foot rectangular structures. (FIG. 2) The day module that contains living, (FIG. 3) dining and a kitchen (FIG. 4) comprises one open space allowing views to the outside and bringing daylight from full height windows and manually operated sliding wood doors. The bedroom module defines two private areas, a master bedroom (FIG. 5) and studio divided by a common bath. (FIG. 6) A thickened wall on the outer west and east facade of the two module serves as a buffer zone. The interior spaces can spill out onto fully shaded generous outdoor decks, three large nine foot wide folding glass doors open up to connect indoor and outdoor living. These outdoor spaces are emblematic of the Austin experience, a sociable one that takes full advantage of temperate weather in the fall, winter, and spring. (FIG. 7) The two modules are separated by a central space that is intended to be enclosed in the winter time increasing the compactness of the entire structure, and capable of transforming itself into a 'dog-trot-porch' configuration seasonally. This breezeway is typical in vernacular Texas architecture.

The NexusHaus design positively affects the energy performance of the house. Traditional passive approaches such as natural ventilation also enhance the occupants' connection to the outdoors. During times of the year when ambient conditions allow, the unit will facilitate passive ways of ventilation and cooling. Because spring and autumn breezes in Austin are most active in the morning and late afternoon, cross ventilation is used during these periods for immediate cooling. The thin width of each module allows not just for effective cross ventilation but also daylighting throughout the interior and ease of highway transportation. Light is an important factor for comfort in the relatively small spaces of the NexusHaus. The goal is to best support the occupants' visual tasks, occupancy, and security via the integration of daylight in combination with artificial lighting use controls. The NexusHaus provides the best balance between illuminance levels, views, creating a sense of space, and solar heat gains via fenestration. All light sources are highly efficient while providing task-appropriate color rendering and color temperature for best light quality. The building orientation and fenestration is designed to take best advantage of the southern exposure during the winter, and to reduce the over-bearing intensity of the sun in the afternoon hours during the hot summer months. Layered onto and around the modules are a series of rain screens, canopies and arrays that either passively filter the sun's rays before they strike the building's skin, or actively harvest their solar energy to power the systems and appliances within the home, or to harvest rainwater and support an edible permaculture landscape. These layers also extend the threshold of the house into the landscape, providing a screen for the flow of indoor/outdoor living.

FIGURE 2: Floor plan of the NexusHaus with the two rectangular day and night modules, the shaded deck for extensive outdoor experience and the rainwater thermal tank. (Credit: UT/TUM NexusHaus team 2015)

FIGURE 3: Living area in the day module with fully height doors to allow maximum interaction with the deck area. (Credit: Thomas Kelsey, U.S. Department of Energy)

The deck is fully shaded with four canopy modules with a low light-transmittance membrane to provide shading for the full height windows and doors.

The day and night modules can be placed in a number of different configurations depending on the site and the needs of the client. The key for the success of integration into the single-family residential properties, which often vary in terms of the lot size, shape, and vegetation, is the flexibility that results from the modularity of the design. The team has identified over a hundred possible plan configurations.

FIGURE 4: Kitchen area with dining in the day module. (Credit: Thomas Kelsey, U.S. Department of Energy)

FIGURE 5: Master bedroom in the night module. (Credit: Thomas Kelsey, U.S. Department of Energy)

FIGURE 6: Shared bathroom in the night module between master bedroom and studio. (Credit: Thomas Kelsey, U.S. Department of Energy)

FIGURE 7: Outdoor living on the extensive shaded deck area of NexusHaus. (Credit: Thomas Kelsey, U.S. Department of Energy)

MATERIALS: HEALTHY AND GREEN

The design of the NexusHaus features extensive use of wood both as the structure for the house and as a finish material. Reclaimed lumber from a former barn is used for interior floors. Cedar is used for the rain screen to create visual continuity around the modules and the deck. Wood is naturally beautiful and adds character and warmth, but beyond aesthetic benefits, it offers exceptional value, especially compared with other high quality materials. (FIG. 8) Wood is a natural, renewable product with many positive characteristics, including low embodied energy and low carbon impact. Carbon is sequestered in trees and remains sequestered in the lumber throughout the life of the building. At the end of a building's life flow of wood products can be maintained indefinitely.

