ACSA | AIA Webinar – A New Norris House
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Learning Objectives:

…better integrate water resource systems (such as rainwater, greywater, and stormwater) into residential projects, and understand how they relate to Water Efficiency (WE) within LEED for Homes.

…better understand the limitations and benefits of off-site fabrication and on-site construction, and how they relate to Materials and Resources (MR) within LEED for Homes.

…better approach the community design process, the integration of contemporary structures into historic neighborhoods, and arising benefits from Locations and Linkages (LL) within LEED for Homes.

…better understand the benefits of post-occupancy evaluation efforts (including building systems; overall energy use; and indoor environmental air quality (IEQ) in small homes and associated IEQ LEED for Homes issues).

A New Norris House
Cover Slide

Text:
Thank you, Stephen, for the introduction and to the AIA for hosting us for this presentation. A New Norris House is an educational, research and outreach project carried out by the University of Tennessee Knoxville and led by the College of Architecture and Design. We are grateful for support from major sponsors, including the US Environmental Protection Agency, the UT Science Alliance, The Alliance of Women Philanthropists, Clayton Homes, the University of Tennessee Knoxville and the Office of Research and College of Architecture and Design.

Presentation Outline

I. History – TVA and The Norris Project
II.Overview – A New Norris House
III. Water Resource Systems
IV: On- and Off-site Construction
V: Post-occupancy Evaluation
VI: Community Design

Images:
NNH Planter and Picture Window

Text:
Working as a team, faculty and students from architecture, landscape architecture, civil and wastewater engineering, interior design, environmental studies, and planning departments – with additional help from industry and professional partners, and community and government bodies – designed and constructed a sustainable home and landscape in Norris, Tennessee.

Completed in July 2011, the home is now host to educational and residency programs. Researchers measure performance of building and landscape systems, yet they also record and consider the experience of living in the home, landscape and community.

I. History – TVA and The Norris Project

Geographic and Social Context
Images:
TVA Region / Tennessee River Watershed Map with Dam Locations; “Electrification” Mural

Text:
The New Norris House project was inspired by the Town of Norris and the 75th anniversary of the Tennessee Valley Authority (or TVA. The TVA was established by congress as a federal corporation formed to holistically address the region’s development and resources during the Great Depression. A technological and social experiment, President Roosevelt declared:

> *“The work proceeds along two lines, both of which are intimately connected - the physical land and water and soil end of it, and the human side of it…”*

In 1930, few rural households in the valley had running water or electricity. A site on the Clinch River, twenty-two miles from Knoxille TN, was chosen for the TVA's first hydroelectric dam, Norris Dam. The Dam is named for Senator George Norris, the "Father of the TVA" and author of legislation that established it.

Power and Flood Control
Images:
Photos of Norris Dam workers; in construction; dam today

Text:
Navigation and flood control were central to the TVA agenda, and a series of dams would simultaneously prevent erosion of agricultural land and create large-scale electrical power supplies. To better understand the technological developments and impacts of electrification, the TVA also established at Norris a model town - one of the nation's first planned communities and earliest examples of what would become the American suburb. In lieu of temporary camps, dam workers and professional staff resided in a permanent town designed to reflect the TVA's broad vision of stewardship and innovation.

A Planned Garden City
Images:
Circle Area Map Town of Norris; Town Plan (call out project site)

Text:
The Town of Norris is bounded by a green belt that exists to this day and serves as an aesthetic and natural preserve. Dormitories and compact houses situated in clusters are connected by footpaths and roads to schools, services and a central common. The town was originally planned to operate economically around several cooperatives including dairy, ceramics and lumber industries. Municipal electricity, water, and sanitary systems served all aspects of the town, which was considered a major achievement.

The New Norris House is located at key location '01' on Oak Road, a service road in the original plan.

Original Norris Homes (1932 – 1937)
Images:
Norris House Types – Plans and Renderings

Text: average no. rooms, area, types
A key feature of this New Deal village is the original "Norris House," a series of experimental cottages. Eight floor plan types ranging from 500 – 1400 sf were designed and approximately 280 homes built. Designers were sensitive to vernacular dwellings, natural topography, and existing trees. At the same time, the homes incorporated a variety of new building materials and techniques, as well as heating, plumbing and electrical services.

Technical Documentation & Analysis
Images:
TVA Analysis/Diagrams

Text:
The TVA collected data on cost and performance during and after construction, assessing for example, the benefits of new materials, insulation, ventilation and heating systems. Studies were utilized in a second phase of house-building and shared for application by others.

