

# INDUSTRIALIZED OFFSITE CONSTRUCTION (IOC)

ARISE

Rethinking Manufactured Housing

3D Concrete Printing Affordable Housing

**Philip Agee, Ph.D.**

Assistant Professor

Myers-Lawson School of Construction

College of Engineering

Assistant Director, Virginia Center for Housing Research

[pragee@vt.edu](mailto:pragee@vt.edu)

# Virginia Center for Housing Research

## 3D Concrete Printing

PI: Dr. Andrew McCoy  
Co-PI: Dr. Keresh Afsari  
Co-PI: Dr. Philip Agee



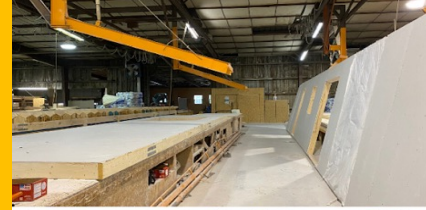
## Off-site Mechanical Systems

PI: Dr. Philip Agee  
Co-PI: Dr. Andrew McCoy



## Re-Imagining Manufactured Housing

PI: Dr. Philip Agee  
Co-PI: Dr. Xinghua Gao  
Co-PI: Dr. Andrew McCoy



## Panelized Construction

PI: Dr. Philip Agee  
Co-PI: Dr. Xinghua Gao  
Co-PI: Dr. Andrew McCoy



Appalachian Regional Initiative for  
Stronger Economies (ARISE)

# Setting Appalachia's Workforce on Track to Adapt to the Changing Construction Industry (Industrialized Construction)

March 7th, 2024

## ***IN PARTNERSHIP WITH:***

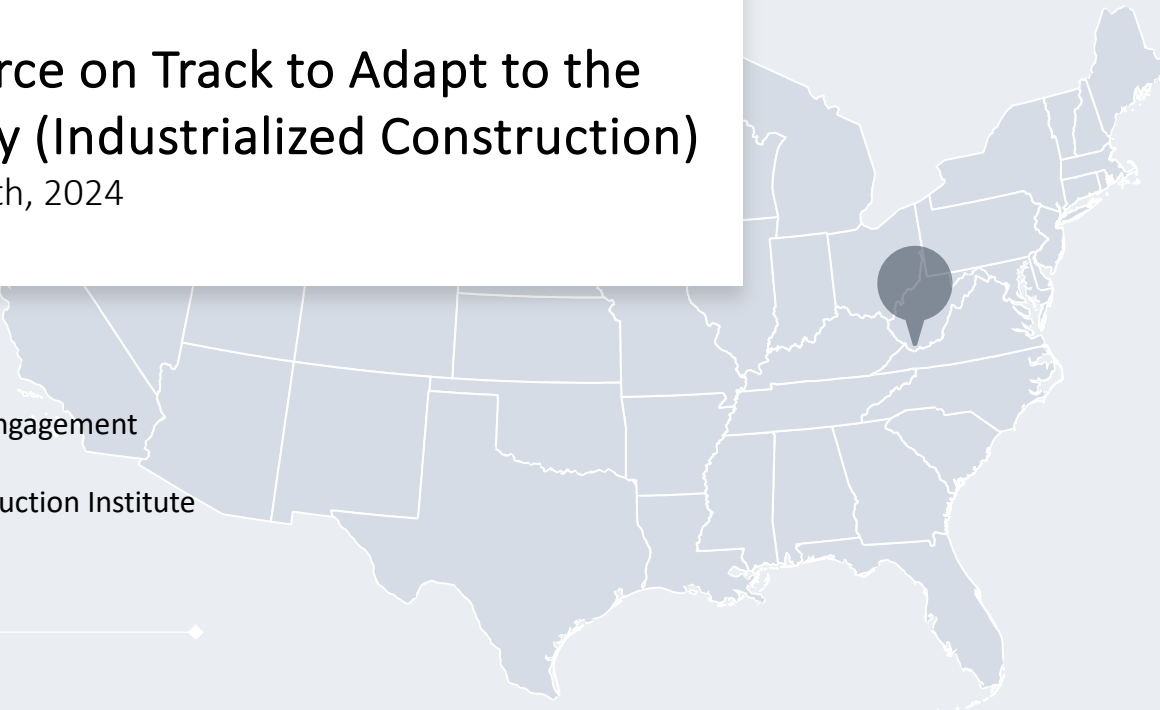
Virginia Tech Center for Economic and Community Engagement

