Richmond's First 3D Home

Virginia Housing

Homeownership: Encouraging New Construction

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VIRGINIA HOUSING

2023 NCSHA Award Submission

ENTRY CATEGORY:

Homeownership – Encouraging New Construction

ENTRY NAME:

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"Innovation requires looking at things differently – imagining the possibilities," said Susan Dewey, CEO of Virginia Housing. *"Because of this focus on innovation, 3D printing is now one of the many tools available to us to help increase housing inventory. And, we're not going to rest on our laurels. We're going to continue to find new solutions to the affordable housing crisis."*

Brief Description

For over 50 years, Virginia Housing has worked to address the statewide shortage of affordable housing. While the commitment to create more housing opportunities is strong and unwavering, the existing housing environment is challenging and innovative concepts need to be introduced to improve cost, efficiency and housing stock. In 2021, Virginia Housing established a public-private partnership to launch a 3D housing development initiative. Spurred by a $500,000 Innovation Demonstration grant to source a large-format 3D printer from Danish company Construction Of Buildings On Demand, or COBOD, this effort helped further innovation in construction in Virginia, as well as three additional homes which have been completed in the last year.

Why is our campaign meritorious and how does it meet NCSHA award judging criteria?

What makes this innovative?

3D printing in a residential setting is very much on the cutting edge in the United States, with Virginia having the first owner-occupied home in the country. An example of a time-saving method is wall construction, which occurs in approximately 24 printing hours and is spaced out over time to allow the walls to cure. This method, while still an emerging technology, is expected to continue to improve and facilitate significant savings in terms of time and money. The on-site labor necessary to complete the wall system is significantly less than traditional building; once the builder team is trained, as few as four people are needed to oversee the process.

Using 3D printer technology and software from COBOD, a company that provides modular printing configurations and construction services, users enter a 3D model simulation of what the wall system would look like, similar to computer-aided drawing. In the 3D environment, users can create a digital twin for code and trade interaction, simulate the expected performance of the building and optimize the printing process. Once the digital model is finalized, additional software translates the house into a G-Code that the printer can understand. Construction entails feeding the 3D printer, called BOD 2, concrete that the nozzle head dispenses as it replicates the digital wall system footprint. The printer moves along a gantry on the perimeter of the house, pausing when it reaches a break in the diagram – such as a window – before it continues at the next print point.

- Staff can monitor metrics such as concrete quality, workflow, speed and accuracy of the printer from a nearby operations center. The system includes a joystick for manual construction as well but it is not recommended as wall system specs are very precise. Once the walls are finished, traditional construction such as mechanical, electrical and plumbing installation follows.
- The 3D-printed houses incorporate a Raspberry Pi-based system that collects indoor environmental data for smart building applications such as air quality (temperature and

humidity), light, sound and gas monitoring. The system provides data on energy consumption optimization and analysis on occupant comfort and space utilization. The data transmission occurs through the homeowner's Wi-Fi, eliminating running costs.

Innovation also occurred during the partnerships created to bring this technology to Virginia. Virginia Housing, along with research university Virginia Tech, two nonprofit development partners, and a for-profit 3D subject matter expert came together on this project. Each partner brought specific experience and leverage – from design and project management, land and construction management, technological expertise, and finance.

Is this model or approach replicable? If so, has it already been replicated?
3D-printed houses will become affordable once builders are able to use the method to build multiple houses at once. To date, a total of four 3D homes have been constructed by this initial investment in the technology, research and development needed to grow capacity in Virginia. Habitat for Humanity in particular has perfected a process to partner with the private sector 3D subject matter expert to continue to build homes, with the expectation that other affiliates will also follow. While the initial investment in the technology was truly the catalyst to initiate the utilization of 3D home building, what this initiative has really done is demonstrate the proof of concept.

How does this effort respond to an important state housing need?
The current housing shortage is severe and making investments in innovative construction and technology is crucial in responding to housing needs. By investing in the COBOD method of 3D home construction, Virginia Housing is able to contribute to housing stock directly and indirectly.

Use data, research and analysis to demonstrate measurable benefits to HFA targeted customers and underserved markets
Data, research and analysis was used during every step of the process in bringing this 3D technology to Virginia. Before even investing in the technology, for-profit and nonprofit partnerships were formed. A market review was conducted and it was determined that according to estimating sizes and sales pricing by location in market that the home would be at least 1,400-1,600 square feet and would be priced at a median of $369,900 in Chesterfield, Virginia. The home needs of the area indicated that the 'starter' type home would be the best fit for the neighborhood, with the target demographic of a young adult that would need an open-concept, three bedroom home.

Throughout the process, data was collected to document the initial cost of the research and development side as well as the actual cost to build. Highlights of the R&D home in Richmond, approximately 1,600 square feet, include: 1) the home's operating cost is $1,246/year or 43% more energy-efficient than the U.S. average for comparable homes, 2) the enclosure tightness is 3.6 air changes per hour (ACH) exceeding energy code standards, largely due to the fact that the home does not have thermal breaks and the wall system offers superior insulation quality, and 3) the first home, including all R&D costs, was built at $241/square foot. However, once adjusted to remove the experimental work, the cost dropped to $188/square foot. The second home was built at $160/square foot, a truly phenomenal measure and dramatic savings based on the learnings from the first home.