A New Norris House (2009 – 2011)
Images:
New Norris House rendering/photomontage with original Norris cottage in background

Text:
In light of the TVA's 75th anniversary, a team of University of Tennessee Knoxville students and faculty pursued and won the EPA's People, Prosperity and Planet Competition, providing seed funding for the New Norris House project. The competition theme and proposal serves as an ideal lens to revisit the Norris experiment and to question the use and scale of public and private resources today.

II. Overview – A New Norris House

Environmental Context
Images:
Bioclimatic Chart (from AIA COTE submission); design degree days; summer/winter solstice and equinox diagrams

Text:

Knoxville summers are hot and humid and winters cool. Still, passive solar design and ventilation in the New Norris House maintain interior temperatures in the comfort zone throughout much of the year.

Response to Context
Images:
Oak Road site model; View of completed site and house from Oak Road

Text:
The town is on the National Register of Historic Places. While residents recognize the benefits of growth and modernized dwellings, they are concerned for possible adverse affects of development on the scale and visual characteristics they appreciate. The New Norris House maintains recognizable aspects of original cottages and settings - a simple, rectangular volume with a gable roof is placed on the hillside between street and forest, largely conforming to the existing pattern but subtly adapting it to better access, solar orientation and views.

Site and Landscape Design
Images:
Rendered Site Plan and Site Section

Text:
The New Norris House encourages the infill and redevelopment of existing land rather than the conversion of agricultural or undeveloped land and open space. New development within and near existing communities are supported by existing infrastructure such as water, sewers and parks. Norris also exemplifies many of the characteristics of new sustainable developments – including the option to walk and bike to community resources like schools, post office, library, shops and restaurants

The NNH is sited on a .25 acre lot within a ½ mile walking distance to 14 community resources. During archival research, the design team discovered that the adjacent property once accommodated a walking path that connected to the historic network of paths. The NNH reinstates the path on its site.

These and other measures earned all 10 of the possible LEED Location and Linkage credits.

Street Approach and Drive Court
Images:
View of drive court and house from Oak Road

Text:
Original to the 1930's town plan, two drainage swales, one stone-lined and one vegetated, flank the site. Treating storm water onsite involves capturing and infiltrating water before it enters the swales. Native grass meadows and spreading shrubs are planted for erosion control and provide storm water infiltration zones. The retaining wall delineates the footprint of the original cottage, and provides a pre-compacted area for the gravel drive court.

These and other measures earned 16 LEED Sustainable Sites credits of 22 possible points.

Spatial Organization
Images:
Floor Plan, Building Cross Section through loft, View of interior marriage line from loft

Text:
An original cottage plan is the genesis for the 24'x32' ground plan with side entries that minimize interior circulation. The home is 768; 1,006 sf with the loft. In response to community criticism of historic homes, the NNH is far more open, flexible and daylit, and it is physically and visually more connected to the outdoors. The home can function as a 1- or 2-bedroom home.

The NNH earned a home size adjustment for its compact area, reducing points required for Platinum certification by 10.

Traditional Form and Contemporary Dwelling
Images:
exterior view from southeast at dawn

Text:
Natural materials, textures and color, hand crafted details where the hand and foot touch, and an intimate scale provide opportunities to speak to the everyday objects we often overlook and to the spirit and physicality of the original cottages. Yet, it is also hoped that visitors might realize special attention, exaggeration, and craftsmanship in designing, detailing and making that put the New in the New Norris House.

Extension of Outdoor Living Space
Images:
View of home from rear deck

Text:
300 sf of decks and ramps provide additional outdoor living space

Interior Volume, Daylight and Views
Images:
Interior view from kitchen looking toward deck with doors open

Text:
The interior is organized into parallel public and private zones. The public living zone is a singular, open space. A front picture window and rear exterior deck continue this zone into the forest and street.

Flexible Inhabitation
Images:
View from living to ladder to storage loft

Text:
The private zone is comprised of the bedroom, bathroom, loft and swing space. The swing space can serve as a second bedroom, home office or extension of the living space.

Public and Private Zones
Images:
View of loft looking toward skylight and swing space

Text:
The home is comprised of two prefabricated modules that reinforce the public and private spatial organization. The marriage of the modules is expressed in the interior symmetry.

Exposed Structure and Built-in Storage
Images:
Views of Bedroom

Text:
Exposed framing and structural decking provide warmth to the interior and maximize headroom in the bedroom and loft above.