Virginia Center for Housing Research

ADL Ventures with Appalachian Industrialized Construction Institute

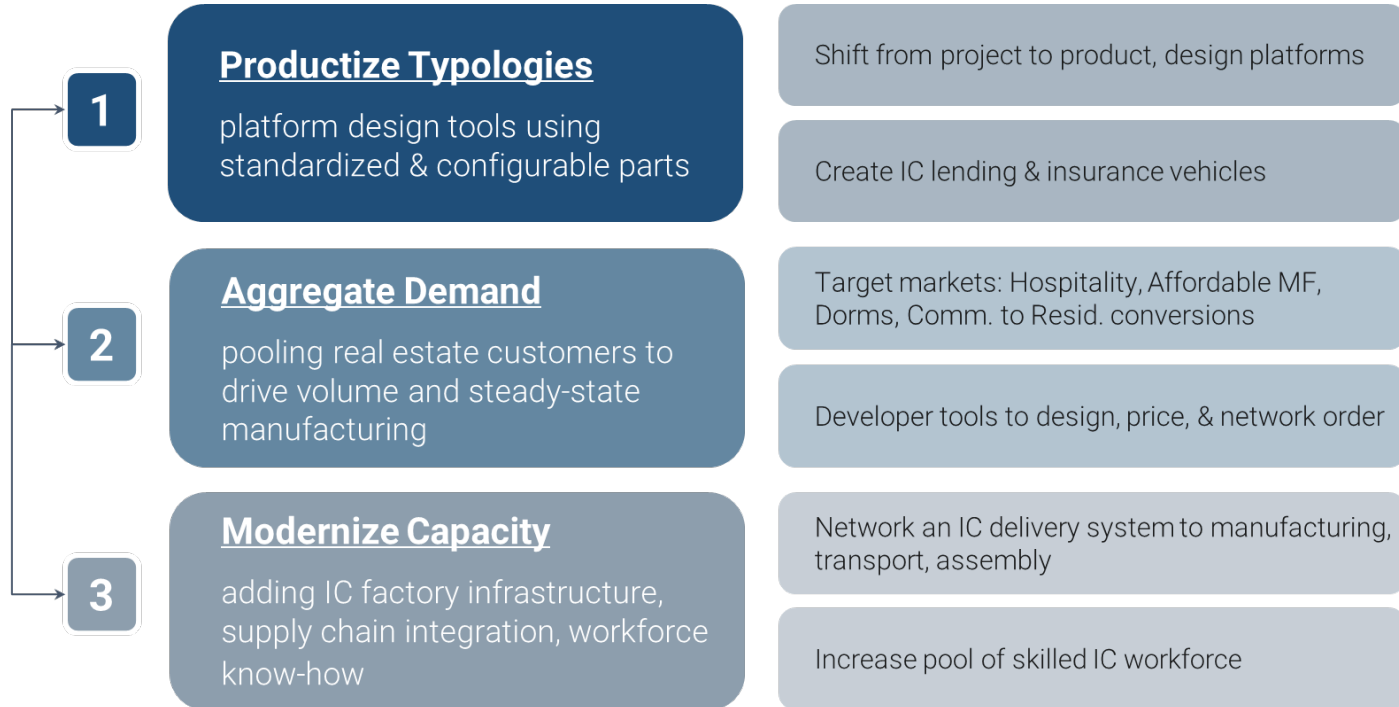
Community Colleges of Appalachia

Ohio University Economic Development Institute



## *ADL's theory of change for construction transformation*

### Industrialized Construction





# Background of this Grant

1. The U.S. construction industry's negative productivity curve represents a significant threat to the nation's economy, infrastructure, environment and overall security
2. We are significantly behind peer countries and industries
3. Bringing advanced processes from industrialization to construction could reduce waste, timelines, costs, increase well-paid jobs and quality, reduce carbonize footprint and address the affordable housing crisis
4. Without "upskilling" our workforce and investing in its development, we cannot bring change to the industry.
5. Central Appalachia, with its existing workforce skills and infrastructure, is well-poised to be a national leader

# Goal and Focus of the Work

## Goals:

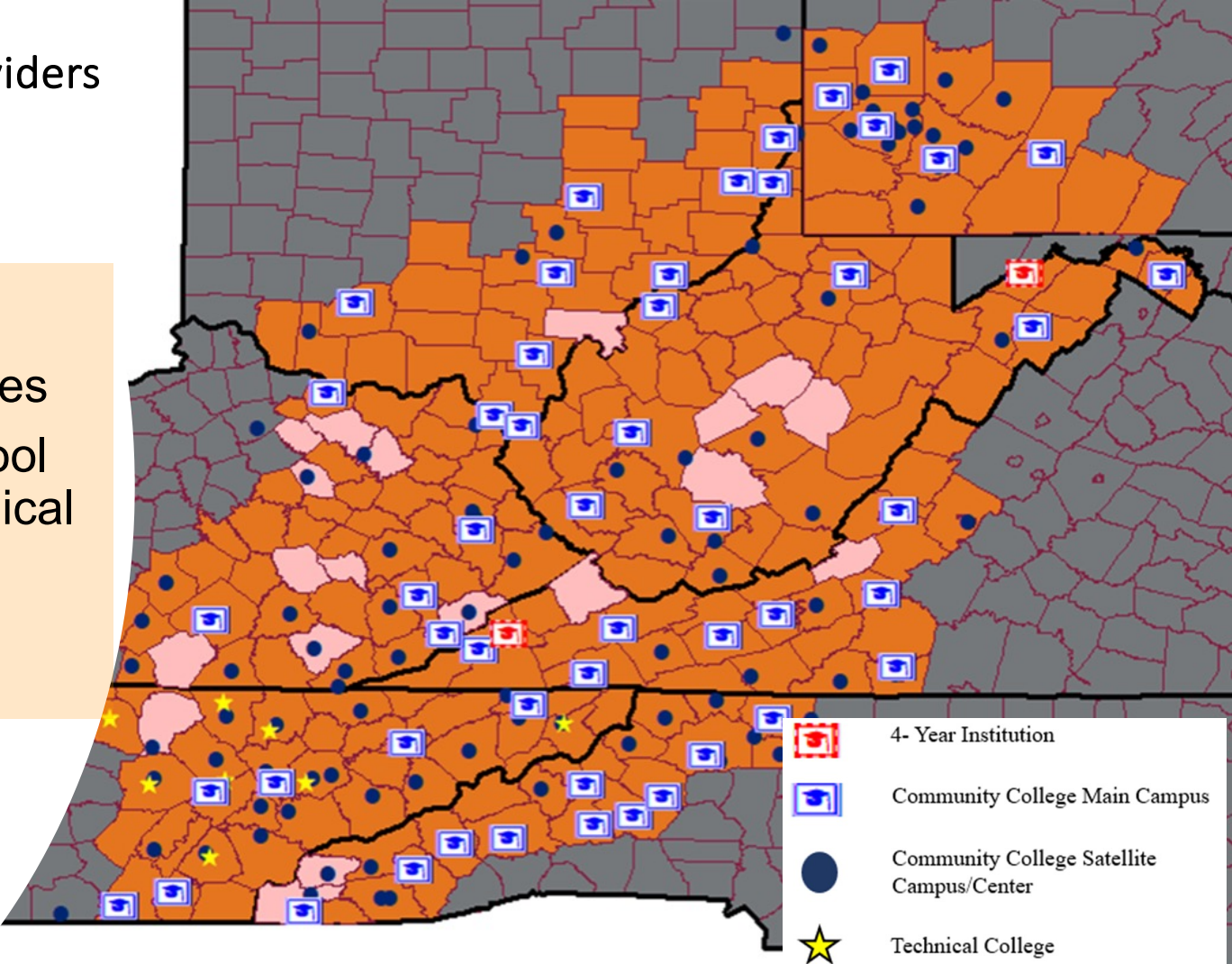
- Identify industrialized construction workforce gaps and assets
- Convene regional stakeholders to create a workforce training roadmap that generates industrial and economic revitalization in Central Appalachia- an economic ecosystem for jobs and housing

