

# Integrating Energy Efficiency and Distributed Energy Resources into Advanced Manufacturing of Buildings



National Renewable Energy Laboratory

Shanti Pless, Senior Energy Efficiency Research Engineer

[Shanti.Pless@nrel.gov](mailto:Shanti.Pless@nrel.gov)

2019 New Project

# Project Summary

## Timeline:

Start date: October 1, 2018

Planned end date: September 30, 2021

## Key Milestones

- 4/15/2019: Convene Energy in Off-Site Industry Advisory Panel and Secure factory partners
- 9/30/2019: Market Interest confirmed, factory standard practices documented, and energy efficiency packages for off-site construction identified

## Budget:

### Total Project \$ to Date (February 2019):

- DOE: \$257k
- Cost Share: \$NA

### Total Project \$ over 3 years:

- DOE: \$4,500k over 3 years
- Cost Share: 10%

## Key Partners:

Momentum Innovation	ModLab/WSU
Factory OS	
Full Stack Modular	
Jones Buckley	
Modular Building Institute	

## Project Outcome:

Demonstrate a viable pathway to 50%+ savings in multifamily by leveraging the benefits of off-site volumetric modular factory construction to address energy efficiency barriers of:

- Poor installation quality
- High installation costs
- Difficult to commission control systems.

# The Need for Lots of New Apartments

- The country will need to build an average of 324,000 new apartments each year to keep up with demand.
- At least 4.6 million new apartments by 2030
- 20.4 million existing apartments today
  - As many as 11.7 million will need to be renovated by 2030

*63% of apartments in 2030 will be new or renovated*



[weareapartments.org/Vision2030.pdf](https://weareapartments.org/Vision2030.pdf)

MCKINSEY GLOBAL INSTITUTE

# REINVENTING CONSTRUCTION: A ROUTE TO HIGHER PRODUCTIVITY

FEBRUARY 2017

IN COLLABORATION WITH  
MCKINSEY'S CAPITAL PROJECTS & INFRASTRUCTURE PRACTICE

***“America’s construction industry productivity is lower today than it was in 1968.”***

“Parts of the industry could move toward a manufacturing-inspired mass-production system, in which the bulk of a construction project is built from prefabricated standardized components off-site in a factory. Adoption of this approach has been limited thus far, although it’s increasing. Examples of firms that are moving in this direction suggest that a productivity boost of five to ten times is possible.”

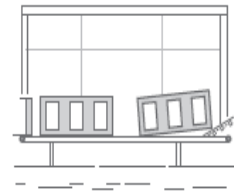
<http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/reinventing-construction-through-a-productivity-revolution>



# Permanent Modular Offsite Construction

- 20%-40% faster to build
- 5%-95% of a building can be constructed offsite in a factory
  - Volumetric modular, wall panels, etc
- 3% of new construction in 2017
  - Multifamily and hotels
- Higher quality
- Can be cheaper to build...
- Any program that can be modularized
- New investment from outside construction industry

***But does it result in more efficient buildings? Perhaps...***



Assembled in a factory



Transported to site

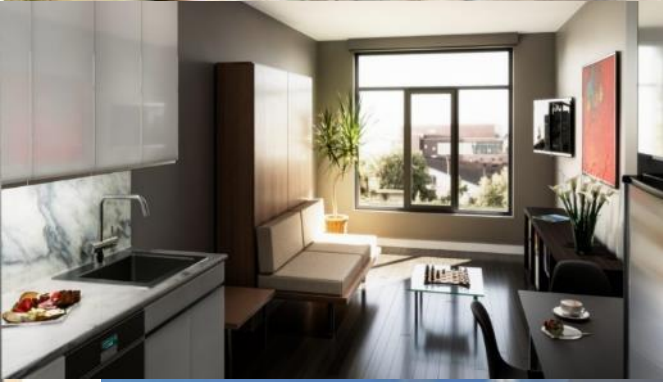


Assembled



Connect to grid

# Prefab housing complex for UC Berkeley students goes up in four days



The prefab modular grad student housing building at 2711 Shattuck Ave. (left) photographed on Aug. 1. Photo: Tracey Taylor