All Spaces Daylit
Images:
Views of Bathroom

Text:
All interior spaces are daylit, including acid-etched privacy glass in the bathroom.

Design Recognition
Image:

Achievement and Recognition
- LEED for Homes Platinum Rating (33% over Platinum threshold)
- Residential Architecture Design Awards (RADA) Merit Award
- AIA Gulf States Merit Award
- AIA Tennessee Award of Excellence
- AIA East Tennessee Honor Award
- National Modular Housing Council (NMHC) New Modular Home Design Award
- NCARB Prize for the Creative Integration of Practice and the Academy
- US EPA P3 Design Competition for Sustainability

Text:
A New Norris House has received numerous accolades for design, pedagogy, and environmental performance, listed here.

Phase IV: Monitor and Evalute
Images: Diagram of Exterior Sensor Locations

Text:
Qualitative and quantitative data is being collected for post-occupancy evaluation. Live-in residents support continuing education through blogs and tours. Their occupancy patterns are monitored digitally by over 50 sensors, installed with the support from the Oak Ridge National Laboratory Buildings Research and Technologies Integration Center (BTRIC).

Exterior sensors include a weather station that records temperature, relative humidity and solar radiance; a digital rain gauge; and moisture saturation sensors in a grey water bed. Raw and treated rainwater samples are collected for analysis by a certified lab.

Phase IV: Monitor and Evalute
Image:
Diagram of Interior Sensor Locations

Text:
Digital data collected inside the house includes: room temperatures, relative humidity, water flow and water temperatures. Data is also collected on solar hot water panel and energy recovery ventilation systems. City water is sampled from the bathroom lavatory; Ports installed in the cistern room provide samples of treated rainwater - before it enters the house - and untreated rain water stored in the cistern.

Phase IV: Monitor and Evalute
Image:
eMonitor System Screen Capture of Interface, eMonitor web address, photo of electrical panel

Text:
The team is using Electrical and Digital Monitoring systems. The eMonitor is a user-friendly, electrical monitoring system that uses off the shelf hardware and software and costs approximately $1000. It monitors overall and specific electrical loads minute-by-minute and contacts are connected directly to the electrical panel. Owners can log into a website and view real-time electrical use, costs and recommendations for savings.

Phase IV: Monitor and Evalute
Image:
Data Logger System Data sets, photo of equipment installation

Text:
ORNL's Building Technologies Research & Integration Center team is supporting our use of a custom, advanced digital monitoring system that records data at 15 minute intervals. Collected data is accessed via the internet, generating a detailed excel file. Digital data sets include air temperature, relative humidity, rainfall, water flow and grey water saturation levels.

III. Water Resource Systems
Images:
Grey water and rainwater terrace beds with home, beyond

A. What were we able to accomplish?
B. How were we able to accomplish this?
C. Key LEED and Design Criteria

Text:
This section of the presentation examines the NNH as a case study to illustrate how to better integrate water resource systems - rainwater, grey water, and storm water - in residential projects

Water Resource Systems - Rain Water Supply - What were we able to accomplish?
Image:
Diagram of lab test results and EPA contaminants

Text:
We are able to collect and treat rainwater to provide water that is <u>safe for human contact by EPA Human Health Criteria</u>.

Water samples are collected at locations noted previously and tested for contaminants. We compare our test results with EPA Maximum Contaminant Levels (or MCLs) for drinking water – meeting all standards. The following slides reflect the results of 10 monthly laboratory tests. A certified laboratory is also provided more comprehensive quarterly and event-based test results. Rainwater and greywater research is conducted with the support of Dr. John Buchanan, in the Department of Biosystems Engineering at the University of Tennessee Knoxville.

Water Resource Systems - Rain Water Supply - What were we able to accomplish?
Images:
Graph of volume of rainwater in cistern and volume of overflow to bioretention beds

Text:
In addition to water quality tests, we are measuring water <u>quantities</u> – the amount of rainfall at the site, the amount of water treated, and the amount of water used – in the home *and* in the landscape.

To date, we are able to provide a little over 800 gallons of safe, treated water, on average, every month - *for use in the home*. Nearly 10,000 gallons of rainwater were used *in the home* during the first year of the study.

On average, approximately 2,000 gallons of rainfall fell on our roof ***each*** month; OR, just over 25,000 gallons of total rainfall on our roof in year one of the study period.

When our primary cistern is full, rainwater overflows for use in the vegetable garden or for infiltration in the site. In one year of the study period, we were able to infiltrate just over 15,000 gallons on-site in the rain gardens and vegetable gardens.

