

U.S. DEPARTMENT OF
ENERGY

Office of
**ENERGY EFFICIENCY &
RENEWABLE ENERGY**

Cracking the Code: Unlocking the Benefits of Off-Site Construction

National Energy Codes Conference Seminar Series

Building Technologies Office

Fall 2022



NECC Seminar Series Lineup

Catch the entire lineup of sessions bi-weekly—Thursdays @ 1p ET:

- 8/18: Taking Charge of Climate Change through Stretch Codes
- 9/8: Energy Codes and Utility Programs: The Peanut Butter & Jelly of Energy Efficiency
- 9/22: Energy Code Implementation: Insights from the Field to the Classroom
- 10/6: Less is more: Building to Zero Energy, Water and Carbon
- **10/20: Cracking the Code: Unlocking the Benefits of Off-site Construction**
- 11/17: Outside-the-Box Options to Advance Multifamily Building Efficiency

> Learn more: <https://www.energycodes.gov/2022-summer-seminar-series>

ABC

ADVANCED BUILDING CONSTRUCTION

Collaborative

ADVANCED BUILDING CONSTRUCTION COLLABORATIVE

Introduction and Codes Activities

20 October 2022

Tim Griffith / PAE Engineers

Motivation: the buildings sector faces a confluence of critical challenges.



Catastrophic climate change is on the horizon; billion-dollar disasters increased 4X in the last 40 years



Noah Berger/AP



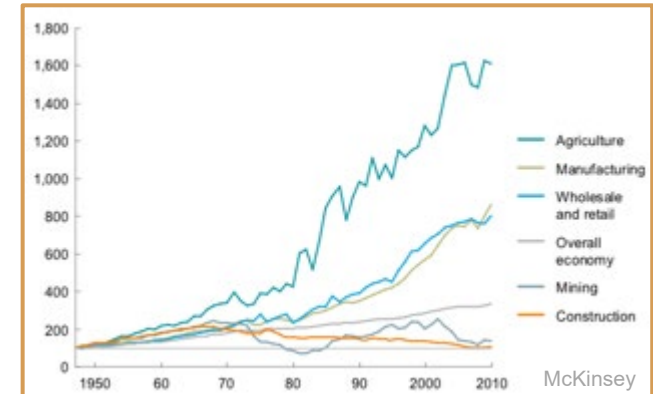
A deficit of millions of units of attainable housing is burdening families, workers, and the economy




iStockphoto



Labor productivity in construction has declined since 1968, in contrast to rising productivity in other sectors




McKinsey

A low-angle photograph of several tall skyscrapers in a city, with a hazy sky. The buildings are made of brick and have many windows. The image is slightly faded to allow the text to be read clearly.

Our goal: to decarbonize the US building stock before 2050 while improving resilience, affordability, and equity.

kolderal/Getty Images



Our hypothesis: by modernizing the construction industry and using more holistic definitions of quality and value, we can accelerate the pace at which decarbonization strategies are adopted by the mainstream buildings sector.

Mariko Reed / Onion Flats



ADVANCED BUILDING CONSTRUCTION

Collaborative

Our approach:

Advanced Building Construction (ABC)

ABC refers to retrofit and new construction solutions that combine:

**Energy-efficient
building decarbonization**

+

**Scalable, streamlined
industrialized construction approaches**

Deep energy efficiency has **substantial co -**
benefits.



Reduced **maintenance**



Increased thermal and acoustic **comfort**



Improved indoor **air quality** and **health outcomes**



Resilience, including passive survivability



Reduced emissions for **climate and compliance**



Electrical **grid stability**

Industrialized construction (IC) can help rapidly deploy energy-efficient, low-carbon buildings at scale.

- Only a small percentage of US construction uses industrialized approaches.
- Yet a large part of the \$1.4T+ US construction market could incorporate IC, which can enable **higher performance, faster deployment, less disruption, reduced schedule risk, precise material use and waste reduction, enhanced QC, technology integration, and workforce benefits.**

But industry and the public sector must collaborate to achieve this—and codes must become an enabler, not a barrier!



Our Mission: Work with incumbent and emergent buildings sector actors to accelerate mainstream adoption of ABC in service of building decarbonization while modernizing the US construction industry.



**2030
Vision**



Demand

- 3M+ net-zero carbon retrofits per year
- All new construction is net-zero carbon



Technology

ABC technologies/ approaches are used in at least 25% of construction activity



Delivery

Innovative private sector business models, public sector support, and enabling regulations and codes unlock the market

The ABC Collaborative's **core activities** incorporate and advance its **mission and strategic priorities.**