## Focus:

- Workforce identification
- Needed skills and training
- Curriculum identification for our needed workforce and skills

# Regional Education Providers

- 250 Localities
- 51 Community Colleges
- Over 1,890 High School Continuing and Technical Education programs





# What is Industrialized Offsite Construction (IOC)?

"an innovative construction system that optimizes the entire build process from design to completion by standardizing building components/systems that can be manufactured/prefabricated, and also standardizing the processes used to design, manufacture, and assemble them."



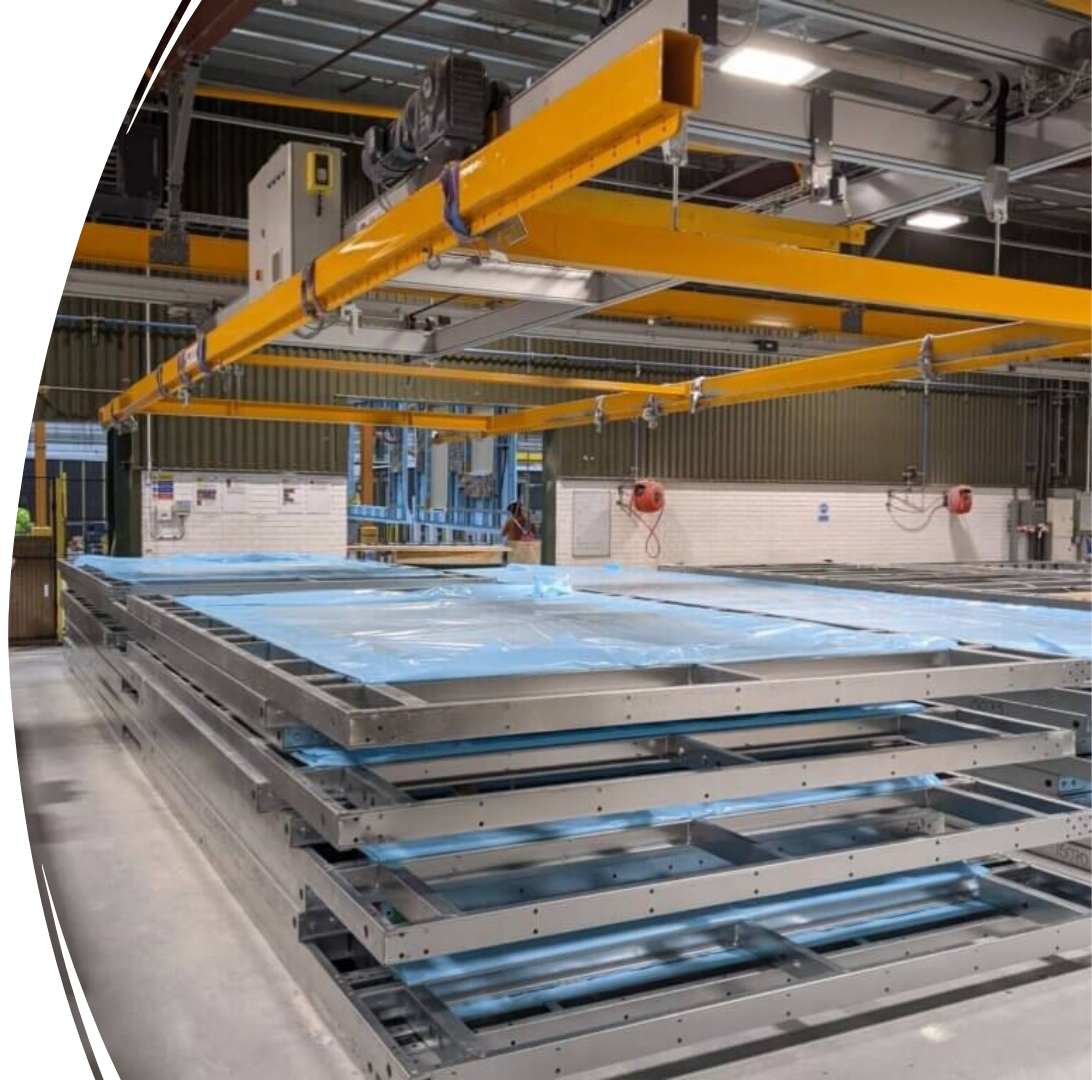
IOC integrates industrial principles of:

- ✓ **Automation:** using machines for greater autonomy: mechanization and standardization, including industrial and dimensional standards
- ✓ **Optimization:** Maximizing efficiency, reducing waste, and minimizing costs while still meeting product and project goals and specifications
- ✓ **Prefabrication:** Structures are manufactured elsewhere but set up on-site.
- ✓ **Robotics:** tools that provide multi-axis flexibility to perform work by themselves for diversified and complex tasks
- ✓ **Digital technologies:** Converting physical items into a digital format, using data, into a common format to consistently share and improve the control
- ✓ **Transportation:** Logistics and services in the movement of objects, products, materials or systems

# Industrialized Offsite Construction (IOC)

## IOC aims to:

- ✓ increase productivity
- ✓ substitute labor-repetitive or intensive processes
- ✓ fast-track construction processes and commissioning
- ✓ reduce costs and risks
- ✓ improve quality and sustainability
- ✓ increase customizable options



Based on Industrialized Offsite Construction (IOC) industry composition...