Water Resource Systems - Rain Water Supply - What were we able to accomplish?
Images:
Diagrams of avg water use by US home compared to NNH; diagram compounded to town

Text:
The NNH reduced its consumption of potable city water by 61%, in comparison to the average US home.

If the NNH strategies and results were applied to all homes in the town, the municipality could reduce its consumption of potable water by 25 million gallons per year – an amount equivalent to 34 Olympic pools.

Water Resource Systems - Rain Water Supply - How were we able to accomplish this?
Images:
Axon of house with key; diagram of cistern room rain water treatment

Text:
We achieved these results by first, installing low-flow fixtures; second, by using treated rainwater for toilet flushing, clothes washing and exterior hose bibbs; and third, by creating a water wise landscape design.

A primary 400 gallon, plastic cistern is located in an insulated, at-grade equipment room accessed from the exterior of the house.

The first flush of rainwater containing loose contaminants from the roof is diverted before entering the cistern. A simple ball float allows subsequent rainwater to pass through a strainer box and enter the cistern. On demand, stored rainwater is pumped through the treatment assembly. In series, this includes: a 100 micron Y strainer; a 10 micron filter; 0.5 micron carbon block filter; and an Ultraviolet lamp. 12 gallons of pressurized, treated water is stored in a hydro-pneumatic tank, minimizing the frequency the pump must be used.

If the primary cistern runs out of rain water, make-up water from the city is automatically supplied to system. City make-up water is not hard-piped; an air gap between the two is avoids such a cross-connection.

Plumbing and valves are installed such that the entire rainwater system can be turned off and residents can rely exclusively on city supply water to meet all of its needs.

Water Resource Systems - Rain Water Supply - How were we able to accomplish this?
Images:
Axon of site water system keyed to photos

Text:
If the primary cistern is full (image a), additional rainwater overflows to a second, 200 gallon cistern (image b) through sub-grade plumbing. This stored rainwater is accessed by an antique hand-pump and used to irrigate the raised vegetable beds.

When primary and secondary cisterns are both full, water overflows via gravity in a sub-grade pipe and enters a series of rain gardens through a rip-rap forebay to slow velocity. The rain gardens (image g) accept overflow roof water *and* capture surface sheet flow from the site. Four terraced, snaking "basins" maximize infiltration into the soil subgrade. An outlet to an existing, natural drainage swale (image c) is the last resort.

Water Resource Systems - Rain Water Supply - How were we able to accomplish this?
Images:
Fore-bay, construction of terraces, construction drawings of terraces; photos of treatment system and secondary cistern

Text:
The upper-left photo shows the fore-bay in the first rain garden. Below the photo is a section through it. The overflow pipe entering the fore bay comes from the secondary cistern (bottom left) which can be drained down for winter. The upper right image shows the rain gardens during excavation. The slope was cut and filled by machine and hand, and earthen retaining walls built to form the basins.

Water Resource Systems - Rain Water Supply - How were we able to accomplish this?
Images:
Diagram of collaborators

Text:
We worked with the Municipal Technical Advisory Service, the Norris Water Commission and city officials to revise city ordinances. Ordinance changes were narrowly written to apply exclusively to NNH and a renewable, 12 month 'sunset' clause was included. Ordinance changes were publicly advertised and voted on by the city council. Members of the design team presented the project to the city prior to votes on ordinance changes, and before that, the team met regularly with the water commission during monthly public meetings.

Required safety measures were inspected and include:
- air gaps in lieu of cross connections where possible
- backflow preventors where cross connection exist
- labeled piping
- signage to denote non-potable water sources

Depending on research outcomes, the city may allow the system to remain in place.

A major hurdle was identifying the people and organizations we needed to work with – on both supply and waste as these are separate departments. There was general uncertainty about who had jurisdiction - local, county or state. The process took 21 months, from the first presentation to the TDEC local field office to approval to operate the rainwater system.

Water Resource Systems - Rain Water Supply – Key LEED and Design Criteria
Images:
Calculations on system sizing; LEED WE and SS credits

Text:
LEED Water Efficiency Credits we obtained are noted in black. We needed to capture and store 75% of our roof water – or 479 gallons – and use it indoors and out to earn the maximum rainwater harvesting credits. However, the cistern we wanted to use held only 400 gallons. We desired to use this cistern because the plastic it is made of is approved for drinking water (even though the treatment system is not legally creating drinking quality water). Our use calculations suggested the 400 gallons would be sufficient for our non-potable needs – especially because we did not expect to irrigate the landscape. To get maximum credit, we included a 200 gallon overflow cistern for use of the excess water in the vegetable gardens.