## Apartments Built in China

<https://www.berkeleyside.com/2018/08/02/prefab-housing-complex-for-uc-berkeley-students-built-in-four-days>



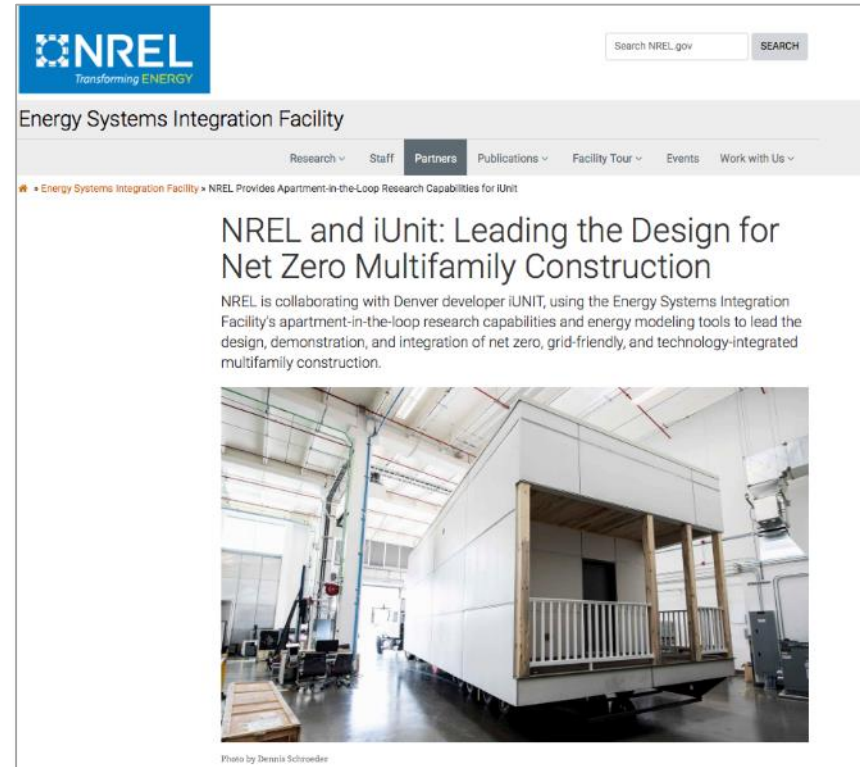
# Modular Apartment Research Platform Background

## Prototype Apartment: Studio Apartment in-the-loop at DOE/NREL's ESIF User Facility

- Integration research platform to optimize factory built apartment design, technology, and operation

## Developed solutions to be implement and scale to the offsite multifamily modular marketplace

- Modeling platform, factory installed high quality envelope, tenant engagement feedback and metering, peak demand management, modular HVAC, hot water heat recovery



# Integrating Energy Efficiency into Advanced Manufacturing of Buildings

Goal:

To leverage the emerging off-site construction and prefabricated manufacturing approaches to achieve cost effective high performance and grid integrated buildings in multifamily and hotel sectors

*“How can optimal integration of energy efficiency strategies and control systems be achieved through advanced manufacturing techniques and technologies with little or no additional cost?”*



# Approach – Year 1

Engage innovators in advanced manufacturing advisory group



Partner with offsite modular factory and pilot projects to:

Baseline existing approaches to understand opportunities for energy efficiency and grid friendly enhancements

Develop factory process improvement recommendations based on advanced manufacturing approaches to implement cost effective efficiency recommendations

Validate costs and savings in pilot BAU Offsite factory and projects

# Year 2 and 3

## Develop

Develop Factory Information Model (FIM) datasets and process diagrams of recommended factory improvements

## Integrate

Integrate FIM with building models (energy and information) to make the case for advanced manufacturing enhancement for energy efficiency and grid-integration