*Transacting
Activities*



**Market
Scaling Support**

*Empowering
Activities*



**Workforce
Development**



**Innovation
Scaling**

*Foundational
Activities*



Convening

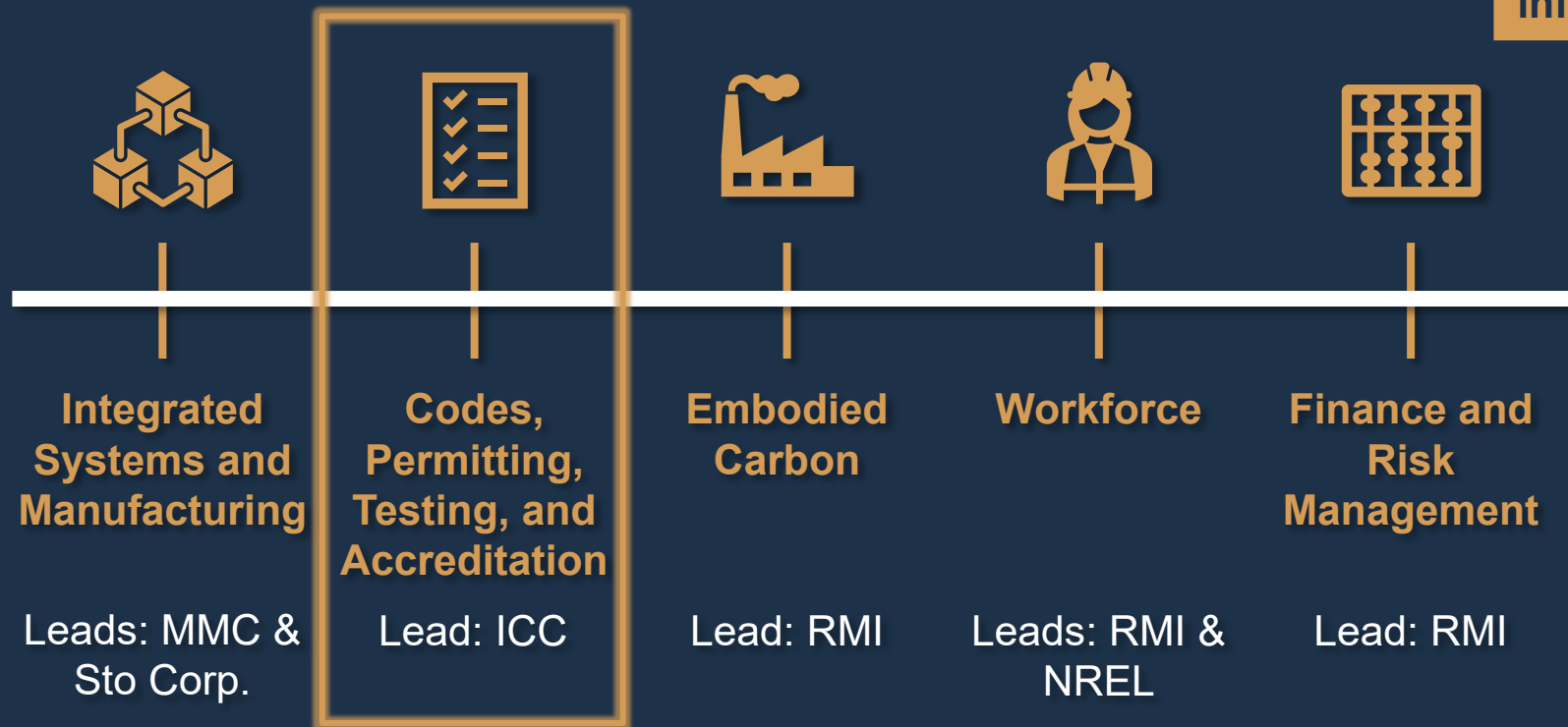


**Thought Leadership
and Education**

The Collaborative organizes **convening activities**, including **topic - specific Working Groups**

The Collaborative's active **Working Groups** offer participants ongoing **interactive programming** on a range of topics.

Other programming includes **monthly Coffee Chats** and **informational sessions**



Note: Working Groups subject to change



ADVANCED BUILDING CONSTRUCTION

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The Collaborative provides **thought leadership** to guide industry actors in the nascent ABC market.

Guidance for ABC stakeholders includes:

- ABC Market Insights Report
- Building Stock Characterization Studies (NREL)
- Industry Guidance Report – residential report expected this fall
- Topical briefs and Working Group outputs
- Topic/stakeholder-specific knowledge shares and educational sessions
- Insights on ABC opportunities

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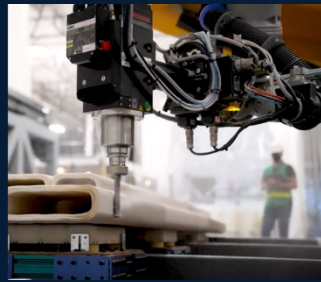
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ABC-C CODES
WORKING GROUP
BRIEF
JULY 2022

July 2021
Opportunities
Challenges for
Modernizing US Buildings

State of Possibilities and Barriers for
the National Buildings Sector with
Advanced Construction

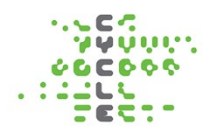
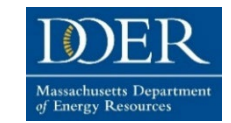


COMING SOON!

ABC Industry
Report: Res

U.S. Building Stock Characterization Study
A National Typology for Decarbonizing U.S. Buildings
Part 1: Residential Buildings

Collaborative Network *



*Partial list; see website for current list of Collaborators and Supporters.

Includes ABC Collaborative team members, funders, MOU signers, Letter of Support writers, and other significant collaborators

ABC

ADVANCED BUILDING CONSTRUCTION

Collaborative

Thank You!

advancedbuildingconstruction.org/contact-us



Off-Site Construction and the Codes

Ryan M. Colker, Vice President, Innovation

DOE National Energy Codes Conference Seminar Series

October 20, 2022

Why Off-Site Construction?



QUALITY



WORKFORCE



SUSTAINABILITY



SPEED TO MARKET



AFFORDABILITY



JOBSITE SAFETY





Open vs. Closed Construction

OPEN CONSTRUCTION. A modular building, modular component or panelized system manufactured in such a manner that all portions can be readily inspected at the building site without disassembly, damage or destruction thereof.