# What Occupations Make-up Industrialized Offsite Construction



## Administration

managers, first-line supervisors, project specialists, training specialists, cost estimators



## Architecture & Engineering

architects, surveyors, civil engineers, industrial engineers



## Transportation

crane operators, truck drivers, laborers & freight, stockers and order fillers



## Production

welders, cabinetmakers, sawing machine setters, inspectors, electrical assemblers, misc. assemblers & fabricators, machinists, production workers, computer controlled tool operators



## Construction & Extraction

brick masons, carpenters, tile & stone setters, construction laborers, operating engineers, drywall installers, glaziers, electricians, insulation workers, painters, plumbers, roofers, sheet metal workers,



## Installation, Maintenance & Repair

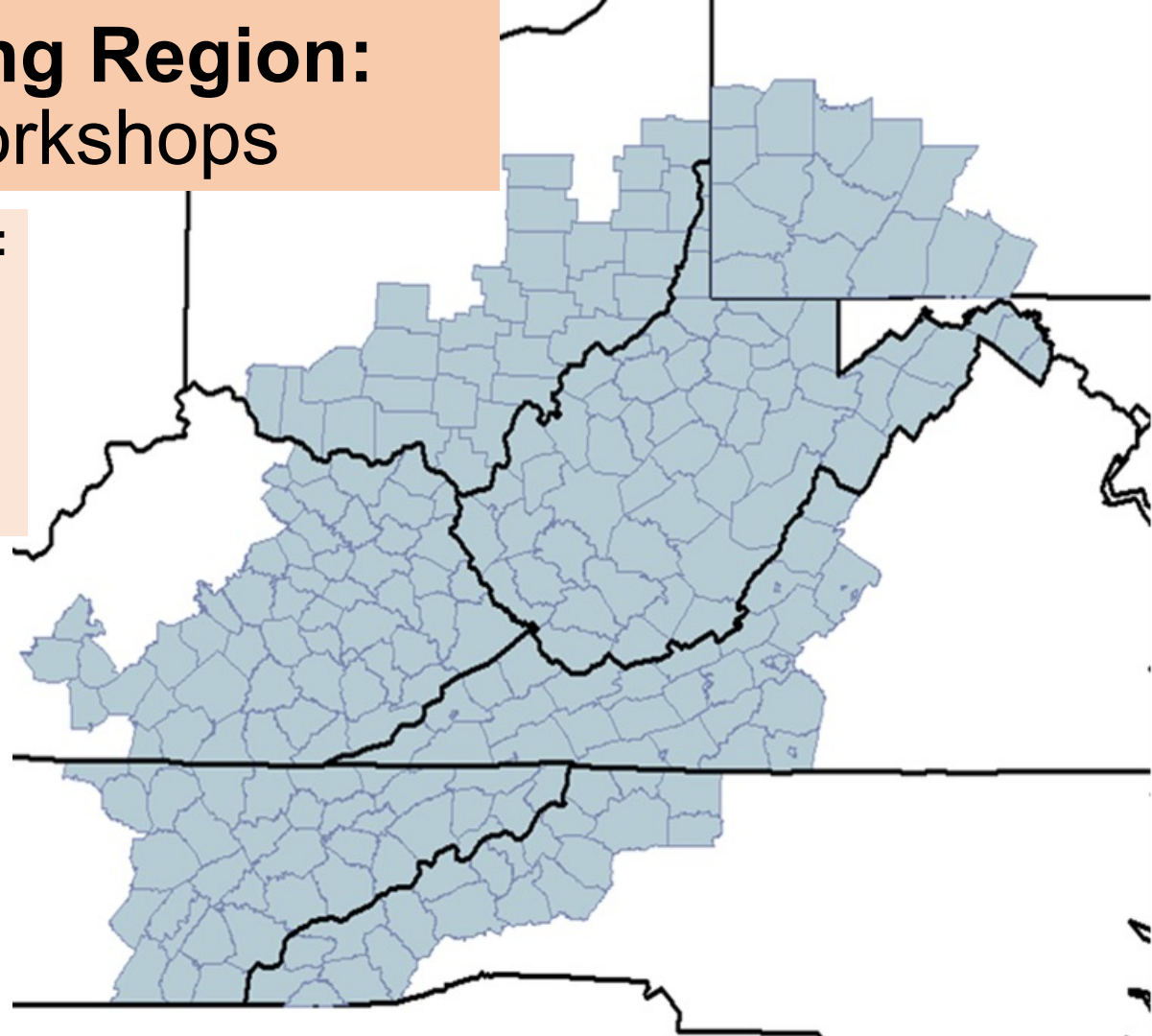
heavy equipment mechanics, HVAC mechanics, power-line installers, maintenance and repair workers, automotive technicians and mechanics, industrial machinery mechanics



# ARISE IOC Planning Region: Design Thinking Workshops

## Workshop in each state/region:

- ✓ Convening partners organize
- ✓ Leverage regional expertise/context
- ✓ Validate findings
- ✓ Compare themes across Appalachia



## PROMPT 1: WHAT IS THE STATUS QUO OF HOUSING IN YOUR REGION?



**PROMPT 2:** HOW COULD INDUSTRIALIZED OFFSITE CONSTRUCTION IMPROVE THE STATUS QUO OF THE HOUSING/CONSTRUCTION INDUSTRY IN YOUR REGION?



