Window-Wall Integrated Panel

LBNL
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ORNL
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Project Summary

Timeline:
Start date: 10/1/2018
Planned end date: 9/30/2021

Key Milestones
1. Design the window receptors for the wall panel; 6/30/2019
2. Print a set of window receptors for the wall panel that allow for streamlined field installation; 9/30/2019
3. Print an optimized set of window receptors for the wall panel that allow for streamlined field installation; 3/31/2020

Budget:
Total Project $ to Date:
- DOE: $267K
- Cost Share: $149K

Total Project $:
- DOE: $1,000K (Plus-up: $1,500K)
- Cost Share: 409K

Key Partners:

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<th>ORNL</th>
<th>Pella</th>
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<td>Sto</td>
<td>ADL</td>
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<td>S. Wall</td>
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Project Outcome:
Develop better integrated window-wall panel and perform field validation of the highly insulated windows, factory-installed in a pre-fabricated wall panels and brought to a building site as integral modular units, ready to be assembled into the full building envelope sections. The choice of highly insulated windows will be made based on the trade-off between energy performance, cost and ease of installation. The selection will be made between vacuum insulated glazing (VIG), hybrid VIG configuration with a third low-e pane of glass and between-glass shading (shading located between VIG and third pane of glass) and thin glass triple glazing.
**Team**

**Dr. Charlie Curcija** is PI in LBNL’s Building Technologies (BT) Department. He is a heat transfer expert and is leading research in thermal and optical performance of windows and shading systems. Charlie has over 35 years of experience in the energy performance of buildings, building facades, windows and shading systems. **Christian Kohler** is BT Department Head. His expertise is in window and envelope heat transfer, related software development and sensors and controls. **Robert Hart** is a scientist with expertise in both modeling and measurements of heat transfer. He is actively involved in highly-insulating windows project and also contributes to the development of models and methods for shading systems. **Howdy Goudey** is the manager of the IR Thermal Lab, with extensive experience in the measurement of heat transfer. He is working on the characterization of highly insulating glazing and windows and insulating materials. **Dr. Luis Fernandes** has experience in both daylighting and heat transfer performance of windows. He is contributing to the measurements and method development for highly insulating materials.

**ORNL team** is led by **Dr. Mahabir Bhandari**, R&D staff with expertise in thermal and whole building energy modeling, **Dr. Simon Palin** is R&D staff with expertise in moisture and durability analysis.
Challenge

- Building construction is **highly fragmented process**, which is particularly true for building envelope construction
- Walls are normally built **on site** with rough opening for windows and doors
- Openings are often **inconsistently dimensioned** and framed with excessive amount of **framing elements** creating **thermal bridges** and additional pathways for **air infiltration** and water penetration
- Windows are often installed in rough openings without regard for full installation instructions from manufacturers and due to **inconsistent dimensioning of openings**
- Window installation is **labor intensive** and therefore expensive process
- **Factory-installed** windows, coupled with proper window opening construction reduces overall labor and can be done **consistently** by workers that are trained specifically for this purpose
- Window opening design that reduces or **eliminates thermal bridging** and provides **good air sealing** and **protection from water penetration** is possible when the window-wall interface is designed with this purpose in mind
- Highly insulated windows with integrated dynamic shading have potential for **net zero energy** performance and will better match insulating value of the wall
Approach

• Develop an integrated design of panelized insulated wall and highly-insulating, (dynamic) windows
  – Design wall panel receptacles for consistent and effective window installation in the field. Use 3D printing to enable rapid prototyping
  – Explore alternative to field installation by investigating issues connected to transportation of fully assembled window-wall sections
  – Measure integrated assembly in a laboratory for moisture, air and thermal performance
  – Model thermal and moisture performance and compare to measured data

• Demonstrate window-wall assembly in an outdoor testbed and validate window-wall energy performance. Verify that air and water tightness are at least 50% better than industry standard
  – Install integrated assembly into the test bed and perform extended testing to confirm air, moisture and thermal performance
  – Observe state of the assembly after the testing is completed and comment on the prospects of overall durability

• Document findings and recommend ways to reduce cost and increase productivity of façade fabrication and installation in the field. Disseminate findings.
Project Plan

Task 1: Development of panelized continuous insulated wall with standardized openings and connectors for windows

- Design panelized continuous insulated wall with standardized openings for windows & standardized connectors/brackets for window installation & connection to DC power
- Design opening trim to meet thermal break, air and water resistance requirements

