

U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

PV-GEMS: Photovoltaic Powered, Grid Enhanced Mechanical Solution



FSEC
Energy
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Center

UNIVERSITY OF CENTRAL FLORIDA

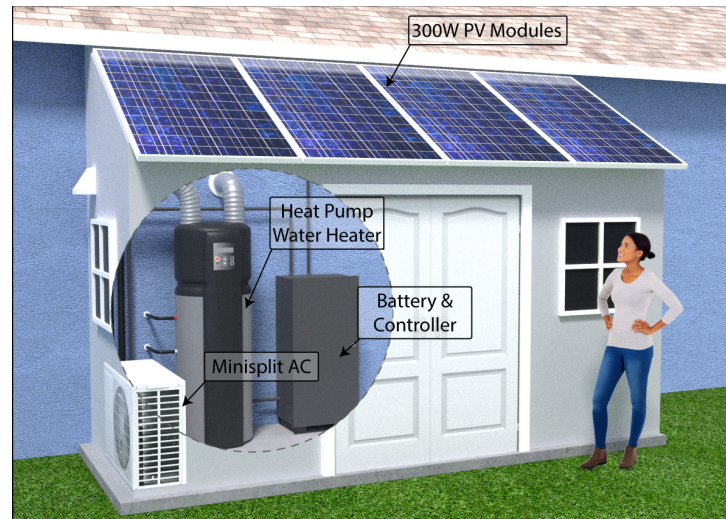
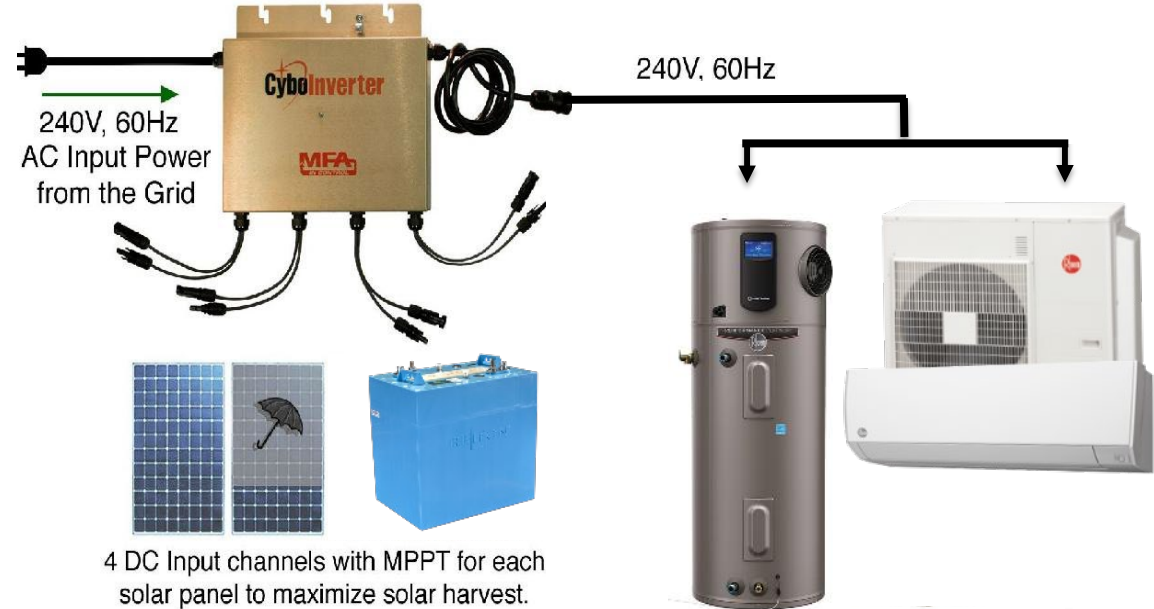
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High efficiency space conditioning and water heating retrofit

- Retrofit consists of a heat pump water heater, and a minisplit heat pump. Existing central space conditioning system remains as backup.
- Grid assisted micro-inverters enhance the resource-use efficiency of the components by minimizing grid energy inputs.
- No PV energy ever sent to grid – excess stored with batteries and used to power loads when sun is down.
- Many possible delivery mechanisms that minimize occupant disruption including pre-packaged “pod” assembled off-site.
- System designed to reduce energy use, demand, and carbon; provide renewable electrification; and offer resiliency by operating critical loads when the grid is down.



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

Phase 1 Pilot Systems

16kBtu/h MSHP, 80 gal HPWH,
6 kWh storage

Building Science Lab



2.4kW PV (320W x 8)