## PROMPT 3: HOW DO WE GET THERE?



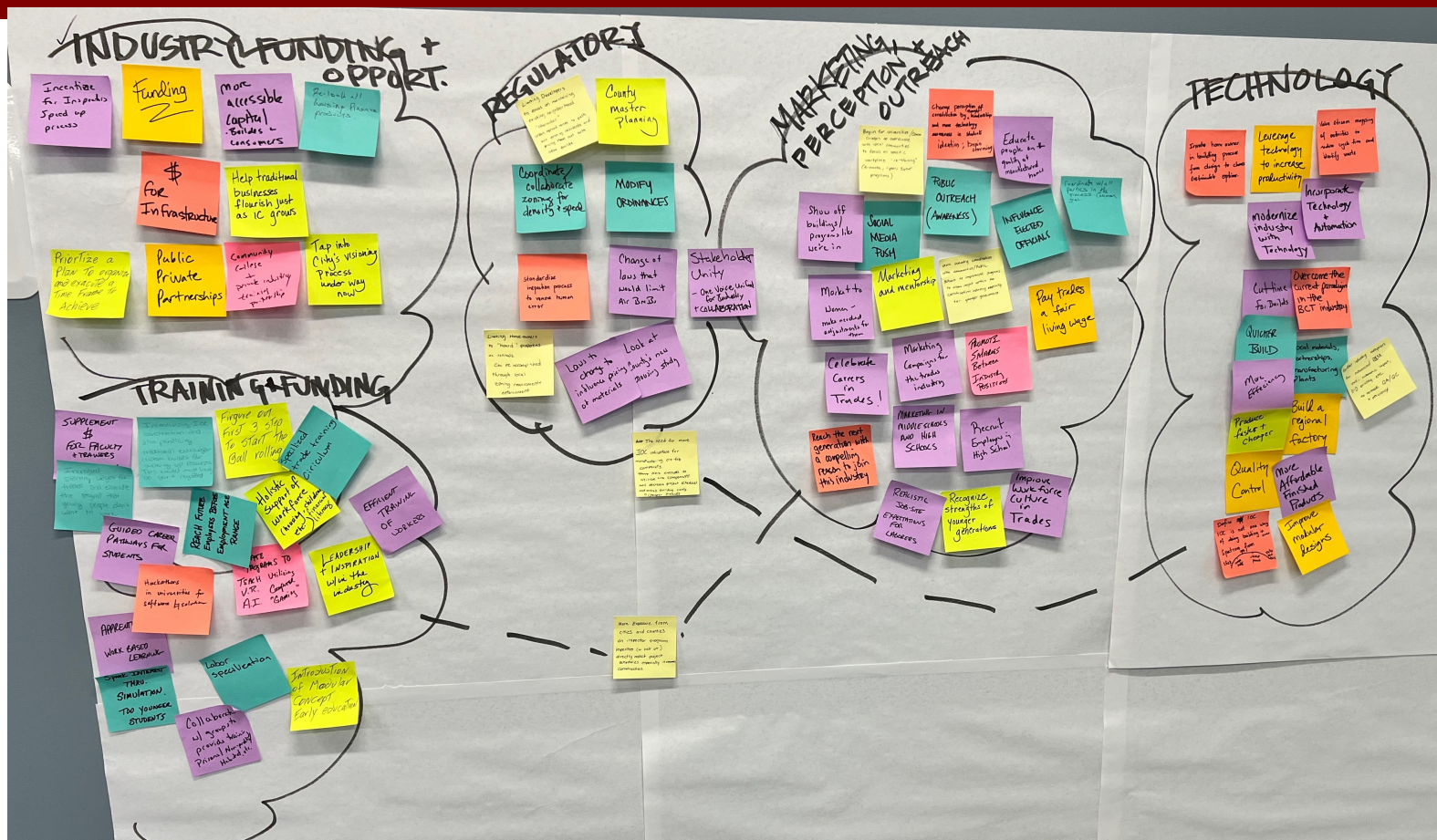
# PROMPT 3: HOW DO WE GET THERE?