Task 2: Development of a window suited for installation in a panel wall

- Select suitable window for the integrated window-wall panel and design necessary modifications/improvements so that it can be installed in newly designed wall opening/trim package.
- Design receiving brackets for installation into the wall brackets

Task 3 (plus-up task): Development of a panel integrated energy efficiency sensor package

Task 4: Integration of components into the panelized wall-window system

- Experiment with the designed components and iterate, as required to achieve the most effective design

Task 5: Fabrication of prototype units

- The fabricator (Southern Wall) will construct prototype walls
- Window manufacturer (Pella) will provide window units for integration.
Task 6: Lab testing

- Section of wall, including window will be tested in HAM chamber for moisture performance and in thermal chambers (hot box and IR) for thermal performance

Task 7: Field installation and validation

- Transport the prototype to the field validation site (testbed) and install into the testbed opening
- Perform measurements for a 3 month period
- Perform EnergyPlus modeling for testbed climate (calibration) and also for all typical climate zones
- Document and report measurement and modeling results

Task 8: Techno-economic analysis

- Perform on a component basis (i.e., cost of component materials and their fabrication) and extend to the cost of the integrated assemblies and overall production process

Task 9: Final report

Task 10: External validation and dissemination

- Technical Advisory Group (TAG)
- Partner manufacturers (Sto and Pella)
- Conferences and industry gatherings
Wall Panel Design and Development Process

Legend
- Sales & Marketing Process
- Production Process (Operations)
- Engineering Process

Panel Engineering Design & Development – Specific

Rev. 2018-05-20

1 Bid Successful and Sale / Marketing Handover

1A Changes

Design Planning & Information

Planning
- Collate all available information, plan the project

Design Input Information

2 Use Reference drawings, general info, site info and GC info to divide project into smaller pieces and to determine Engineering, Fabrication, and Installation Sequence

3 Collate and review Architects – Engineers, GC’s and owners drawings and internal information

Design Output Information

4 From Architects – Engineers - GC’s drawings / information, make a set of Panel Reference drawing(s) and get sign off approval

Design Control Design Review

5 On completion of fully detailed Panel Standards drawings, and mock up drawings, review and get Engineer, Architect, Owner, GC, etc. approvals and sign off as applicable

Design Control Design Verification

6 Process Drawings & Information and use to make a set of fully detailed Panel Standards’ drawings and mock up drawings. The Panel Standards drawings must represent a typical portion of the building and account for all design inputs.

Design Output

7 Build mock-ups / Prototypes and get approvals

Design Validation

8 Use the approved Panel Standards and Reference drawings to make a set of Erection drawings.

Design Output

9 Concurrently make a schedule of changes / deviations from the original Architect - Engineer drawings either by (i) Request for information / confirmation, or (ii) note the changes on the drawings.

Design Output

10 Get Engineer - Architect, Owner, G/C approvals and sign off of the erection drawings and the changes / deviations from their original drawings

Design Control Design Review & Verification

11 Use the Erection Drawings and site erection schedule to (i) Determine the panel production sequence, (ii) The production schedule, (iii) Make Bills of Material for materials purchase, and (iv) Make the piece (shop) drawings for shop production

Scheduling and Purchasing

12 Engineering release – Forward the piece drawings to the shop for production

Production and Procurement

Design Validation
Wall Panel Design and Fabrication
Window Design and Performance

UNIT SECTIONS
Aluminum-Clad Exterior

GLAZING PERFORMANCE - TOTAL UNIT
Wood Exterior
Vent Awning and Large Awning Triple-Pane Glass

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3D Printing of Integration Components

Fused Deposition Modeling
Uses a heated nozzle to melt and deposit a thin layer of thermoplastic material into a two-dimensional pattern.

Equipment: Stratasys, 3D Systems, Altisys, Solidoodle

Multi-head Photopolymer
Inkjet print heads are used to jet liquid photopolymers onto a build platform. The material is immediately cured by UV lamps and solidified which allows to build layers on top of each other.

Equipment: Stratasys/Objet
Integration Process Design and Documentation

Refer to the nail fin installation preparation section at the beginning of this booklet.

A. Inspect the joints of the water resistant exterior insulation.
   The insulation must be fastened and sealed according to
   the insulation manufacturer’s instructions. Pella
   Corporation assumes no responsibility for the design,
   quality or durability of the exterior insulation system or its
   joints.
   Taped joints intersecting with the bottom or sides of
   the opening must have tape installed before beginning
   window installation.

