

U.S. DEPARTMENT OF ENERGY BUILDING TECHNOLOGIES OFFICE

# **BTO Peer Review: PV-GEMS**

Photovoltaic Powered, Grid Enhanced, Mechanical Solution



# **PV-GEMS:** Photovoltaic Powered, Grid Enhanced Mechanical Solution





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# **Project Summary**

#### **OBJECTIVE, OUTCOME, & IMPACT**

- Demonstrate use of a pre-packaged, mechanical system pod to reduce energy used for heating, cooling, and water heating in existing homes by 75%.
- Conduct Technology-to-Market activity exploring business models leading to scalable deployment in thousands of homes.



#### STATS

 Performance Period: Phase 1 - Jul 2020 – Jan 2022 Phase 2 - Jul 2023 – Dec 2027
DOE Budget: \$4,052k Cost Share: \$1,013k
Milestone 1: Phase1 – Validate Performance
Milestone 2: Phase 2 – Conduct Demonstrations
Milestone 3: Phase 2 – Explore Tech-to-Market

#### TEAM & PARTNERS





# Problem

- Limited innovation hinders construction industry productivity resulting in low penetration of energy efficient new buildings and retrofits.
- To achieve climate mitigation goals, need to address energy use in existing homes but only 1.75% of homes are retrofitted each

Solution

year.

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### Advanced Building Construction

Demonstrate and commercialize technologies for new buildings and retrofits that are:

- Highly energy-efficient with low carbon footprints.
- Affordable to developers and consumers.
- Faster to implement, with less disruption to building occupants.
- Adding value, such as better indoor air quality, improved comfort, and reduced maintenance.



In Europe, Energiesprong combines off-site manufactured façade panels bundled with innovative mechanical solutions to deliver net-zero retrofits. *Photo credit: Energiesprong* 

For more info on the BTO ABC Initiative visit: <u>https://www.energy.gov/eere/buildings/what-advanced-building-construction-initiative</u>



Deep energy retrofits typically involve combinations of extensive enclosure + equipment retrofits.

- Major enclosure renovations often:
  - Costly.
  - Disruptive and involve multiple contractors.
  - Result in minimal energy savings in mild climates.
- Manufactured homes present additional challenges including:
  - Deferral of Wx and enclosure retrofits due to condition of existing structure.
  - Limited efficient equipment options due to space constraints.



**FSEC PDR Study:** EIFS + window retrofit in FL cost \$27,821 and generated minimal energy savings.

Energy Trust of Oregon Study: HPWH installation \$300-\$700 more than site built garage install due to space constraints.



Methods envisioned to deliver shed and maneuver in place.



# **Alignment and Impact**

PV-GEMS helps achieve climate mitigation goals by overcoming challenges with deploying residential deep energy retrofits at scale:

- Primarily installed in an external, dedicated enclosure.
- Affordable, primarily equipment –based solution assembled offsite minimizing installation time and disruption.
- Sold, installed, and serviced by a single, turn-key contractor.
- Delivers deep energy reductions for homes in a variety of climates.



https://www.younghouselove.com/backyard-shed/

https://www.youtube.com/watch?v=mRHLW0sD1go

#### Range of Simulated Annual HVAC&DHW Savings by City



baseline heating systems, different mini-split capacity, PV and Battery size.



# **Alignment and Impact**

PV-GEMS addresses National Buildings Blueprint priorities including:

- Equity and Affordability
  - Manufactured housing sector often left out of efficiency programs.
  - 45% of residents face high energy burdens; 25% are severely burdened.
- Electrification of Heating and DHW
  - Minimizes need for electrical service and panel upgrades.
- On-Site Distributed Energy Resources
  - Renewable energy generated, stored, and used onsite rather than sent to grid.
- Resilience Limited capacity to operate without grid.





### **PV-GEMS** Components

- New heat pump water heater replaces existing water heater.
- New mini-split heat pump supplements existing space conditioning system.
  - Wall hung indoor unit centrally located.
- PV, batteries, and grid assisted inverters enhance the resource-use efficiency of the components by minimizing use of energy from grid.
- No energy generated by the system is sent to the grid – avoids interconnection.

### Supplemental Mini-Split Version

#### **Hybrid Inverters**





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# Approach

### **PV-GEMS Demonstration System Enclosure**

- 6'x10' "Lean-to" shed supplied by Tuff Shed and color matched to home.
- Connections to home:
  - Main electrical connection
  - Hot and cold water connection
  - Electrical and refrigerant lines run between minisplit indoor and outdoor units.



### Panelized Tuff Shed assembly at FSEC









Future sheds to be assembled inside FSEC High Bay Lab.



### Bundling cost-effective building retrofits with deployment of PV-GEMS pod.

- Participating homes will undergo an energy audit to include testing for envelope and duct leakage.
- Depending on results of audit, certain shallow energy related improvements will be performed by licensed contractors at the time of PV-GEMS installation.

**Duct Sealing** 



Envelope Sealing



**Ceiling Insulation** 





### EnergyPlus Simulation – Atlanta Results, 80s, ER, System B





### Central Space Conditioning System Replacement Version Also to be Demonstrated



# **Progress - Demonstration Site Recruitment**

- Obtained IRB Approval April 2024
- Targeting eight manufactured homes.
  - ROC USA recommends candidate communities, FSEC presents project to community boards of directors.
  - Recruitment postcards mailed to residents inviting participation.
  - Phone interviews identify ~ five potential participants per community.
  - Site visits down-select to two potential participants per community.
- Targeting four site built single-family homes in southeastern US.