CLOSED CONSTRUCTION. A modular building, modular component, or assembly manufactured in such a manner that all portions cannot be readily inspected at the installation site without disassembly, damage or destruction thereof.



What is Off-Site Construction?

OFF-SITE CONSTRUCTION. A modular building, modular component or panelized system which is designed and constructed in compliance with this standard and is wholly or in substantial part fabricated or assembled in manufacturing plants for installation - or assembly and installation - on a separate building site and has been manufactured in such a manner that all parts or processes cannot be inspected at the installation site without disassembly, damage to, or destruction thereof.

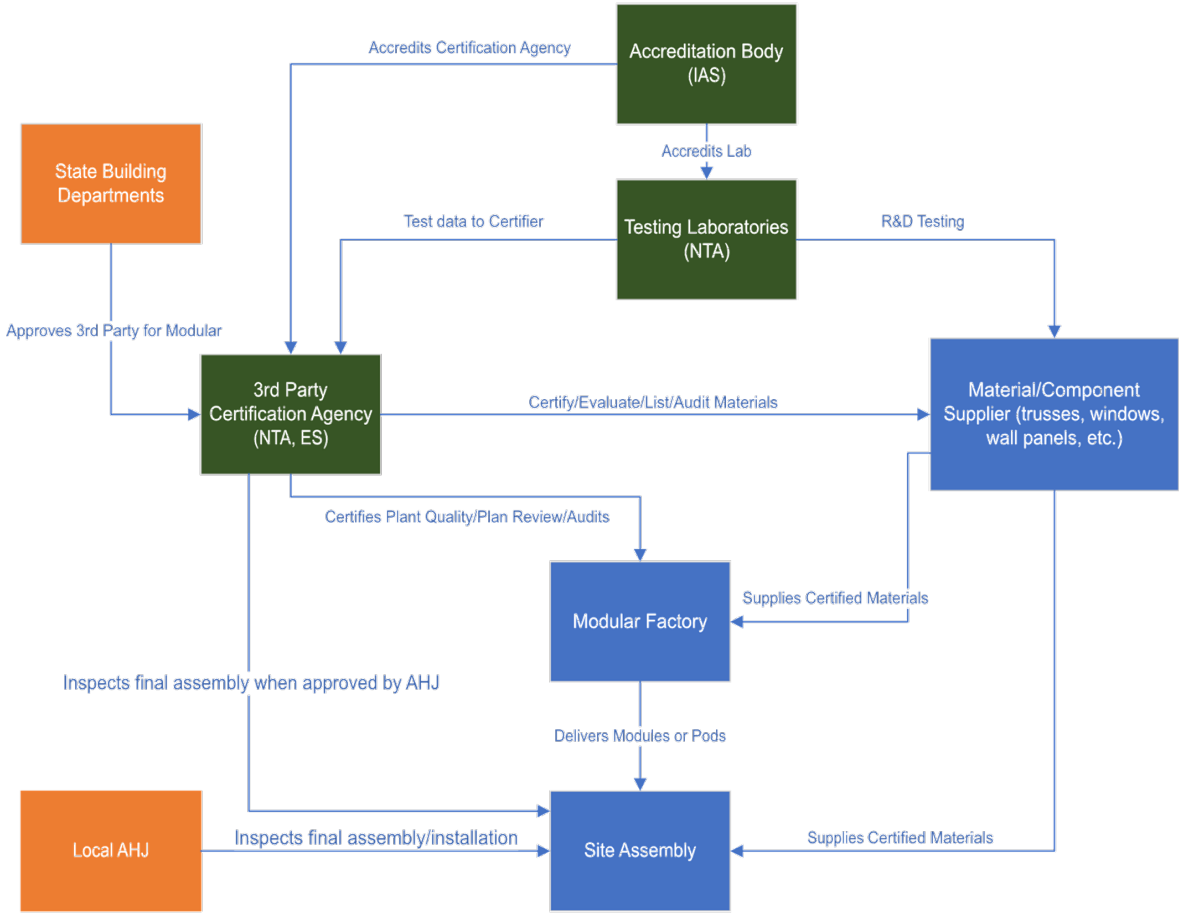
- ICC/MBI Standard 1200/1205