Calculating a 72% reduction in overall irrigation demand using the LEED for Homes Water Use calculator, we earned full points (10 points) for credit SS2.5, WE 2.3, and were eligible more two points based on exemplary performance.

As an aside, rain gardens do not count toward reduced irrigation demand. Further, the LEED for Homes Water Use calculator is a controversial measure and will likely see modification in forthcoming revisions of the LEED for Homes program.

32 Water Resource Systems - Grey Water - What were we able to accomplish?
Images:
Photo of Norris water manhole cover; diagram showing Avg US home's irrigation use compared to NNH irrigation in the establishing year. (move grey water sizing calcs per notes at end of presentation)

Text:
Centralized municipal water and sanitary systems were celebrated achievements in the 1930's Plan of Norris. The NNH offers alternatives that combine centralized and decentralized water and waste systems, with numerous safeguards for safety and redundancy.

At the NNH, grey water is released below ground to treatment and infiltration beds. This includes lightly used waste water from the bathroom sink, shower, and washing machine, but excludes water from the kitchen sink and toilet.

With greywater representing about 60% of the total household wastewater volume **(Ask Andrea/Buchanan for source**), the productive life of existing wastewater treatment facilities could be extended if grey water could be used at or near the location it was generated– saving energy and recharging the water table.

At the NNH, 80% of the water used in and to establish the landscape came from grey water discharge. The NNH landscape is designed to flourish without irrigation. The average US home uses 73,000 gallons of potable water for irrigation each year.

Water Resource Systems - Grey Water - What were we able to accomplish?
Images:
Grey water soil saturation chart; monitoring installation (cross-section through bed (diagrammatic), photo of system install

Text:
Piezometers, or monitoring wells are used to collect data on water levels within the grey water bed to determine the rate of water movement – either through infiltration and/or evapotranspiration. The spikes on the graph show an increase relative to atmospheric pressure, which indicates water entering the bed.

We will use the data to create a simple water budget to estimate the quantity and proportion of the inputs (grey water inflow and rainfall) versus the outputs (infiltration, evapotransipration, and overflow) to establish design parameters for grey water infiltration bed guidelines.

Initial results suggest it takes approximately 4 hours for a load of clothes washing water to infiltrate in the bed, and about 2 hours for a 15 minute shower to infiltrate.

Water Resource Systems - Grey Water – How were we able to accomplish this? Design
Image:
Site axon showing grey water bed location, soil drainage/measure photo, plants selected for grey water bed (plant list)

Text:
The design process began by testing the infiltration rate of the soil. The soil type on the project site is Fullerton cherty silt loam. The USDA classifies this soil type as “well drained” with a depth to a restrictive layer or the water table of more than 80 inches.

An onsite infiltration test was performed by excavating a hole where the bioretention bed was to be located. The hole was filled with water and a ruler was placed in the water to observe the rate of infiltration per hour. We determined an average rate of 0.2 inches per hour. The bed is located away from existing surface water features, and in full sunlight.

Water Resource Systems - Grey Water – How were we able to accomplish this? Design
Image:
construction section details through grey water bucket and bed;; calculations for sizing gray water bed and rainwater beds relative to storm event / 2.5”

Text:
Based on two residents and the low-flow fixtures specified, we projected 40 gallons of greywater/day would be produced. Our goal was to design the bed to infiltrate all of this, as well as 2.5” of rainfall – a very significant storm. We made the grey water bed 7.5 times larger than required for two people.

The holding capacity of the grey water bed is 300 gallons, and the gravel layer alone can hold 112 gallons.

Water Resource Systems - Grey Water / Waste – How were we able to accomplish this? (Regulatory)
Images:
TDEC sign in bed, close up; photo of Matthew at TDEC field office, photo of the TDEC group touring the site, weekly observation log, and timeline

Text:
Similar to rainwater permitting, we worked with the Municipal Technical Advisory Service, the Norris Water Commission and city officials to revise city ordinances that were exclusive to the NNH research site. The main authority, however, lay with the state and the Division of Water Pollution Control. A delegation from Nashville visited the site and ultimately issued a State Operating Permit good for two years.

The permit requires informational signage in the bed with our permit and contact numbers, and an annual report that summarizes inspection logs we maintain, suggested design revisions, and the project user/maintenance manual.