## Validate

Validate pilot factory enhancements and building improvements in pilot projects

# The Focus Market

- **Off-site volumetric modular prefabricated units for new construction of:**
  - Multifamily apartments/condos and mixed use
    - 40%+ of new commercial real estate construction in the US in 2017 (CoStar stats)
    - Includes affordable, senior care, market rate apartments,
  - Hotels, student housing, barracks, etc.
- **Can also apply to major renovations of apartments and multifamily**
  - Industrialized off-site prefabricated retrofit packages
    - Envelope panels
    - Modularized HVAC, hot water, control packages
  - Frequent planned renovations of rental market to maintain competitiveness across rental multifamily marketplace
    - Expect carryover of solutions from apartment sector to townhomes and urban residential retrofit marketplace



# The Team

## NREL Buildings Researchers

Zero Energy Buildings

Open Studio Tool Integration and life cycle cost optimization

Apartment-in-the-Loop Research Platform

## Industry Advisory Group

Inform team of industry barriers and opportunities

Quarterly calls and annual in-person meetings

Disseminate results to off-site industry

- Dr. Ryan Smith: WSU ModLab Director
- Modular Building Institute
  - Industry Trade Association, World of Modular,
- Additional factories, projects, industry members

## Factory Partners with Pilot Projects

Factory OS

Johns Buckley

FullStack Modular



# Industry Advisory Group

## Advisory Group Goals

- Provide guidance and technical support to project team
- Provide insight/support in development of modular industrialization standards document which can be shared w/ other industry players

## 50+ interested industry participants in the areas of interest:

- Smart Apartment Technology integration
- Data/software for design to factory to installation
- Modular scale Systems (HVAC, water heating, renewables, etc.)
- Building envelope
- Site assembly
- Automation and advanced manufacturing factory partners
- Owners, Developers and Housing Agencies with pilot project interests
- Codes, industry outreach and research, other
- Standards/Industrialization

# Our Role



**Energy Efficient buildings system integration expertise in Commercial, Residential, and Multifamily**

Volumetric modular prototype apartment in the laboratory at NREL

<https://www.nrel.gov/esif/partnerships-iunit.html>

Zero Energy Mixed Use Advanced Energy Design Guide development



**Assessment of existing approaches to prefabrication and energy efficiency strategies**

Data collection, prefabrication recommendations, strategy improvements based on leading industry best practices



**Recommendations for prefabrication improvements to reach zero energy ready solutions cost effectively while addressing industry quality barriers**

Energy and life cycle cost optimization

OpenStudio Building Energy Model Platform integration into design and factory process

Prefabrication innovation



**Independent validation and recognition of attempted innovations to utilize prefabrication benefits to cost effectively reach energy goals**