Evaluating the life-cycle of the house with an estimated time frame of 40 years was the basis for material and system selection. The analysis followed a cradle to grave approach, considering the environmental impacts from resource extraction through building use and operation to deconstruction and reuse/recycling. The NexusHaus as a whole was the functional unit with the site boundaries as system boundaries. Advanced Framing was proved as a successful and as the best option according to the environmental analysis compared to Standard Stick Framing and Cross Laminated Timber. For the rigid insulation, natural expanded cork outperformed the other alternatives XPS and PIR.

WATER: SAVING AND COLLECTING

Water conservation is mandatory in Central Texas that has been facing a drought for several years. NexusHaus collects rainwater for potable water, uses grey water for irrigation and provides highly water efficient appliances and fixtures. Buildings are responsible for 12% of the overall direct water consumption in the U.S and for 34% of the indirect one based on electricity demand. The team estimated that the overall water consumption of the NexusHaus would be approximately half as compared to an average household in the USA.

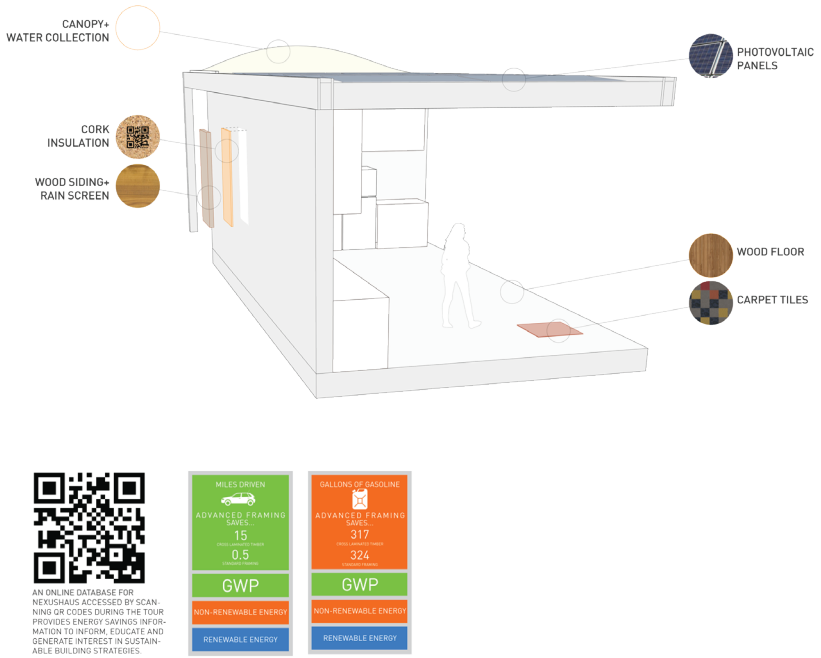

FIGURE 8: Material selection in NexusHaus. (Credit: UT/TUM NexusHaus team 2015)

The roofs of the two modules and the breezeway canopy collect rainwater to meet the majority of NexusHaus's potable water demand and additionally to reduce the load on the existing neighbourhood water and wastewater infrastructure. A city water re-fill line serves as back-up supply during long dry conditions. The on-site treatment system avoids the water losses along the municipal distribution system by approximately 10%.

After cleaned from large debris the first-flush diverter separates the initial rainfall from the rest of the rainwater collection system. The primary tank either stores rainwater for eventual potable water use in the house, or transfers it to the thermal storage tank, depending on need. To avoid contaminants accumulating in the primary tank, an additional filter is used to screen organic materials like leaves and bugs from the incoming water. The filtration and treatment system with a 5-micron paper and charcoal filter and ultraviolet light cleans the water to potable water standards. A pressure tank accumulates water to maintain the system pressure and keeps the rainwater pump from short cycling. Grey water collected from the bathroom sink, shower, and laundry is used to irrigate the landscape. It is periodically pumped from the grey water tank into a subsurface irrigation system. Waste water from the kitchen sink, dishwasher and toilets is collected and conveyed to a black water tank.