This figure continues to adjust down as more experience is gained. The cost is already comparable to site built-costs, helping to demonstrate the effectiveness of the technology. Virginia Tech continues to be an active player and has secured funding to develop a 3D print operator curriculum to help expand awareness and build the technical capacity needed to further deploy the technology.

Does this approach have a proven track record of success in the marketplace?
Cost savings have dropped significantly as more experience is gained, making this an attractive building

option for developers. Further, our Habitat network has embraced this technology by completing three 3D homes and continuing to plan for more. The general contractor for the first home was so impressed they purchased two printers for their own use and signed an agreement with a community in North Carolina to build a substantial number of homes.

Does the benefit outweigh the cost?
Cost savings of construction quickly became realized with more experience. Already the cost per square foot has dropped significantly and the time to print the wall system has decreased as more expertise has been gained; this building technology is expanding, not just in Virginia but nationwide and is doing so because it is cost-effective. Beyond the actual cost, this effort has provided the proof of concept to demonstrate the savings and provide developers and builders with the confidence to know this technology works and further, the return on investment will be realized.

How does the approach demonstrate the effective use of resources?
Virginia Housing made the initial seed investment to bring this technology to Virginia. However, through the public-private partnership necessary to realize this project, other entities pledged close to $700,000. Resources covered costs such as design, labor, some homebuyer assistance, and potentially most important to this effort, the data collection and evaluation necessary to document the process and evaluate development cost and building performance.

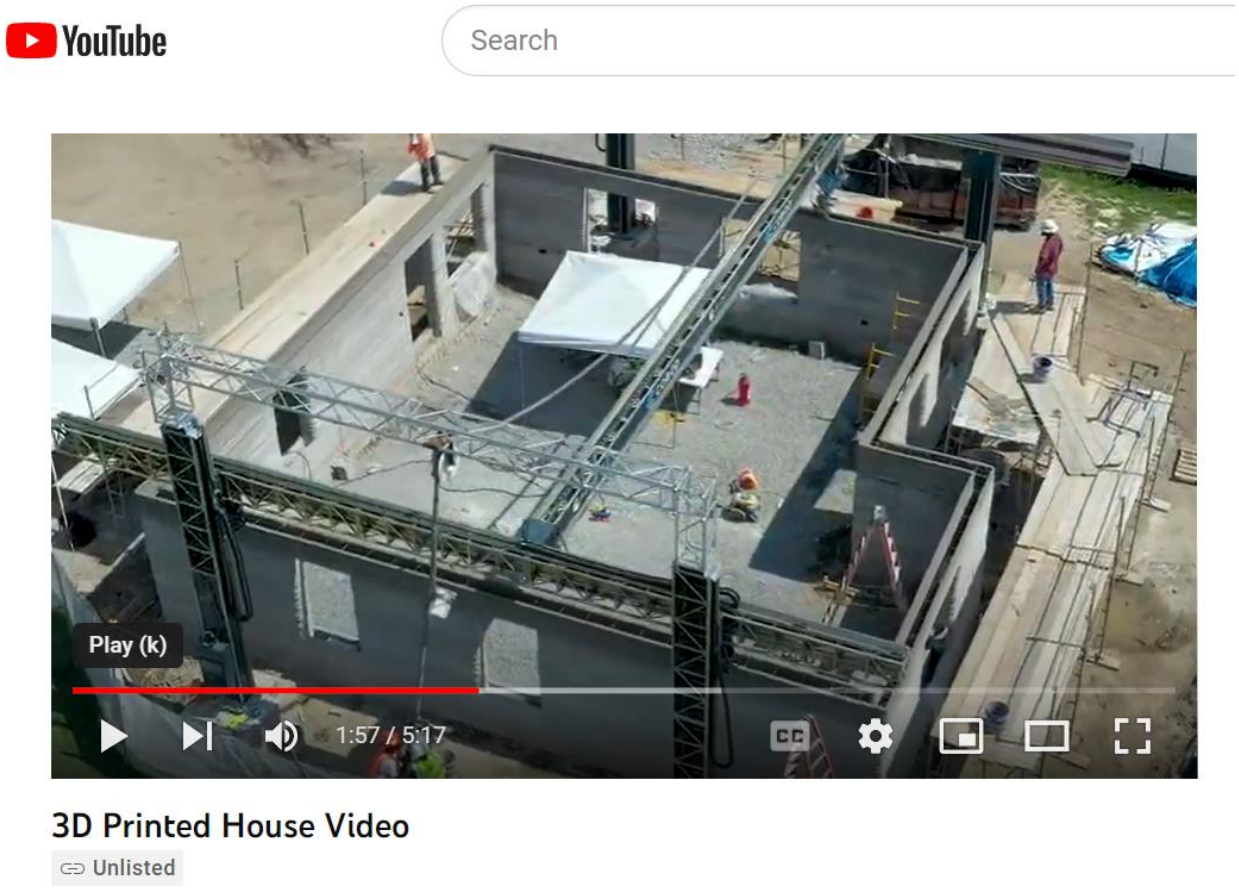
How did the approach effectively employ partnerships?
Virginia Housing and the Virginia Center for Housing Research, or VCHR, at Virginia Tech collaborated with project:HOMES and Better Housing Coalition, two long-time partners that each played an integral role. New parternships were also founded with RMT Construction & Development Group, Alquist and VCHR.