Offer neutral third-party measurement and verification

- Data acquisition equipment and installation
- Assessment of performance



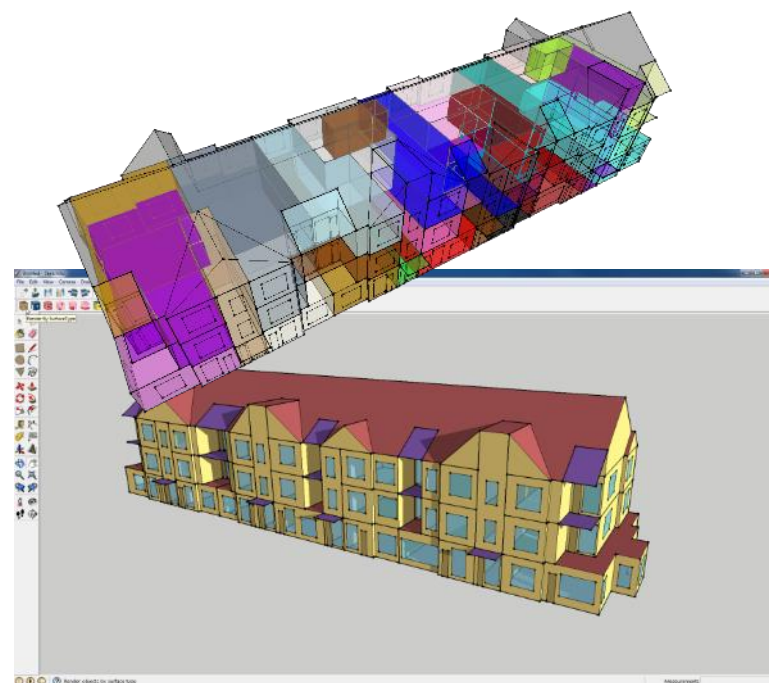
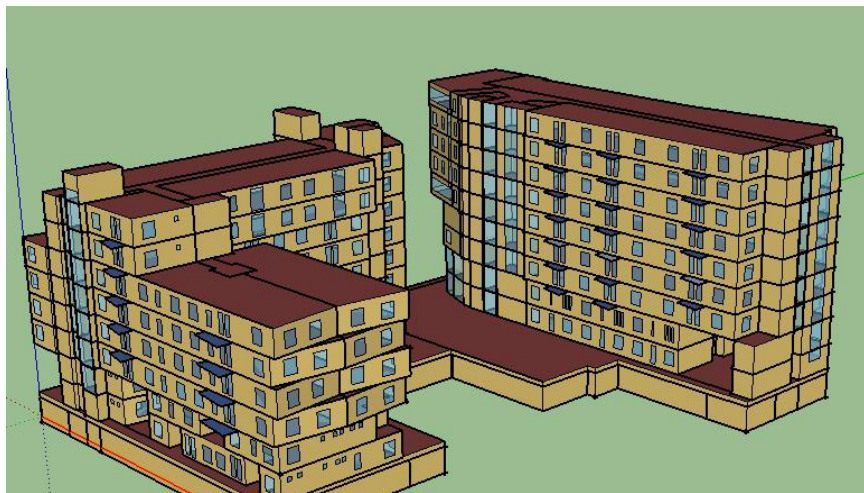
# Offsite Factory Partner Role

- **Willing to partner to improve prefabrication process to target high performance and zero energy ready**
  - CRADAs, NDAs, etc to formalize partnership
  - Make existing prefabrication process available for evaluation
- **Actively interested and prepared with project partners within 1 year**
- **Open to considering improvement recommendations in prefabrication process**
- **Willing to partner to make future projects available for field data collection for measurement and validation**
- **Contribute to advancement of high performance building practices in offsite construction through participation in Energy Efficiency in Advanced Manufacturing Industry Advisory Group**
  - Quarterly calls to discuss challenges and opportunities
  - 2 in-person meetings
  - Commit to approving public participation in press, website, outreach

# Energy Efficiency and DER in Offsite: Possible Pathways for EE Integration

## Building Energy Modeling integration into the digital design-factory process and software tools

- OpenStudio energy modeling platform integration
- Off-line life cycle cost analysis for standardized designs
- Streamline energy design modeling of individual projects
  - Zero energy design
  - Code compliance, LEED, etc.



# Energy Efficiency and DER in Offsite: Possible Pathways for EE Integration

## Envelope

–Maximize life cycle cost savings of insulation systems that include factory installation cost profile

- More insulation at a better quality possible with lower installation costs
- Additional wall/floor/roof cavities available due to structural requirements of volumetric modular

–Utilize inherent envelope air barrier quality control opportunities to ensure higher air tightness

- Low infiltration levels can be reached more cost effectively and inherently
- Common interface issues around windows can be detailed and installed with higher quality
- Manufacturing line air barrier quality control testing

Photo by Dennis Schroeder, NREL



# Energy Efficiency and DER in Offsite: Possible Pathways for EE Integration

## EE Controls and Occupant Engagement Platform

- Explore viable integration of EE and GEB controls into emerging smart apartment technology solutions
- Grid integrated HVAC and hot water controls that optimize to utility price signals and renewables
- Enable single utility meter with software submetering and tenant feedback with monthly budgets
- Develop factory quality control measures to ensure EE controls and data platform work as intended from factory
- “Smart Apartment” in a box



Photo by Dennis Schroeder, NREL

## News & Media

# Skender Celebrates Unveiling of Modular Smart Apartment Prototype

November 27, 2018



Share [f](#) [t](#) [in](#)

CHICAGO (Nov. 27, 2018) – Smart phones roll off the factory assembly line—and now, smart apartments. Skender’s vision for a modular building process has reached a milestone: an actual smart apartment module prototype is complete and on-display, featuring Google Home technology systems throughout its structure. The prototype is an early version of the apartment units that will be built in Skender’s factory for a building in Chicago’s West Loop early next year.