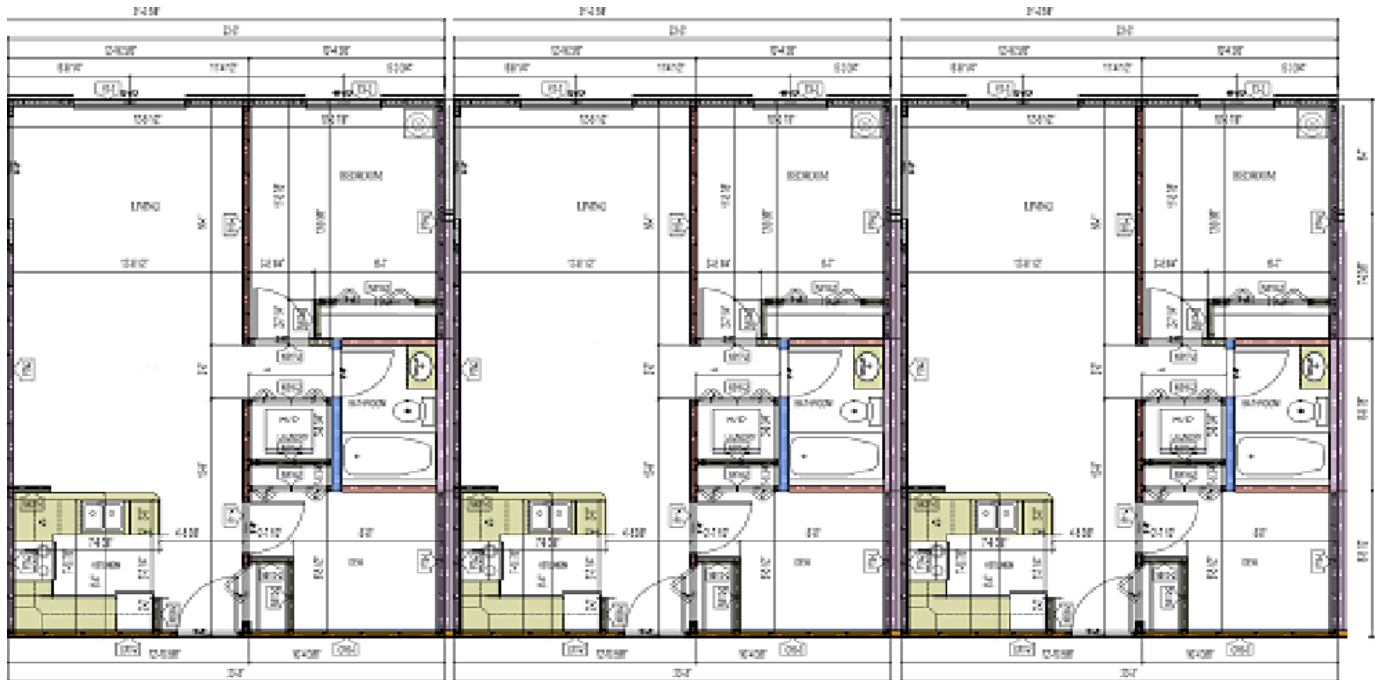
Multiple Off-Site Approaches



Off-Site Construction Regulatory Process



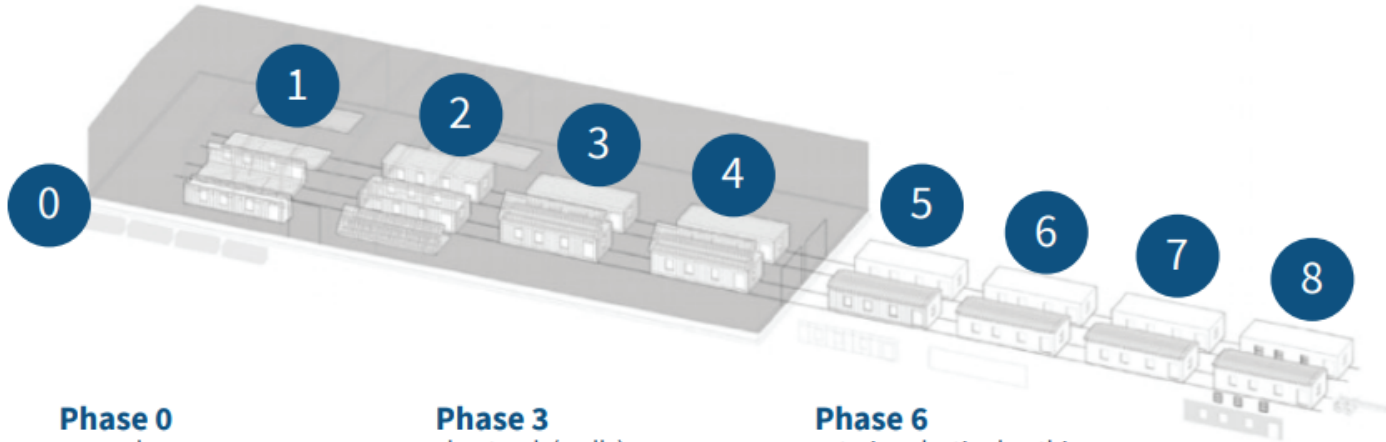
Plan Review



In-Plant Inspection



The Fabrication Process



Phase 0

general
material assembly

Phase 1

floor framing and decking
int./ext. wall framing
“box” mounted to chassis

Phase 2

roof framing/mounting
ceiling attached to “box”
interior partition installation
rough plumbing

Phase 3

sheetrock (walls)
rough electrical (walls)

Phase 4

sheetrock (ceiling)
batt/spray foam insulation
rough electrical

Phase 5

exterior plywood sheathing
rough opening cleanup
general interior cleanup

Phase 6

exterior plastic sheathing
interior finish work
(paint, trim)

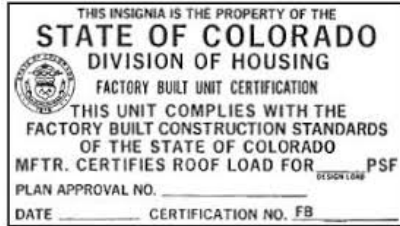
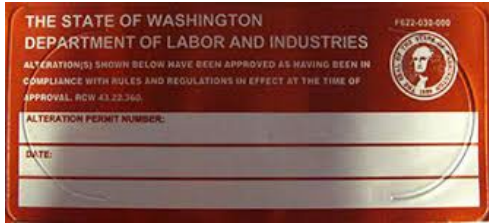
Phase 7