## PROMPT 4: AFFINITY DIAGRAMMING EXERCISE (cluster emergent themes)

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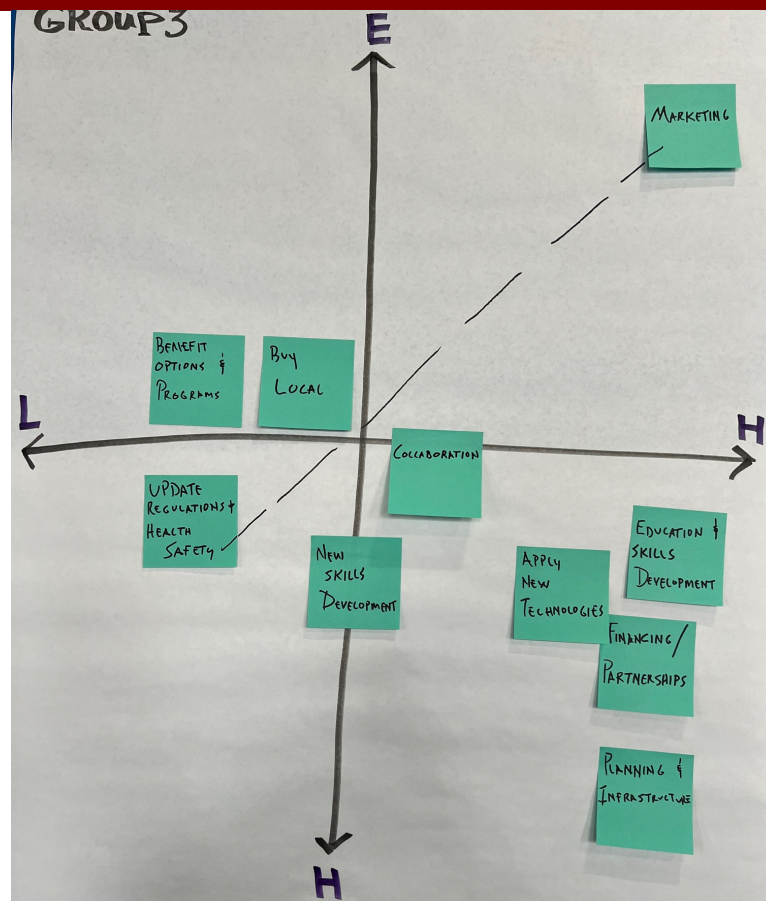
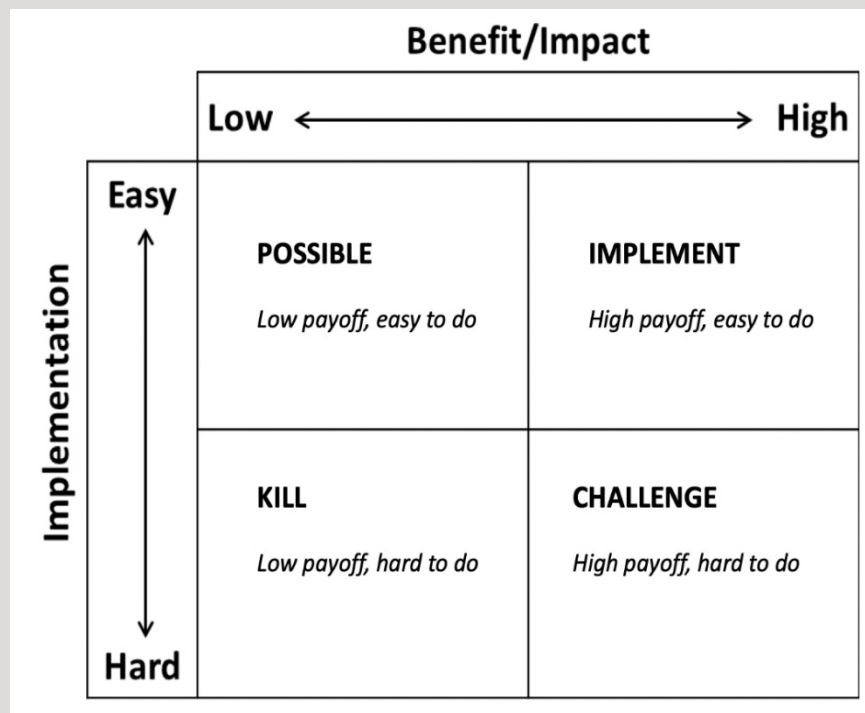




# PROMPT 5: PICK EXERCISE (prioritize themes)

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## Possible, Implement, Challenge, Kill



# RETHINKING MANUFACTURED HOUSING

CENTER FOR ECONOMIC AND COMMUNITY ENGAGEMENT | March 2024

# BERMUDA ESTATES | CHESTERFIELD, VA

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✓ 50 units, Scope: unit repair + replacement with enhanced units

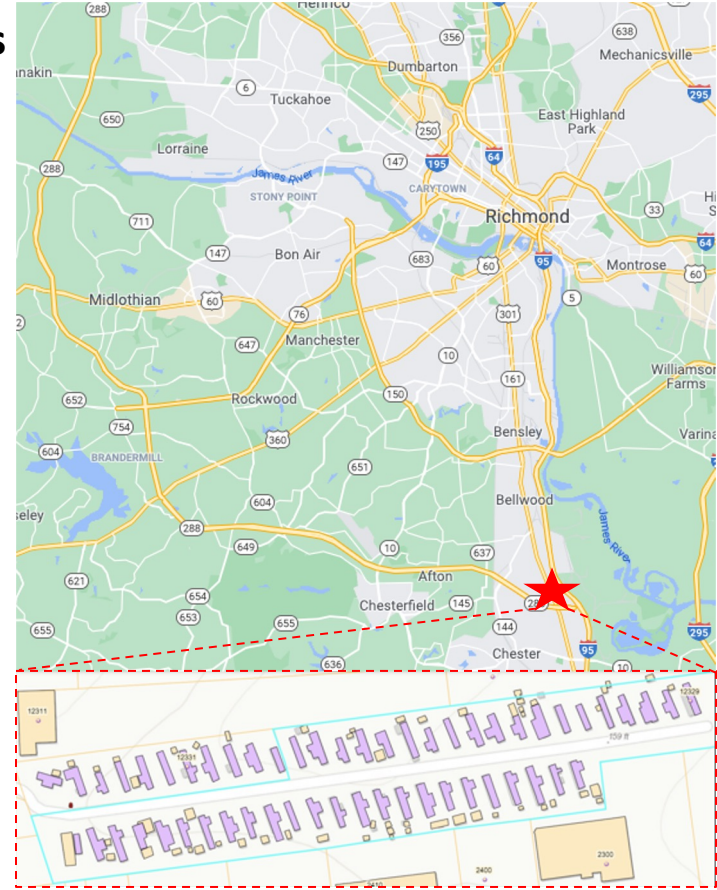
## 2021 REPORT TO THE COMMUNITY



## Improving Lives in Bermuda Estates

“project:HOMES rescued us,” said Bonnie Newton, a resident of the Bermuda Estates Manufactured Home Community in Chesterfield County.