Water Resource Systems - Grey Water – How were we able to accomplish this? LEED criteria
Images:
historic stone channel

Text:
Though we did not pursue LEED WE1.2, Greywater reuse system credits, the NNH earned 6 points for design and installation of an irrigation reducing landscape-- calculated to require 72% less water than a baseline model, and exceeding the credit requirements of SS 2.5. The terraced, bioretention beds that infiltrate rain and grey water are central to performance goals – and are designed as aesthetic landscape elements. Plants in the beds are chosen for their ability to withstand frequent inundation, assist in removing contaminants from the greywater, evapotranspire water, and provide year-round visual and wildlife benefits.

IV: On- and Off-site Construction
Images:
Process photos of site install

A. What were we able to accomplish?
B. How were we able to accomplish this?
C. Key LEED and Design Criteria (MR and LL)

Text:
In this section, the NNH will help explain limitations and benefits of off-site fabrication and
on-site construction, and how they relate to LEED for Homes Materials and Resources and Location and Linkages credits.

On- and Off-site Construction - What were we able to accomplish?
Images:
Exterior view gravel court in front and interior view of marriage wall

Text:
Working with Clayton Homes, a manufactured and modular homebuilder, the UT team:
designed and executed a factory-built home that is prototypical yet site-specific; combined on- and off-site fabrication methods and components to respond effectively to climate and context; and used a previously developed, compact infill site, overcoming access limitations during installation.

The NNH is comprised of two, standard 12' wide modules with gable roofs – a line from the peak of the gable to ground reflects the modules marriage line. Rafters are hinged for lifting on-site. Clayton Homes had experience with hinged roofs, but the design eliminates collar ties and most full height walls. This complicated design loads, transport durability and set-up processes.

Atypical design issues include: optimized and, in some places, exposed framing; strict skylight and dormer details, a high performance thermal envelope, benign material specifications, and prepping for green technology integration at the site – such as solar hot water and greywater systems. UT and Clayton Homes tightly coordinated on- and off-site scopes of work and the joining the physical components well in advance.

On- and Off-site Construction - What were we able to accomplish?
Images:
Hinging photo in factory; axon diagrams compare 16"/24" framing; diagram of diversion

Text:
The prefab shell created zero waste in the Clayton factory due to detailed cut lists and a system of ordering pre-cut members like rafters; any off-cuts and, even sawdust, are collected and recycled.

Later: :and sold for use in wood byproducts (vfy)."

Atypical for Clayton, the NNH employs optimized framing, which accounted for a 17.4% reduction in lumber use from the outset. Conscientious planning of material orders and a construction waste recycling contract with TN Waste led to 70% total of- and off-site construction waste diversion.

On- and Off-site Construction - What were we able to accomplish?
Images:
photo of horizontal window at kitchen sink and detail section /perspective; window install

Text:
The shell was built in the factory, including insulated headers - a practice Clayton Homes has since adopted. Cavity and exterior insulation, drywall, and house-wrap were largely complete; rough openings were carefully coordinated and Anderson operable windows were shipped loose; these

were combined with large, fixed frames built off-site by UT for field glazing. Extreme care with flashing, sealing and drainage creates a tight, durale envelope clad with a timber rain screen.

Inside, custom millwork by UT in the kitchen, swing-space, and bedroom conceals appliances and provides lots of storage. Environmentally preferable products are used: local, recycled, reclaimed, or low-VOC materials. Laminated oak countertops fabricated from reclaimed truck-bed trailer liners and flooring made of 150 year old oak barn siding provide warm foils to clean white surfaces – both completed at the site.

On- and Off-site Construction – How were we able to accomplish?
Images:
Wall/Building Section with on- and off-site columns, axon of modules with exploded envelope and components

Text:
Detailed shop drawings were drawn by and shared between Clayton and UT and comprehensive specifications written. Material contents and sourcing were scrutinized well in advance of ordering to meet regional, recycled, and sustainably harvested criteria. Glues, sealants, and coatings were limited to those that met indoor environmental quality standards.

All factory-build components had to be at the Clayton plant prior to the start of fabrication so factory production lines were not affected despite the customization we required. Clayton acquired materials for most of their needs but UT supplied specialty items. Early and tight coordination and clear communication was critical to completing the factory-built portion in five days.