The rainwater thermal storage tank, which is highly visible, is either used for water thermal or back-up rainwater storage, as the name indicates. During the summer months when thermal storage operation is desired over additional rainwater capacity, it provides beneficial load shifting. In the non-summer months, it acts as additional capacity for the rainwater harvesting system. (FIG. 9)

THE NEXUS: WATER AND ENERGY

Buildings account for 40% of total primary energy and 75% of electricity produced in the U.S. In Texas with its hot and humid summers air conditioning is responsible for up to 40% of peak load on the electric grid. NexusHaus's goal is to be a unit of production and source of

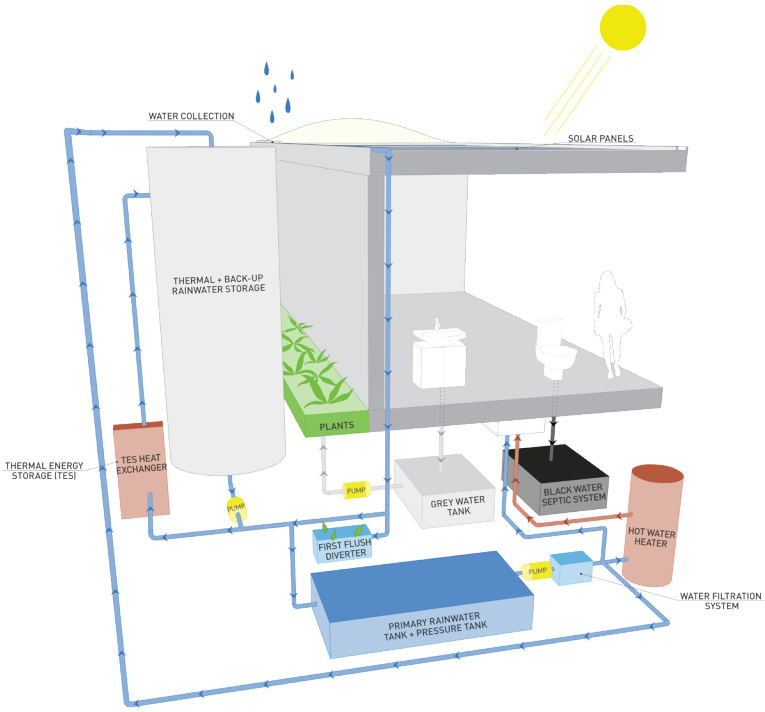

FIGURE 9: Water concept with thermal storage rainwater tank, grey water use for drip irrigation and potable water treatment system. (Credit: UT/TUM NexusHaus team 2015)