finish plumbing
finish electrical
install flooring

Phase 8

install windows
install siding
weatherproof

Local Code Officials

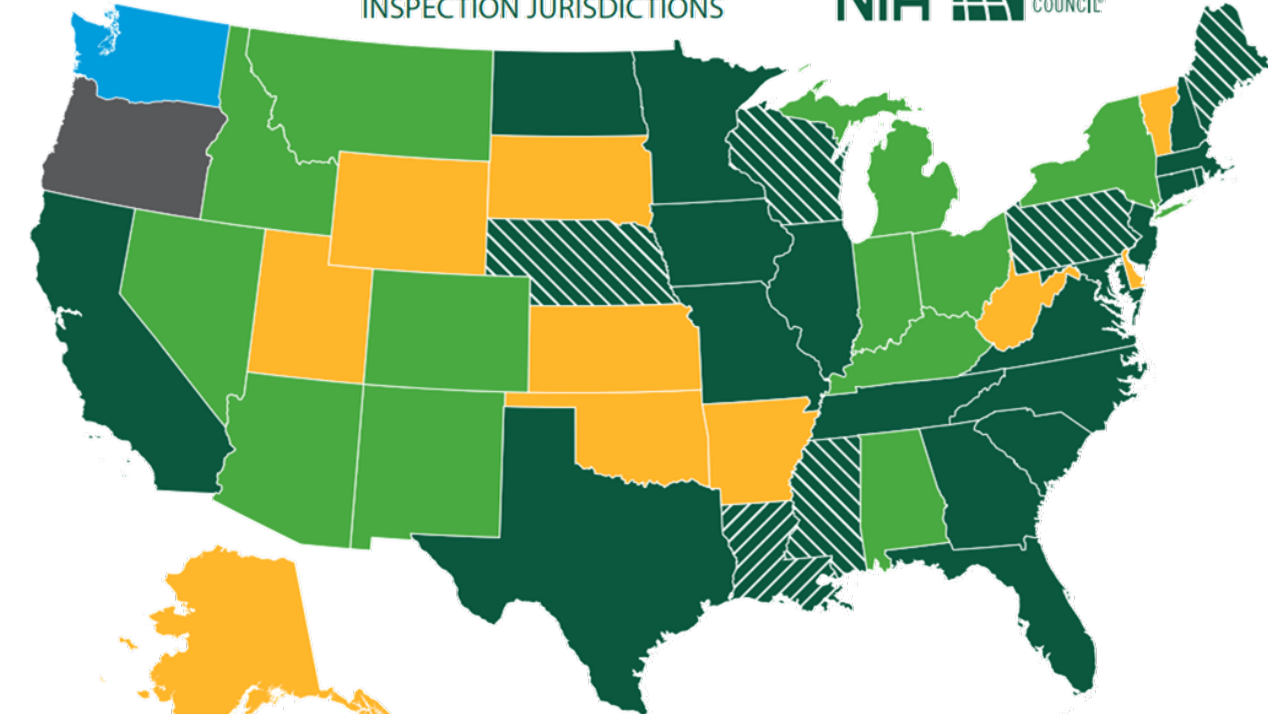


Colorado State Modular Code Label



Regulation of Off-Site Construction

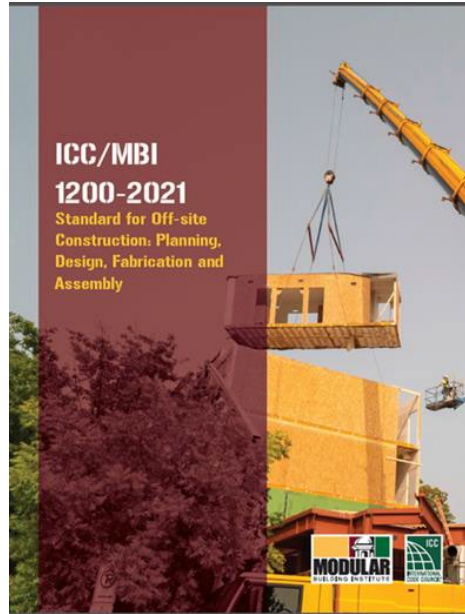
PLAN REVIEW
INSPECTION JURISDICTIONS



- Third Party Plan Review & Third Party Inspection
- Third Party Plan Review & Third Party Inspection – Commercial only
- Third Party Plan Review & Third Party Inspection – Residential only
- Third Party Plan Review & State Inspection
- State Plan Review & Third Party Inspection
- Local Plan Review & Local Inspection
- State Plan Review & State Inspection



New Off-Site Construction Standards



Developed by the
ICC/MBI Off-Site and
Modular Construction
Standard Consensus
Committee (IS-OSMC)

ICC/MBI Standard

1210 (upcoming)

Mechanical, Electrical,
Plumbing Systems, Energy
Efficiency and Water
Conservation

<https://www.iccsafe.org/offsite>

ICC/MBI Off-Site Construction Standards

ICC/MBI 1200: Planning, Design, Fabrication and Assembly

“...provide minimum requirements to safeguard the public health, safety, general welfare and address societal and industry challenges in multiple facets of the off-site construction process including: planning, designing, fabricating, transporting and assembling...”

ICC/MBI 1205: Inspection and Regulatory Compliance

“...provide minimum requirements to safeguard the public health, safety, general welfare and address societal and industry challenges for the inspection and regulatory compliance of off-site and modular construction.”

Manufactured Housing



**HUD Manufactured Home
Construction and Safety Standards;
Local Codes (Foundation, Site,
Utilities, Accessories)**





Primer on Off-Site Construction, Codes, Standards and Compliance

August 2022
www.iccsafe.org



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Solutions for Today's Challenges

What is Off-Site Construction?