B. Insert the Rough Opening Support Brackets by pressing
   the support bracket into the edge of the insulation panel.
   Ensure that the bracket is tight against the wall system’s
   sheathing or rough opening framing. Support brackets
   are required at each shim location.
   - Sill: 1/2" from each bottom corner.
   - Jambs: Refer to Step 2C.
   Place additional support brackets at each mullion or
   interlock.
   Refer to the anchor schedule at the end of the booklet for
   all additional shim and support bracket locations that are
   required for larger windows and combinations.
   For vinyl windows, add support brackets so maximum
   spacing is 18" along the sill.
   NOTE: No support brackets are required above the
   window.

C. Fasten the support bracket to the rough opening framing.
   - For wood framing, use either two roofing nails or two #6
     or #8 screws with minimum 1-1/2" embedment. Stagger
     the fasteners.
   - For light gauge steel framing, use one #10 or two #8
     self-drilling / tapping screws.
   - For concrete or masonry, use one 3/16" masonry screw
     with 1-1/4" minimum embedment.

D. Cut 6" pieces of flashing tape and apply tape over each
   support bracket, covering each bracket completely.

E. Cut 2 pieces of flashing tape 12" longer than the opening
   width.

F. Apply sill flashing tape #1 at the sill extending 2" to the
   exterior and 6" up each jamb.

G. Cut 1" wide tabs at each corner by tearing the foil 1/2"
   each way from corner.

H. Apply sill flashing tape #2 overlapping tape #1 by 1" minimum.

I. Cut 4 pieces of flashing tape equal to the height of the
   opening.

J. Apply one piece on each jamb extending 2" onto the
   surface of the insulating panel.

K. Apply a second piece on each jamb overlapping the first
   piece by 1". Press tape down firmly.

L. Install and level sill shims. Place 1" wide x 1/4" to 3/8" thick shims onto each rough opening support bracket
   on the sill. Keep shims back 1/2" from interior face of the
   window.

M. Use flashing tape to attach shims to prevent movement
   after they are level.

NOTE: Improper placement of shims may result in
bowing the bottom of the window.
Site Installation and Integration Issues
Lab Testing

HAM Chamber for moisture & thermal performance measurements

IR Thermography Apparatus
Field Testing – FLEXLAB at LBNL
Project Impacts

• Windows (including transparent façade) and opaque envelope have the technical potential for net zero energy performance, which translates to approximately 11 quads per year, or $110 billion/year. This is equivalent to nearly 600 Mt of CO$_2$.
  – Cooling impacts for windows: 1.4 quads / 66 Mt CO$_2$
  – Heating impacts for windows: 3.9 quads / 202 Mt CO$_2$
  – Cooling impacts for walls (including infiltration): 0.6 quads / 24 Mt CO$_2$
  – Heating impacts of walls (including infiltration): 6.5 quads / 345 Mt CO$_2$.

• Installation of highly insulated, dynamic windows into the wall panel at the factory assures that integrated assembly performs better by reducing unwanted thermal bridges and pathways for air infiltration, while increasing durability and integrity of the construction.

• Integrated wall panel with window makes it more cost-effective to integrate sensors into the construction, which will be explored if plus-up funding is provided in years 2 & 3.

• Streamlined window-wall integration can lead to increased efficiency, labor reduction and overall cost reduction
Remaining Project Work

- Complete design of panelized continuous wall with standardized openings and connectors for windows
- Complete design of a window with highly insulating glazing and installation components that will fit wall panelized receptors
- Print a set of window receptors for the wall panel that allow for streamlined field installation
- Design integration of components into the panelized wall-window system
- Fabricate prototype units to demonstrate technology and to use for lab and field testing
- Perform lab testing for thermal, air infiltration and moisture performance
- Perform techno-economic analysis on a component and integration level
- Perform field testing to demonstrate integrated performance as installed in real building
- Write final report with detailed design and installation details
- Form technical advisory group (TAG) and disseminate results of design, measurements, and validation
Thank You

D. Charlie Curcija, Staff Engineer, Mahabir Bhandari, Scientist

DCCurcija@lbl.gov, bhandarims@ornl.gov
REFERENCE SLIDES
LBNL Project Budget

Project Budget: $1,000K for 3 years. Plus-up option: $1,500K
Variances: None
Cost to Date: $100K
Additional Funding: $409K cost share from industry partners

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# Project Plan and Schedule

## Project Schedule

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### Past Work

- NA

### Current/Future Work

- Design the window receptors for the wall panel
- Print a set of window receptors for the wall panel
- Print an optimized set of window receptors
- Moisture analysis of the completed design
- Lab testing
- Field validation results, Techno-Economic Analysis