On- and Off-site Construction – How were we able to accomplish?
Images:
Scope of Work with dashed box and enlarged detail to give a flavor for details and categories

Text:
The slide shows an excerpt from the Scope of Work that defined tasks and overlaps between UT, Clayton Homes and Johnson & Galyon, the local contractor and subcontractorss retained to support student-build. The Scope of Work is organized in the following categories:

- Engineering and Design – for modular permitting
- Permits and Procedures – mainly by UT
- Temporary Site Facilities
- Site Preparation
- Foundation
- Water, Septic, Drainage Prep
- Erection / Set Up
- Electrical, Plumbing, HVAC
- Interior Finish
- Appliances and Furniture

On- and Off-site Construction – How were we able to accomplish?
Images:
Install Diagrams 01 and 02 (process photo(s) if room/time)

Text:
Clayton's experience with transport and set-up and a trusted installer were critical to solving the challenges of locating in a historic town with narrow roads, mature trees, significant topography, and small lots. Clayton, UT and the installer met early-on at the site to assess issues and make design changes affected by install methods. The most significant of these was determination that a crane was not feasible – altering plans for a panelized, insulated, precast concrete foundation wall and integral footing system. "Old" tools – and more importantly skills – were instead unearthed for install. Costs were largely equivalent – and the crane fee instead went to increased labor and wages for the two-day set-up with an additional day scheduled two weeks later.

The following ten diagrams summarize preparation and installation stages.
01 After grading and excavation, a portion of the cmu crawlspace was built by UT students. A level area to accommodate the chassis, or carrier, was provided.

02 The scale of the street prevented delivery of modules directly to the site. Instead, modules were staged in a nearby lot. A remote-control "tug" towed one module at a time on a steel chassis to the site, and backed it into the unfinished side of the foundation.

On- and Off-site Construction – How were we able to accomplish?
Images:
Install Diagrams 03 and 04

Text:

03 Winches were used to pull the module to the west, approximately 4” above the sill plate and timber supports were placed to support the module above the foundation. The tug pulled the chassis bag to the staging lot.

04 Poles with winches were used to raise the hinged roof, supporting the plane at regular intervals.

On- and Off-site Construction – How were we able to accomplish?
Image:
Install Diagrams 05 and 06

Text:
05 Temporary wood supports were placed under the raised roof.

06 The “tug” towed the second module to the site and backed it into the drive. The hinged roof was raised before moving into place for access.

On- and Off-site Construction – How were we able to accomplish?
Image:
Install Diagrams 07 and 08 (process photo(s) if room/time)

Text:
07 Temporary wood supports were again placed under the raised roof. Also note temporary walls used to stiffen the open-plan module during transport.
08 Steel carriers were set up under the module and the chassis removed. Winches were used to pull the module to the west to within 1” of the first unit. The double ridge beam is married and the temporary walls are removed.

On- and Off-site Construction – How were we able to accomplish?
Image:
Install Diagrams 09 and 10

Text:
09 Gables are infilled using studs from the temporary walls and roof supports. Floor to ceiling portions of interior walls are completed where shipping and roof hinging prevented full height.

A panelized dormer built by UT with rough-in for a window and solar panel piping is installed.

Remaining building wrap and roofing felt are installed to dry-in the modules.

10 With the modules temporarily supported above the crawlspace, remaining cmu foundation walls and piers are completed, cores reinforced, filled or insulated and anchor bolts set. The sill sealer and top plate is completed.

The installer returns and the house is lowered on top of foundations and bolted in place. Temporary supports are removed through the crawlspace door.

Roof sheathing was pre-scored to denote the location of the skylight from above in order to expose interior rafters at the skylights as detailed. Sheathing and roofing felt cover the opening, roof, and dormer until the roofing subcontractor arrives.

On- and Off-site Construction – How were we able to accomplish?
Images:
Matrix of finish process photos

Text:
UT worked on the project at the site and in its own warehouse simultaneous to Clayton’s work. After the modules were lowered and joined to the foundation, UT’s work on the wood siding, window installation, canopies and roofing commenced. Inside, spray foam insulation was applied to the roof, infill end gables and dormer; interior rigid applied to the underside of the ceiling, and the remaining drywall (above the shipping line) was finished.

On- and Off-site Construction –Key LEED (MR) and Design Criteria
Images:
Materials photos and list that required working closely with Clayton / Chris on spec products/tracking sources

Text:
The project team worked closely with Clayton Home's purchasing department to source ideal materials related to MR2.2 and earned all 8 credits. Particular effort was required to control glues and sealants used in the factory. Modular and manufactured housing often use a thin layer of luan plywood over wall framing to increase rigidity during transport. Instead of this tropical wood, the NNH uses a dense cardboard product for this purpose.