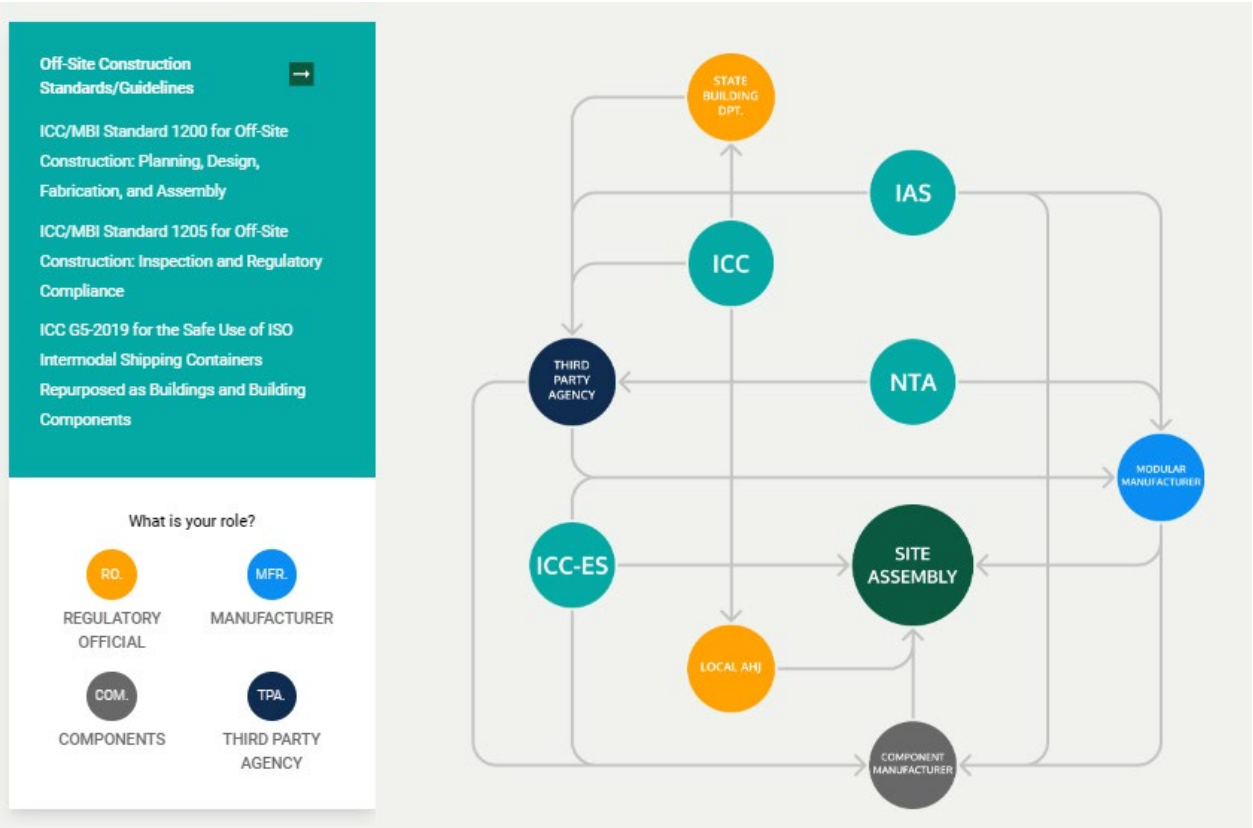
The process of constructing buildings or components of buildings in a factory to increase quality, sustainability and job site safety to project completion over site-building projects. The International Code Council helps project teams and communities unlock the potential of off-site construction.

[WATCH VIDEO](#)



<https://solutions.iccsafe.org/offsite>

Off-Site Construction Solutions Map



Adopting ICC/MBI 1200 & 1205

Jurisdictions can adopt now as stand-alone effort or part of code adoption.

Incorporate into Building Code & Residential Code:

- IBC Section 429 (new)
- IRC Section 301.1.5 (new)

Salt Lake City, UT adopted March 2021

Active efforts in multiple states



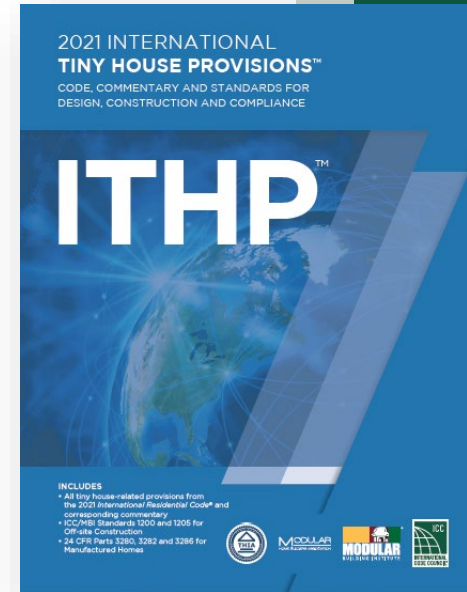
“On a large scale, widespread adoption of the standards effectively reduces the burden of navigating the current patchwork of regional regulations and promotes industry standardization, allowing manufacturers to operate more efficiently and expand their markets.”

<https://advancedbuildingconstruction.org/codes-working-group-brief-new-off-site-construction-standards/>

International Tiny House Provisions

Developed with Tiny Home Industry Association (THIA), Modular Buildings Institute & Modular Homebuilders Association
Single source of codes, standards & other guidance for tiny houses

- Introduction to tiny houses
- Model legislation
- IRC with Appendix AQ integrated including commentary
- HUD Manufactured Housing Standards
- ICC/MBI Standards 1200 & 1205
- References to recreational vehicle standards



Additional Off-Site Resources



Primer on Off-Site Construction, Codes, Standards and Compliance

August 2022
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FAQs on Off-Site Construction

Why is there a growing interest in off-site construction?