Yesterday, Skender unveiled its smart apartment prototype in Skender’s advanced manufacturing facility on the southwest side of Chicago. The prototype demonstrates how modular design and construction has the potential to disrupt the building process making the design, manufacture and construction of buildings safer, faster and more affordable, as well as more technology and environmentally friendly.

The prototype offers a way to leverage a technology-based solution to the affordable housing crisis, and more broadly, to keep construction costs manageable and significantly reduce schedules for market-rate

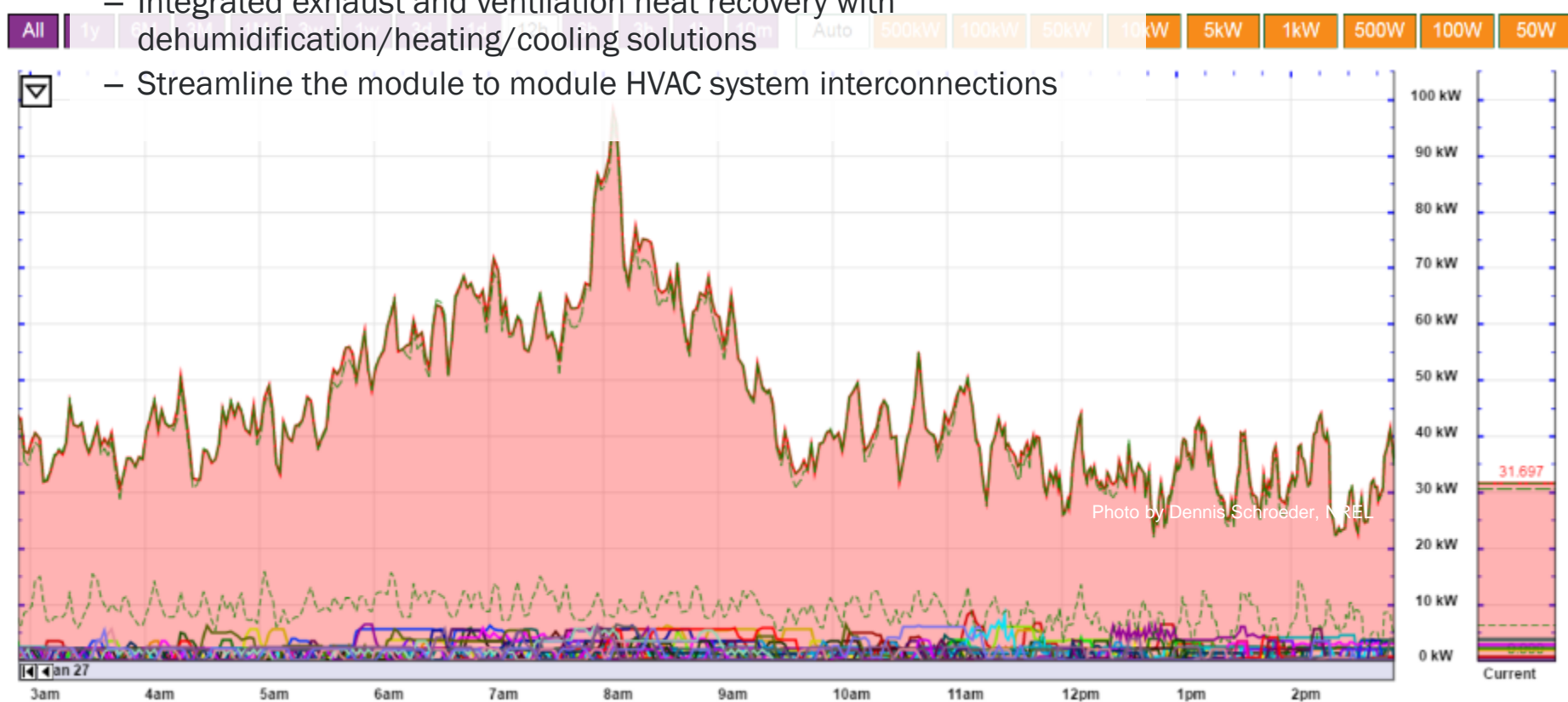
**“We have already uncovered several manufacturing efficiencies through the creation of this prototype, including the ability to install smart apartment tech at a fraction of the cost it would normally take to install in an already-existing unit”**