In September 2020, project:HOMES purchased Bermuda Estates Manufactured Home Community with equity partner VCDC, to enhance the quality of life for existing residents, prevent displacement and eliminate the stigma associated with manufactured housing communities. Support from the Bob & Anna Lou Schaberg Foundation allowed project:HOMES to make the necessary down-payment on the property. The redevelopment of Bermuda Estates includes major infrastructure improvements, home repairs at no cost to residents, unit replacement, community engagement and a Community Resource Center.





# INTERVENTION | ADAPT MANUFACTURED HOUSING

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## ***50 existing units:***

- 1973-2000 vintage
- Durability issues
- High utility costs
- Not affordable



## ***[Stock] Factory Units:***

- Heating only
- Open crawl space
- Added hardie-plank siding



## ***Enhanced Units:***

- Added porch & gutters
- Added central air conditioning
- Added conditioned crawlspace

# FACTORY UNITS

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**2 BEDROOM**



**3 BEDROOM**



# ENHANCED UNITS

22



**3 BEDROOM**



**2 BEDROOM**



# AFFORDABILITY IMPACT | ENERGY BURDEN

Use Case Scenarios										
	Exist. 3BD	Exist. 2BD	Fact. 3BD	Fact. 2BD	Enhan. 3BD	Enhan. 2BD	ZERMH 3BD	ZERMH 2BD	ZEMH 3BD (8kW PV)	ZEMH 2BD (8kW PV)
<b>Annual Energy Cost</b>	\$1,839	\$1,755	\$1,452	\$1,355	\$1,232	\$1,122	\$1,008	\$929	\$47	\$25
<b>100% AMI</b>	2.7%	2.6%	2.1%	2.0%	1.8%	1.6%	1.5%	1.4%	0.1%	0.0%
<b>80% AMI</b> (moderate-income)	3.4%	3.2%	2.7%	2.5%	2.3%	2.1%	1.8%	1.7%	0.1%	0.0%
<b>50% AMI</b> (low-income)	5.4%	5.1%	4.3%	4.0%	3.6%	3.3%	3.0%	2.7%	0.1%	0.1%
<b>30% AMI</b> (extremely low-income)	9.0%	8.6%	7.1%	6.6%	6.0%	5.5%	4.9%	4.5%	0.2%	0.1%
<b>Higher energy burden</b>					<b>Lower energy burden</b>					

**KEY FINDING:** from the factory manufactured housing creates energy burdened residents at 30-50% AMI (primary MH customer)

- Energy burdened: > 3% gross income spent on energy
- High energy burdened: > 6% gross income spent on energy
- Severe energy burdened: > 10% gross income spent on energy

# 3D CONCRETE PRINTING



# 3D Concrete Printing, Building Performance and Human-Centered technology trends in the industry

PHILIP AGEE, PH.D. | Virginia Center for Housing Research | Virginia Tech | [pragee@vt.edu](mailto:pragee@vt.edu)





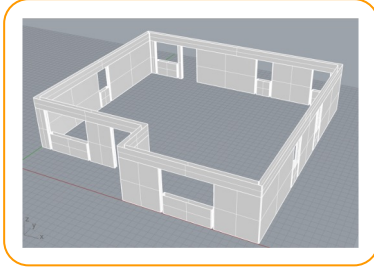
# OVERVIEW OF THE 3DCP PROCESS

26

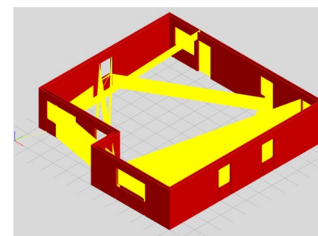
**Digitization of the built environment**



**Surface Modeling**



**3D Printing Simulation & Optimization**



**Optimization**

**Realization**



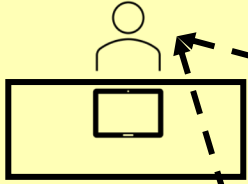
**3D Printing**



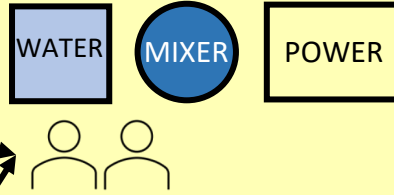
**Computer numerical control**



### Unit Operation 1: Slicer



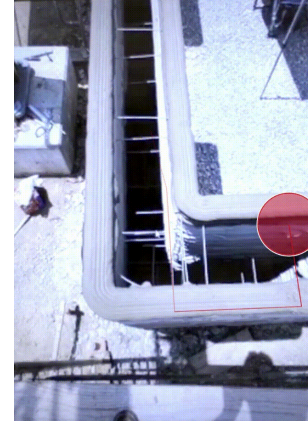
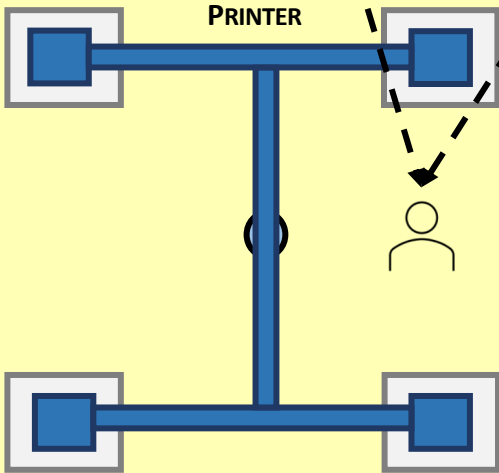
### Unit Operation 2: Support Systems