The use of off-site construction is expected to increase significantly as the building industry and society struggles to address key challenges including the availability of affordable housing, a lack of skilled workers, material use and sustainability, job site safety and industry productivity.

What is off-site construction? Pre-Fab? Modular?

Off-site construction (also called pre-fab or modular construction) is defined by the [National Institute of Building Sciences Off-Site Construction Council](#) as, "the planning, design, fabrication and assembly of building elements at a location other than their final installed location to support the rapid and efficient construction of a permanent structure. Such building elements may be prefabricated at a different location and transported to the site or prefabricated on the construction site and then transported to their final location." Often, the broad concept of off-site construction is broken into additional characteristics including open versus closed construction, permanent versus relocatable and manufactured housing versus modular housing versus tiny homes.

What is the difference between open construction and closed construction?

Closed construction means that the final product cannot be inspected at the installation site without disassembly, damage or destruction. Open construction still allows for inspection of the product at the installation site. The fact that a closed construction product cannot be readily inspected at installation has caused the regulatory process to move into the factory. Examples of open construction include mechanical racking and certain panels (without embedded MEP for instance). Examples of closed construction include volumetric modules, pods, and some panelized systems.

www.iccsafe.org Page 1

Facilitating Affordability, Sustainability Goals through Standards for Off-site Construction

With national housing costs rising 52 percent from 2017 to 2022, modular construction offers an affordable solution, capable of curbing construction timelines and reducing costs.¹ Off-site construction can deliver projects 20 to 50 percent faster than traditional methods, which can provide cost savings of up to 20 percent.²

Off-site construction includes a variety of processes including production of volumetric modules (fully enclosed rooms with six sides), wall panels with integrated insulation and building system components, bathroom or kitchen pods, pre-fabricated accessory dwelling units (ADUs), tiny homes, and shipping containers, that are fabricated in a factory. Doing so enables economies of scale, increases job site safety, can ensure greater and more consistent construction quality, and enhanced sustainability through reduced waste and product spoilage. Off-site construction processes vary from traditional construction such that traditional on-site inspection methods are not adequate to determine compliance with building codes.

Currently, a patchwork of compliance processes exist for off-site construction—hindering some of the efficiency gains that off-site construction can provide.

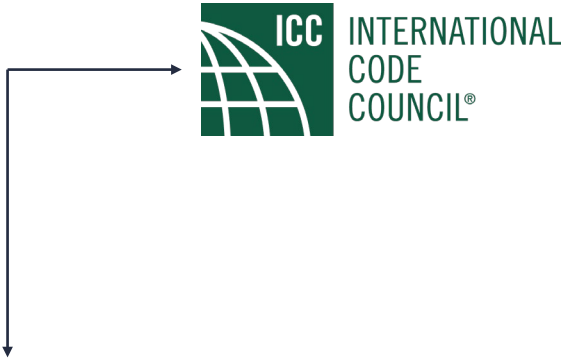
The Current Gap in Consistency of the Off-site Construction Process

Currently, 39 states, plus Washington, D.C., regulate off-site construction at the state level. State programs are responsible for plan review and inspection of off-site construction components. However, these programs vary significantly from state to state—some states allow third-party agencies (like ICC-NITA) to conduct both plan review and in-factory inspections whereas others only allow state employees to perform these functions. There is also inconsistency in the types of projects and components covered in each state—some only cover

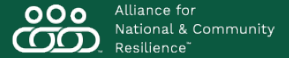
1. S&P Case-Shiller U.S. National Home Price Index (2017 to 2022) <https://fred.stlouisfed.org/graphs.aspx?v=1>
2. McKinsey & Company, Modular construction: From projects to products (June 2019), Gensler et al., Building Affordability by Building off-site: Exploring the Benefits, Barriers, and Breakthroughs Needed to Scale Off-Site Multifamily Construction, Turner Center for Inclusive Housing at UC Berkeley (Mar. 2017).

Facilitating Affordability, Sustainability Goals through Standards for Off-site Construction Page 1

solutions.iccsafe.org/offsite



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Buildings XV Conference

December 5-8, 2022 | Clearwater Beach, FL



Off-Site Construction (Practices)

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University of Nebraska-Lincoln

J. Elliott, PhD and J. Killingsworth, PhD
Colorado State University

I. Blanding and M. Tyler, PE
Pacific Northwest National Laboratory

C. Dennehy, N. Cindrich and S. Pless
National Renewable Energy Laboratory

Kevin.Grosskopf@unl.edu

Modular Multifamily Construction: A Field Study of Energy Code Compliance and Performance Through Offsite Prefabrication



Introduction

- Prefabrication in a controlled, factory setting may improve energy code compliance and energy performance compared to site-built construction
 - Goal 1 - compare key **energy code compliance** measures of 10 modular and 10 site-built multifamily buildings under construction
 - Goal 2 - compare **energy performance** (kBtu/sf/yr) of 25 completed modular multifamily buildings to 120 completed site-built buildings
- Los Angeles (CZ3b), San Francisco (CZ3c), Philadelphia (CZ4a) and Seattle (CZ4c)
- Title 24, IECC 2015 and 2018