<https://www.skender.com/news-media-item/skender-celebrates-unveiling-of-modular-smart-apartment-prototype/>

# Energy Efficiency and DER in Offsite: Possible Pathways for EE Integration

## Volumetric modular scale HVAC to maximize equipment off-site installation

- Identify modular scale HVAC system with efficiency of larger centralized systems
- Integrated exhaust and ventilation heat recovery with dehumidification/heating/cooling solutions
- Streamline the module to module HVAC system interconnections





# Energy Efficiency and DER in Offsite: Possible Pathways for EE Integration

## Renewables

- Single meter to enable large scale PV, with unit submetering
- Modular electrical room(s) with battery UPS and demand management
- Façade rainscreen and roof top PV installed offsite
- Document cost savings pathways for replication



Ryan Wallace  
Solar Home Factory

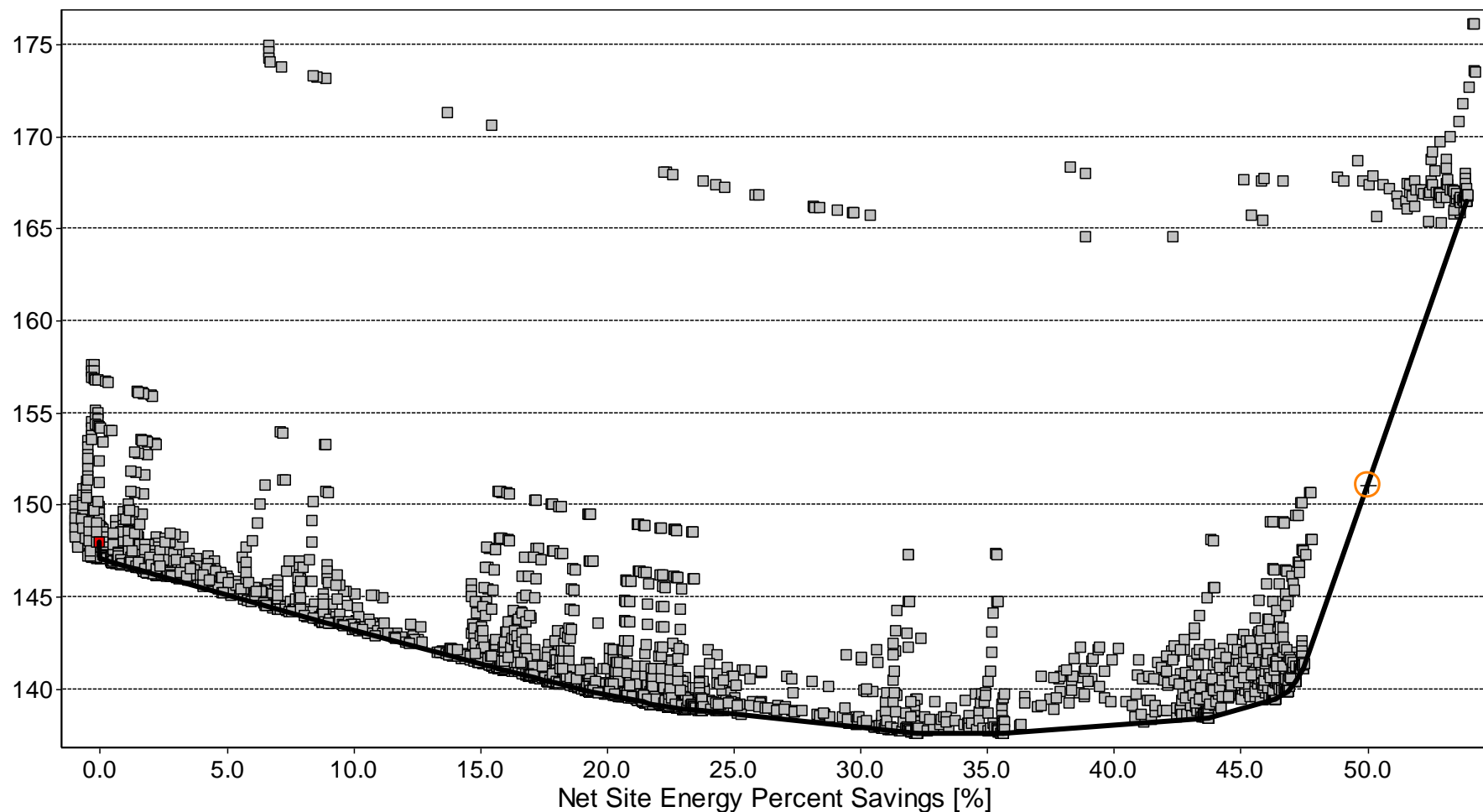
“Factory installed solar reduces the cost of residential solar by 40%”