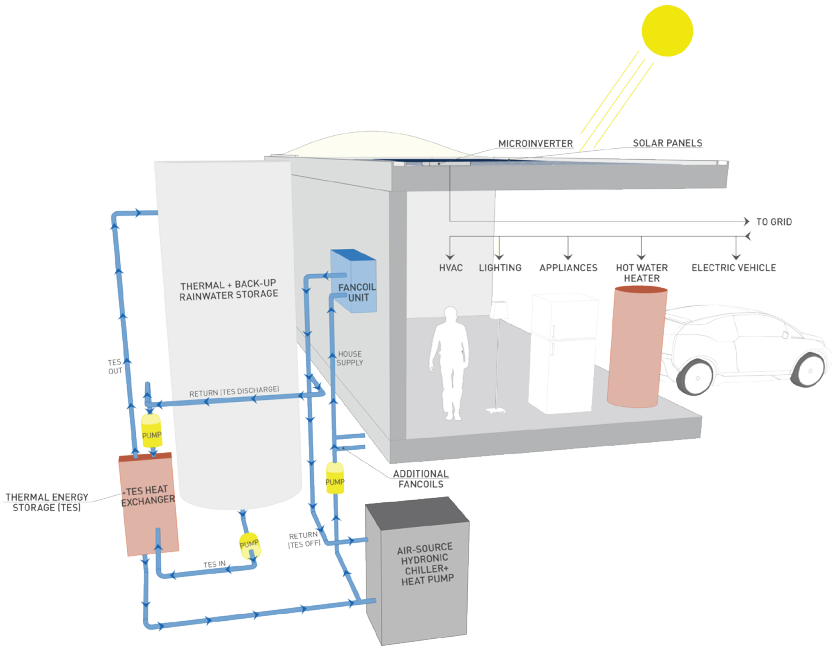

FIGURE 10: Water concept with thermal storage rainwater tank, grey water use for drip irrigation and potable water treatment system. (Credit: UT/TUM NexusHaus team 2015)

savings, reducing air conditioning load while providing as much excess energy as possible to support the neighborhood, especially during peak hours. This will benefit both the users and neighbors economically by linking energy usage to real-time need and avoiding higher pricing but also the utility companies by not having to provide additional power at peak hours.

The photovoltaic system is designed to maximize affordability. It is sized to meet the electrical needs of the house, rather than installing the largest system for the space available. Appliances, lighting and mechanical equipment are highly energy efficient. Micro-inverters minimize connection complexity and wiring costs.

The array is tilted 10 degree and can provide approximately 10 kWh with 8.1kW direct current (DC) or 7kW alternating current (AC). It is optimized between the tilt of the panels and the available panel spacing. Micro-inverters convert the DC generated by the solar cells to AC at the panel level. This allows each panel to operate independently and reduces the impacts of partially shaded or damaged panels or arrays. NexusHaus uses 28 SolarWorld® SunModule Mono 290W solar panels with great life-time performance and warranty, and Enphase®M250 micro-inverters.

An Integrated Thermal Energy and Rainwater Storage (ITHERST) system shifts air conditioning load off-peak to early morning hours. Cooling and heating for the NexusHaus is provided by an air-source reversible heat pump with hydronic distribution to ductless fan coil units. ITHERST was developed by Charles Upshaw, PhD, student at UT Austin, and Team Co-Captain of the UT/TUM students' team. NexusHaus is one of the first houses to demonstrate thermal storage technology on a residential rather than large commercial and industrial scale. (FIG. 10) The hydronic heating and cooling system uses an indirect chilled water thermal storage utilizing rainwater—a design not typical of a normal residential home.

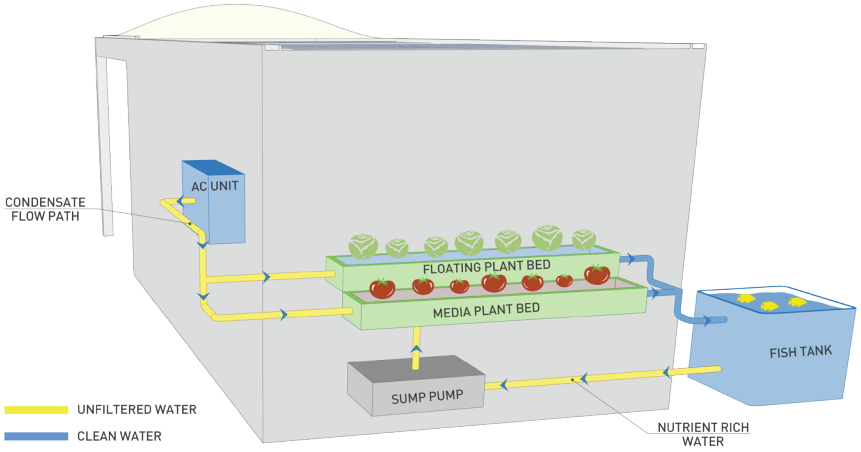

FIGURE 11: Aquaponics system for local food production with minimal water demand. (Credit: UT/TUM NexusHaus team 2015)

The highly insulated cylindrical tank serves both as auxiliary rainwater collection and thermal storage volume to utilize an otherwise un-utilized thermal mass. Compared to the same system without thermal storage, ITHERST can minimize the on-peak cooling-related electricity load to 20 to 25%. However, the electricity demand will increase by 5-10% during low-demand hours operating in Texas due to lowest prices.