IV: On- and Off-site Construction – Key LEED (MR) and Design Criteria
Images:
Table showing LEED MR credits

Text:
Additional material credits were earned for Exemplary Performance in Innovation and Design 3.1 and 3.2. In fact, we used more preferable materials than we were able to count. Our location in the southeast US made regional sourcing relatively easy to do.

V: Post-occupancy Evaluation
Images:
View of House from bottom of rain gardens

A. What were we able to accomplish?
B. How were we able to accomplish this?
C. Key LEED and Design Criteria

Learning Objectives

Text:
In this section, we will share preliminary results from the first year of energy data collection.

Post-occupancy Evaluation - Overall Energy Use
Image:
Comparison of Avg House, Avg Norris House, NNH

Text:
LEED for Homes incentivizes small homes like the NNH through credit adjustments that lower the rating point thresholds. For example, the NNH platinum threshold was lowered 10 points owing to its compact size. Downsizing, coupled with passive design strategies and efficient mechanical systems, helped the NNH reduce energy consumption to 56% of that used by the average home in our region. Rightsizing and passive means play a central role in reducing mechanical and electrical loads.

Post-occupancy Evaluation – Passive Heating/Cooling
Image:
Graph of Temperatures (Su,Sp,Wi) when no power going to heat/cool

Text:
The building envelope is tight and well-insulated – capable of passively resisting most external temperature fluctuations. Graphs of collected data illustrate representative, 3-day summer, spring and winter periods where outdoor temperatures (bottom, blue line) fluctuate widely, but interior temperatures in all four areas of the home remain within, or close to, the seasonal comfort zone. Electrical data showed that residents were not running any heat or air mechanical systems during these periods. ERV

Post-occupancy Evaluation – Energy Recovery Ventilator (Design/system)
Image:
ERV diagram, intake ext photo, supply interior photo

Text:
Apertures are composed for cross ventilation and useful solar gain while overhangs and plantings mitigate unwanted solar gain. High, open spaces and a concealed loft shutter promote stack ventilation and further extend the comfort zone. Summer diurnal temperature differentials permit night flushing and reduce daytime mechanical cooling if humidity is managed (through ceiling and mini-split fans and an ERV.) Use of the mud room / hallway as an airlock is encouraged during extreme months.

A high-efficiency heat pump supports three ductless heating/cooling/fan units, for three zones; and an energy recovery ventilator provides constant pre-heated or pre-cooled fresh air. Ceiling fans also help with stratification and ventilation.

The NNH uses a Fantech energy recovery ventilator to achieve interior whole house ventilation. The unit provides code required amounts of fresh air, and reduces the load of the heat and air system, saving energy and money.

Post-occupancy Evaluation – Energy Recovery Ventilator (Energy/Cost Analysis)
Images:
Graph of ERV impact, use, savings, and calculation formula

Text:
Electrical consumption from the installed heat and air system is used to generate BTUs delivered to the home by the heat pump. Temperature sensors within ERV ductwork are used to generate a similar figure for comparison of BTUs delivered to the home by the ERV. These figures reveal that 21% of delivered BTUs to the home during year one of the NNH's study period originated from the energy recovery ventilator. This translates to a $56 savings over the course of the year, but only yields a $27 savings given operating cost of the unit itself. Based on price of the installed Fantech equipment, this savings compounds to a 16 year payback period.

Post-occupancy Evaluation – Solar Hot Water Heater (Design/system)
Image:
hot water system diagram, solar panel location, photo of install if space/composition allow

Text:
An Enerworks solar hot water panel mounted on the dormer heats water through exchange. A thermostatically-controlled Eemax tankless electric hot water heater boosts the solar-heated stored water if it is below desired temps, and provides back up water heating during cloudy periods. The equipment fits within a closet in the mud room.

Post-occupancy Evaluation – Solar Hot Water Heater (Energy/Cost Analysis)
Image:
hot water use/cost; comparison avg South Central House and NNH

Text:
Based on a year of collected data, The NNH household required 73% less energy for water heating than the average home in our region. 77% of this annual cost originated from electricity to run the instantaneous water heater. With federal incentives, our solar hot water system would pay for itself in 22.7 years.

(in the future, add an excerpt from Mary Leverance interview/blog)

Post-occupancy Evaluation – Typical Energy Use
Image:
Simple charts from eMonitor dashboard such
Text: The primary energy load within the home originated from the heat and air system, followed by hot water heating equipment. While these values are significantly lowered, their distribution is on par with typical single family homes in the US.

Outreach - What did we accomplish?
[not included]