[www.solarhomefactory.com](http://www.solarhomefactory.com)



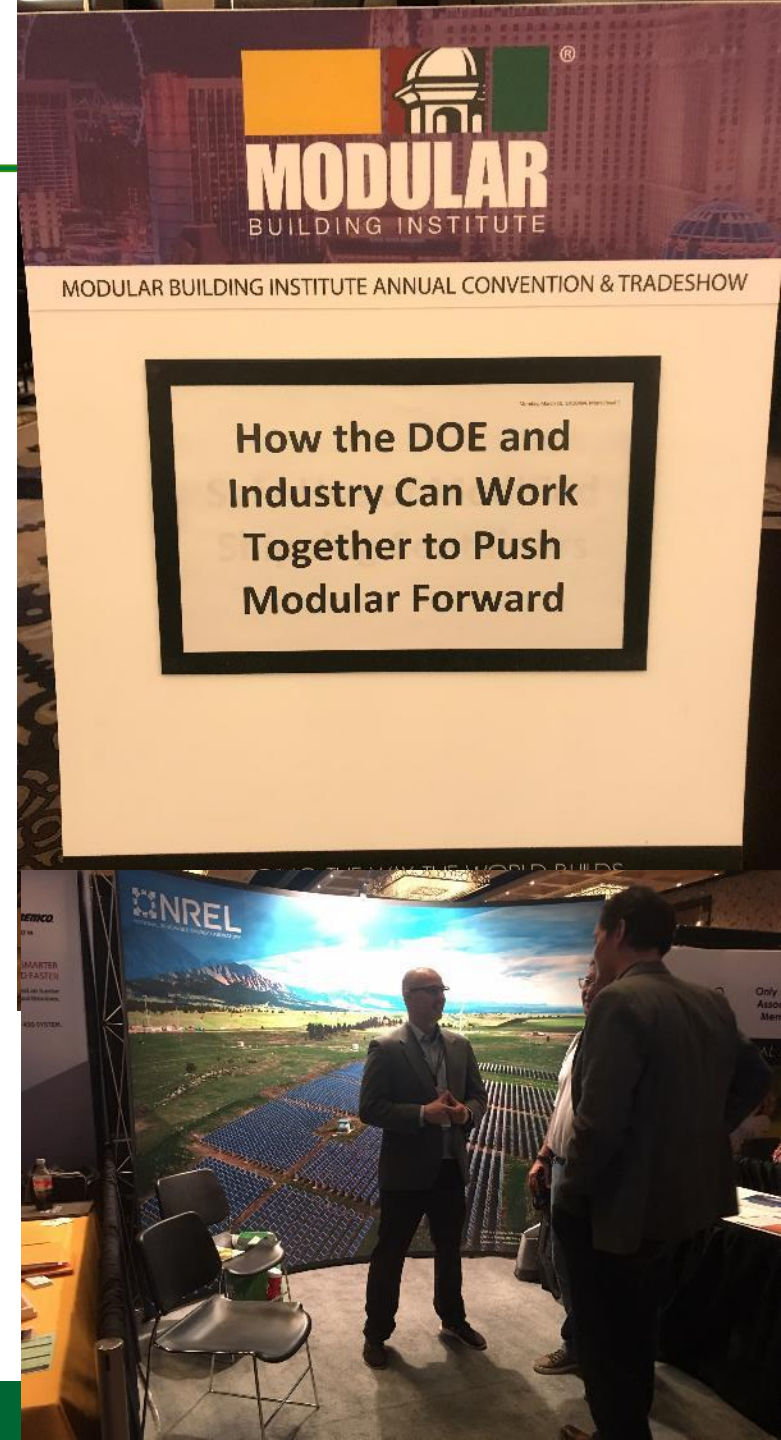


# Moving the Life Cycle Cost Optimal with Offsite



# Progress

- 6 Months into a 3-year project
  - Held kickoff at World of Modular March 16-18, 2019
  - Announced industry advisory panel and recruited leading industry partners
    - New market and new partners
  - Secured partnership agreements with leading commercial off-site construction factories
- By end of 2019:
  - Baseline dataset from factory partners
    - Cost, performance, design approach, BAU savings, factory standards
  - Industry advisory panel feedback
  - Develop initial set of energy solutions for factory partners to consider
    - Design process models and life cycle cost assessment
    - Smart Apartment technology platform
  - An opportunity for factory partners to explore solutions to be able to meet next round of efficiency codes before they invest in factory line changes



---

# Thank You

Shanti Pless  
Stacey Rothgeb

---

# REFERENCE SLIDES



# Project Budget

**Project Budget: \$1,500k/yr for 2019, 2020, 2021**

**Variances: None to date**

**Cost to Date: \$257k to date**

**Additional Funding: None to date**

**Cost Share: TBD – Will be expected from factory partners as investment in implementation of factory process improvements and piloting of efficiency recommendations**

## Budget History

FY2018 (past)		FY2019 (current)		FY2020 – FY2021 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
		1,500k	TBD	3,000k	TBD

# Project Plan and Schedule

**New Project: Start October 2018, End Sept 2021**

Milestone Name/Description	Criteria	Due Date
Kick-off Innovation Advisory Panel Report Out	In Q2, Convene an Energy Efficiency in Off-Site Construction Innovation Kick-off Advisory Panel to define current US off-site manufacturing processes and propose factory improvements. Provide an advisory panel report-out documenting the key strategies, next steps, and innovation focus areas.	4/15/2019