### Shading indicates states with ROC USA communities.

![](_page_12_Figure_9.jpeg)

# **Progress - Demonstration Site Selection**

#### Meadowbrook Community, Hudson, MA

- 196 homes, 1970's vintage
- All electric community.

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• Collecting pre-retrofit data.

![](_page_13_Figure_5.jpeg)

![](_page_13_Picture_6.jpeg)

![](_page_13_Picture_7.jpeg)

![](_page_13_Picture_8.jpeg)

![](_page_13_Picture_9.jpeg)

# **Progress - Demonstration System Design and Permitting**

- Working with EXP, inc. to communicate with building departments and prepare permit packages.
  - Adding drywall to shed for required 1-hr fire barrier due to Li-ion batteries.
- Evaluated shed modifications to reduce air infiltration for cold climate deployment.
  - Add drywall and duct HPWH in/out of shed.
- Finalizing development of master controller.
  - Direct communication with HPWH to modulate set point for load up.
  - Low cost methods for monitoring PV module and battery current.
- Confirmed resiliency operation without grid for select PV-GEMS versions.

![](_page_14_Figure_9.jpeg)

![](_page_15_Picture_0.jpeg)

![](_page_15_Picture_1.jpeg)

### NASEO is facilitating a PV-GEMS Deployment Advisory Group working to:

### Identify "Customers" and Associated Market Demand

- Look beyond marketing to *homeowners* with a direct-to-consumer approach.
- Market to existing *programs* facilitating energy efficiency/renewable energy retrofits to influence demand: Utility, state/local government, non-profit, etc.
- Identify financing/incentives that can be leveraged to influence demand, such as those incentivizing whole house energy savings, efficient equipment, solar/storage, electrification, demand response, etc.

### Explore Business Models for PV-GEMS Manufacture, Sales, Installation, and Service

- Envisioning a turn-key company.
- Ideas modeled after existing companies acting as a "one-stop-shop" for home upgrades, but plan to bring diverse trade contractors under one roof.
- Evaluate potential for energy service agreement and aggregator models.

![](_page_15_Picture_11.jpeg)

# **Progress -** Technology-to-Market Activity, cont.

### Inform revisions to design, function, and features of PV-GEMS technology.

- Include additional end-use loads?
- Modify or offer multiple pod designs and form factors?
- Include additional solar / storage capacity?

![](_page_16_Picture_5.jpeg)

![](_page_16_Picture_6.jpeg)

![](_page_16_Picture_7.jpeg)

"Maine Solar Sheds" by Upright Energy

https://uprightenergymaine.com/solarsheds/

![](_page_16_Picture_10.jpeg)

https://www.zoozpower.com/

![](_page_16_Picture_12.jpeg)

# Future Work – Upcoming Milestones and Go/No-GO

### April 2025 – Go/No-Go

- Complete demonstration site audits and installation of pre-retrofit instrumentation.
- Finalize PV-GEMS demonstration system specification and contractor scopes of work.

#### February 2026- Complete installation of PV-GEMS demonstration systems.

• Post-retrofit data collection spans one year for each site.

### August 2026- Go/No-Go

- Draft PV-GEMS sales and installation training modules and beta test results.
- Finalize input on design of commercial PV-GEMS enclosure options.

### August 2027 – Finalize Tech-to-Market Plan to include input on:

- Manufacturing plans
- Creation of sales/distribution/installation networks.

![](_page_17_Picture_12.jpeg)

![](_page_17_Picture_13.jpeg)

# Thank you

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![](_page_18_Picture_2.jpeg)

Florida's Premier Energy Research Center at the University of Central Florida

![](_page_18_Picture_4.jpeg)

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# **Reference Slides**

# **Project Execution – Phase 2**

![](_page_20_Picture_2.jpeg)

| Phase 2 (BP2) funding authorized July 2023    | 2024     |    |    |    | 2025 |          |    |     | 2026 |    |     |          | 2027 |    |    |    |
|---|----------|----|----|----|------|----------|----|-----|------|----|-----|----------|------|----|----|----|
| Planned budget (Phase 1 BP1 \$527k)           | \$1 081k |    |    |    |      | \$2 279k |    |     |      |    |     | \$1 178k |      |    |    |    |
| Spent hudget (Phase 1 BP1 \$437k)             | \$881k   |    |    |    |      | \$0      |    |     |      |    | \$0 |          |      |    |    |    |
|   |          |    |    |    | 01   | 02       | 03 |     |      |    |     | 04       | 01   |    | 03 | 04 |
| Past Work                                     | QT       | QL | QU | QŦ | G    | QL       | QU | Q.T | G    | QL | QU  | QT       | G    | QL | QU | T  |
| Submit IRB application                        |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Submit draft of Tech-to-Market Plan           |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Convene Deployment Advisory Group             |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Current/Future Work                           |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Secure demonstration sites                    |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Install pre-retrofit instrumentation          |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Select contractors to install PV-GEMS systems |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Complete installation of PV-GEMS Systems      |          |    |    |    |      |          |    |     | •    |    |     |          |      |    |    |    |
| Develop draft contractor training modules     |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Complete field demo data collection           |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Submit final Tech-to-Market Plan              |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |
| Submit draft technical report.                |          |    |    |    |      |          |    |     |      |    |     |          |      |    |    |    |

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Team

![](_page_21_Picture_2.jpeg)

**Eric Martin** 

![](_page_21_Picture_4.jpeg)

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![](_page_21_Picture_8.jpeg)

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National Association of State Energy Officials