What strategic objectives does the approach achieve (i.e. state, local, Virginia Housing, etc.)?
Virginia Housing remains committed to increasing local capacity to develop and manage affordable housing and provide access to thriving and more inclusive communities. This effort aligns with the following goals from our Opportunity 2025 Strategic Plan:

- Address state housing needs by partnering with the housing delivery network.
- Strengthen homeownership for first-time homebuyers in Virginia.

Visual Aids

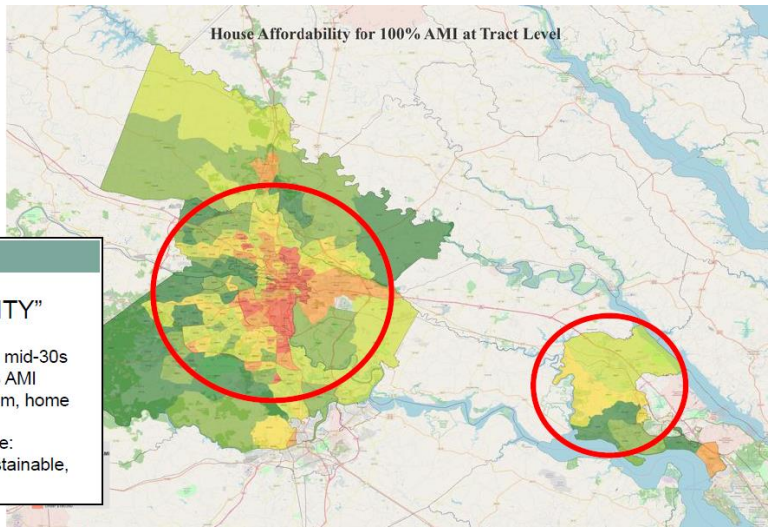
Video: 3D Home Documentary



https://www.youtube.com/watch?v=V0eaDOj8HUE

The Build: Where and How?

Find an appropriate location for an affordable home:



THE "STARTER" TYPE

"START BUILDING EQUITY"

- SIZE: 1400-1600 sf
- TARGET: Out of College to mid-30s
- PRICE RANGE: 100-120% AMI
- FEATURES: baby/kid's room, home office, open concept
- FINISHES: contractor grade: low-cost tile or flooring, sustainable, low maintenance

Data collection

1. **Motion**
2. **Temperature**
3. **Humidity**
4. **Air pressure**
5. **Lighting**
6. **Sound** (high, medium, and low frequency)
7. **Oxidizing gases** (NO, NO2, etc.)
8. **Methane, Ammonia, Hydrogen, Propane, Ethanol, etc.**

The system is customizable and has more sensing capacities

The interior of the home

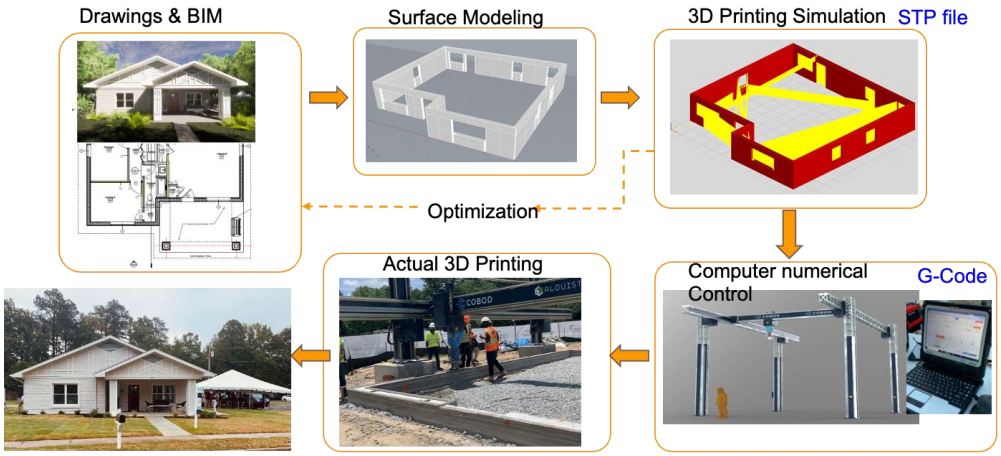


Image: 3D Printing Process, from digital twin to final product

The finished 3D-printed home