An Off-site Factory Information Model Summary	An Off-site Factory Information Model flow chart documenting standard manufacturing approaches, material flow, and factory data and cost information.	9/30/2019
Integrated EE and Advanced Commissioning Packages	Develop integrated packages, documenting the most beneficial, factory implemented energy efficiency, automated commissioning, and quality control savings including steps and key levers to implement these packages.	12/15/2019



## Advance Prefabricated Building Manufacturing

Are you interested in partnering with NREL? We're looking for building manufacturers, developers, and prefabrication factory operators for our Integrating Energy Efficiency and Distributed Energy Resources into Advanced Manufacturing of Buildings Project. Partners will help overcome barriers of cost, speed of construction, and limited labor expertise using advanced manufacturing techniques to achieve cost-effective zero energy ready goals.

### Partnership Benefits

Through the project, partners will be better able to:

- Achieve cost-effective optimal integration of energy efficiency strategies and control systems by leveraging innovation in modular construction practices
- Receive recommendations, energy modeling assistance, and more from NREL experts to help reduce costs, improve efficiencies, and save energy in high-performance buildings
- Provide insight into production processes, access to prototypes for study, and connections to real-world developments for validation.

### Applications

The integration and process-improvement outcomes of this project can be applied to:

- Multifamily apartments/condos
- Barracks
- Hotels
- Student housing
- Retrofit packages.



## Project Scope

ACHIEVING ZERO ENERGY BUILDINGS THROUGH COST-EFFECTIVE ADVANCED MANUFACTURING

- 2019** Assess factory-standard processes and baseline measurements
- 2020** Develop prototype(s) that will be validated with partners
- 2021** Evaluate new product(s) at complete building/production scale to ensure success