Food is the example for the energy-water nexus. Energy is needed to produce and distribute food and water; water is needed to produce food. Agriculture is responsible for 70% of global water use, food for 30% of global energy demand. The more locally grown and seasonal the food we eat, the lower its energy and water footprint.

The NexusHaus employs an aquaponics system for on-site food production. (FIG. 11) As a combination of aquaculture and hydroponics this cohesive cyclical system provides an environment that produces edible plants that are denser and grow quicker than traditional farming methods and can use up to 90% less water. The ammonia rich effluent from the fish fertilizes the water, which is pumped to vegetable grow beds where bacteria convert the effluent into usable nutrients for the plants. The plants in turn absorb nutrients from the water, thereby purifying it, which flows back to the fish tank. Water is supplied to the tank from the

condensate from the fan coil units and the re-circulating nature of the s system. The condensate production could be a few gallons per day, which is not enough to water a large landscaping area, but to meet much of the re-fill needs for the aquaponics system. The system requires a circulation pump for sufficient aeration of the water, as well as daily monitoring to make sure the fish are alive and happy.

NEXSMART: MONITORING AND EDUCATING

NexusHaus enables affordable urban living. NexSmart encourages sustainable habits by informing and educating users about their energy and water consumption and the home's self-produced resources. This student-designed home monitoring and management system displays all information in an easy-to-use way.

The SenseBar is the primary way the users interact with the system. This touch panel is centrally integrated in a wall. A web-based application for a phone or tablet is available as well. The SenseBar is divided into three primary sections: (I) an integrated display for time, temperature, and other common status information; (II) an array of sensors to measure temperature, relative humidity, light levels, and other environmental variables; (III) a touchscreen interface for more detailed occupant interaction and information communication.

A Beagle Bone Black acts as microcontroller for all sensors, storing the collected data and performing the necessary operations. The eGauge meter measures both consumption and production of electricity.

The user can simply view the energy or water demand over time and compare it with weather conditions. Thereby an energy and water 'battery' shows the consumption of the allowed energy or water amount. Weather data from the on-site weather station informs the user if outside conditions allow passive strategies like natural ventilation to turn on so that mechanical systems may turn off. Analyzing forecast data enables users to pre-cool or pre-heat the NexusHaus before they arrive home.

SOLAR DECATHLON: COMPETING AND CHALLENGING

The U.S. Department of Energy Solar Decathlon is a biennial competition to promote the application of solar technologies in buildings. Student teams from across the world can apply to compete with 20 teams in the 10 days of competition and to showcase their project to the public. Each team earns points through 10 contests. The juried contests are Architecture, Market Appeal, Engineering and Communications. The measured ones are Comfort Zone with a temperature zone between 71°F to 76°F and a maximum relative humidity of 60%; appliances, home life; commuting by driving an electric car 25 miles a day; energy balance with consuming less than 175kWh while producing at least as much energy as consumed. In the 2015 U.S. Department of Energy Solar Decathlon, the NexusHaus team won first place in energy balance, second in affordability, third in engineering, fourth in communications, and fifth in market appeal. The team took fourth place overall.

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architecture leaders Kendall Claus and Michael Rahmatoullin, NexSmart leader Julia Park, landscape leader Alexandra Krippner as well as communications leaders Molly McNamara, Jessica Janzen, Kelsey Kaiser and Eneida Lila.

More information can be found here:

http://www.nexushaus.com
http://www.solardecathlon.gov
http://www.austinchronicle.com
http://www.twdb.texas.gov
http://austinenergy.com