### Unit Operation 3: Printer

#### EXAMPLE:

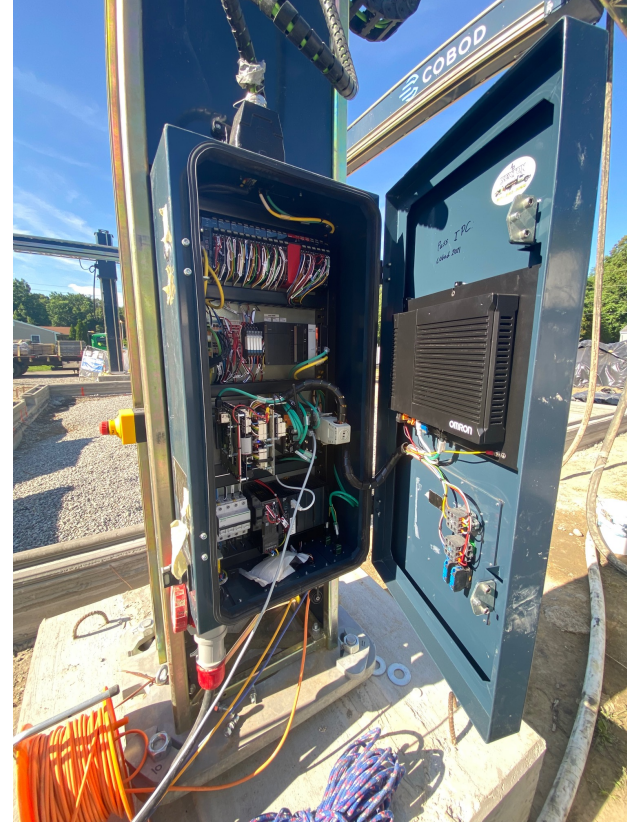
- ✓ Production efficiency
- ✓ Quality control and assurance
- ✓ Data integration
- ✓ Cost and schedule integration
- ✓ Safety
- ✓ Environmental (air temp., humidity and water temp.) controls





# WHY DON'T WE MANUFACTURE OUTDOORS?

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# PROJECT 1 | RICHMOND, VA

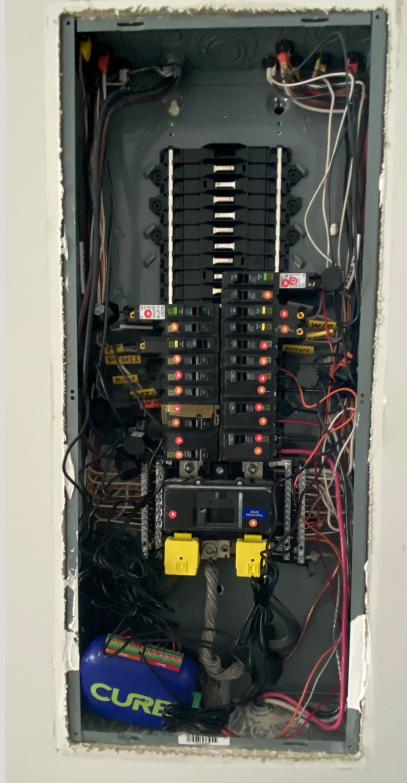
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# PROJECT 2 | PENINSULA AND GREATER HABITAT FOR HUMANITY

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# PROJECT 3 & 4 | NEWPORT NEWS, VA

31





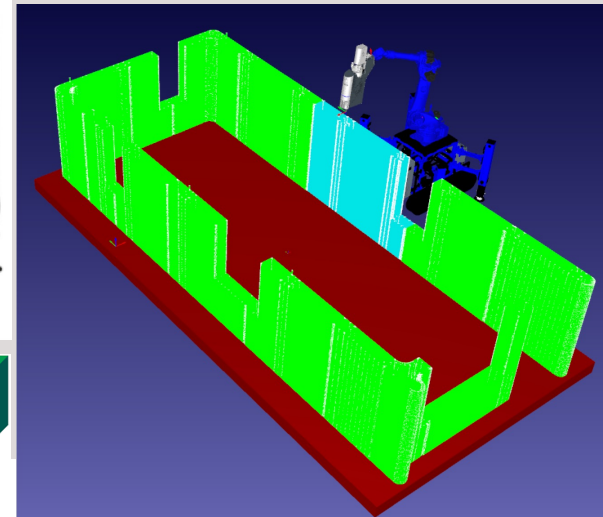
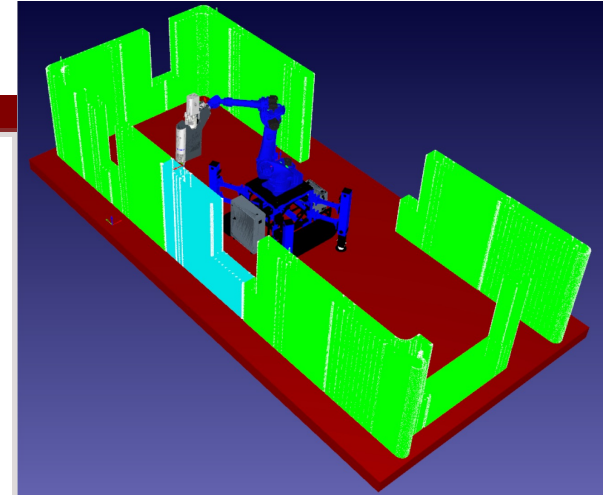
# RECENT FUNDING

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**Goal: build a "runway" of affordable housing projects**

**Integrate training and project support**

**Formative and summative evaluations of the technology and housing outcomes**



**Virginia  
Housing**

Research generously supported by:

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