Background



- Reduced schedule
- Reduced weather delays
- Improved productivity and safety

- Added transportation costs
- Less adaptable
- Perception of inferior quality

Background



Compliance - Methods

Data Category	Data Collected	Document Review	Factory Inspection	Site Inspection
Building	Location, gross floor area, conditioned floor area, story height, dwelling units	✓		
Code	Climate zone, code, code year, compliance path	✓		
Roof	Assembly type, area, reflectance, insulation type, U-factor, install quality	✓	✓	
Wall	Assembly type, area, orientation, insulation type, U-factor, install quality	✓	✓	
Window	Assembly type, area, U-factor, SHGC, frame type, pane type, WWR	✓	✓	
Air Barrier	Assembly type, air leakage rate	✓	✓	
HVAC	Equipment type, energy source, capacity, efficiency, unit count, duct location	✓	✓	✓
Controls	Thermostat type, deadband, setback, ventilation night fan control	✓		✓
DHW	Equipment type, energy source, capacity, efficiency, unit count, pipe	✓	✓	✓
Controls	Temperature, recirculation control, heat trap	✓		✓
Lighting	Fixture type, fixture wattage, interior/exterior location, LPD	✓		✓
Controls	Manual, occupancy sensor, dimmer, daylight, photocell, time switch	✓		✓

Compliance - Results

	Modular (<i>n</i> = 11)			Sitebuilt (<i>n</i> = 9)		
	Min	Max	Avg	Min	Max	Avg
Floor Area (GSF)	36,000	536,000	136,000	21,000	689,000	167,000
Story Height	4	7	6	4	9	6
Residential Units	40	410	127	14	363	111

	Climate Zone 3				Climate Zone 4			
	Modular	n	Sitebuilt	<i>n</i> *	Modular	n	Sitebuilt	<i>n</i> *
Roof (U)	0.027 ←	6	0.030	13	0.027	5	0.026 ←	3
Wall (U)	0.050 ←	6	0.051	16	0.046 ←	5	0.049	4
Window (U)	0.29	6	0.29	15	0.28 ←	7	0.29	8
Window (SHGC)	0.22 ←	6	0.23	15	0.29	6	0.29	8
Window-Wall Ratio	0.16 ←	6	0.24	7	0.25	5	0.24 ←	2
HVAC (SEER)	16.2 ←	9	14.9	7	13.8	6	14.2 ←	5
HVAC (HSPF)	9.7 ←	8	9.1	7	10.7	6	11.7 ←	2
DHW (UEF)	0.95 ←	8	0.89	6	0.94 ←	4	0.92	2
Lighting (W/sf)	0.28	6	0.23 ←	6	0.32 ←	5	0.47	1

Performance - Methods

- Energy Star Portfolio Manager
- Annual energy benchmarking data publicly available in each study region by building type, size, age, etc.
 - Energy use by source
 - Energy use intensity (kBtu/sf/yr)
 - Greenhouse gas emissions

Performance - Results

	Modular				Sitebuilt					
	CZ	Year Built	Data Range	GSF	Avg Site EUI	Avg E-Star Score	No. of Bldgs	Avg GSF	Avg Site EUI	Avg E-Star Score
Mod 1	3B	2013	2017-20	69,111	45.2	58	10	68,658	37.2	74
Mod 2	3B	2017	2020	386,000	40.7	65	10	282,133	38.0	76
Mod 3	3C	2014	2019-20	500,000	30.9	95	10	253,521	38.4	78
Mod 4	3C	2019	2019-20	50,406	56.3	79	7	230,829	25.6	84
Mod 5	3C	2017	2019-20	107,521	51.7	87	10	195,892	29.9	87
Mod 6	3C	2017	2019-20	162,575	27.9	96	10	195,892	29.9	87
Mod 7	3C	2016	2019	66,813	57.1	93	10	122,263	30.6	86
Mod 8	3C	2017	2019-20	198,258	22.2	100	10	248,628	41.6	79
Mod 9	4A	2016	2018-20	65,864	33.4	78	10	189,307	44.1	62
Mod 10	4A	2012	2016-20	129,330	53.3	81	10	122,523	44.2	65
Mod 11	4A	2019	2020	218,277	15.0	100	7	138,605	32.9	81
Mod 12	4C	2014	2015-20	47,343	30.2	98	10	62,781	38.9	84
Mod 13	4C	2017	2019-20	41,132	24.2	-	5	42,903	31.4	92
Mod 14	4C	2018	2019-20	167,777	22.3	100	10	201,979	27.9	94
Average				157,125	36.4	87	129	167,494	35.0	81

Performance - Results

- Energy performance of site-built (35.0 kBtu/sf/yr) slightly better than modular (36.4 kBtu/sf/yr)
- Occupant density in modular buildings ~50% greater than site-built
- Normalized for occupant density and other energy use factors, average Energy Star score for modular (87) exceeded site-built (81)

Air Leakage



	Number of Units	Average Unit Floor	Average Unit ACH	Average Unit cfm/sf*
Modular units (project)	7	460	6.0	0.22
Site-built units (project)	11	810	4.7	0.23
Site-built units (project)	8	1,975	3.7	0.21

* Cubic feet per minute (cfm) of air leakage per square foot (sf) of unit envelope area.

Conclusions

- Few differences between materials and equipment used in modular and site-built construction
- Quality controls and installation quality for envelope measures better on average for modular construction

Conclusions



Bibliography

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ANSI/RESNET/ICC 380-2019 Standard for Testing Airtightness of Dwelling Unit Enclosures.

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Questions?

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Thank You!

Building Energy Codes Program

www.energycodes.gov/training

BECP help desk

<https://www.energycodes.gov/technical-assistance/help-desk>



NECC Seminar Series Lineup

Catch the entire lineup of sessions bi-weekly—Thursdays @ 1p ET:

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