Manufactured Housing Lab



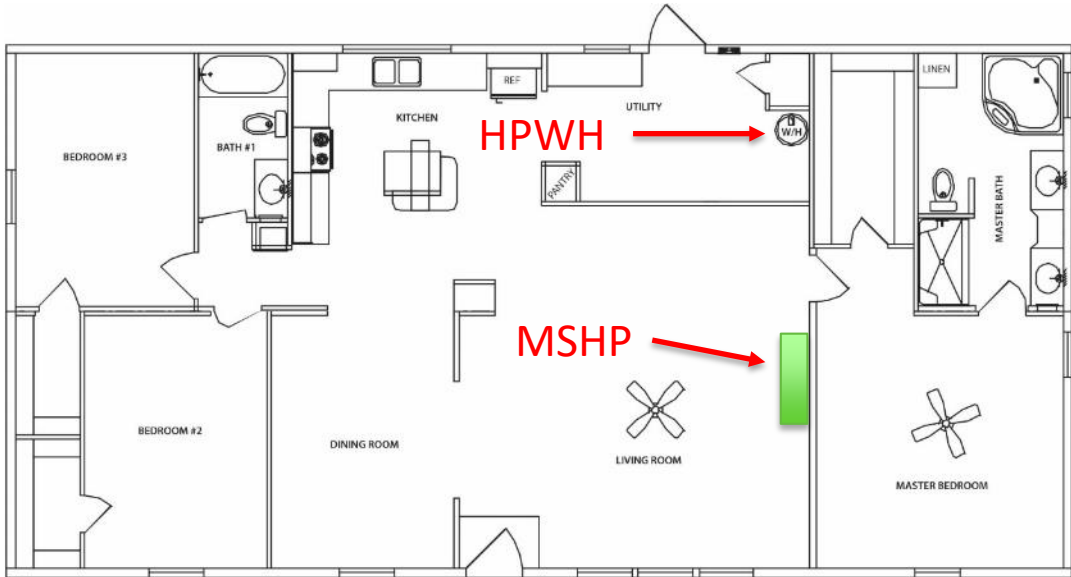
1.24kW PV (310W x 4)



12kBtu/h MSHP, 50 gal HPWH,
3 kWh storage



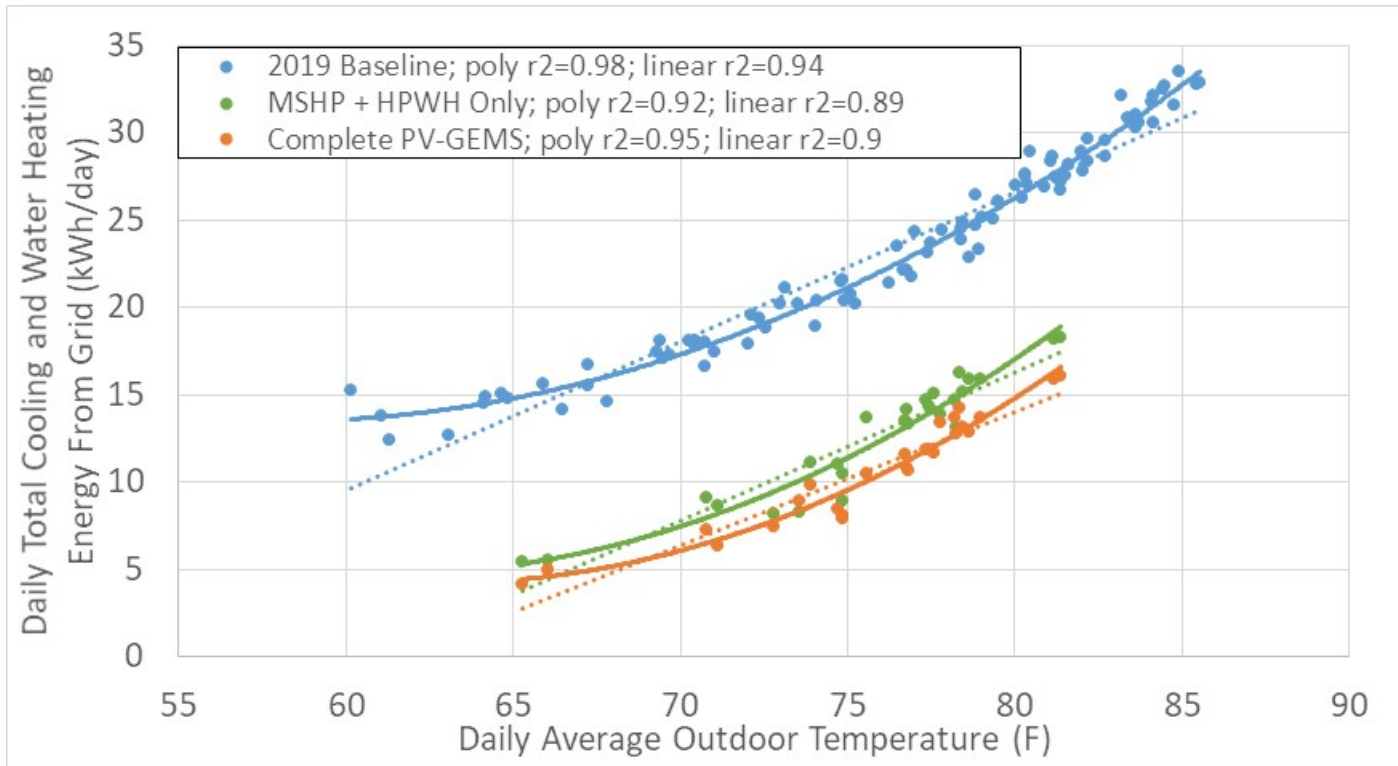
FSEC Manufactured Housing Lab



Floor Area (sqft)	1600
Space Cooling	13 SEER heat pump, interior ducts
Wall	Wood frame, R-19 batt
Roof/Attic	Shingle/vented/R-30 cellulose
Floor	Sealed crawl, R-19 batt at floor
Windows	Single clear
Infiltration	5 ACH 50, no mech vent

Laboratory Results - Central Florida Cooling and DHW

PV-GEMS monitored performance vs. baseline lab condition



Baseline = SEER 13 + Electric Resistance DHW

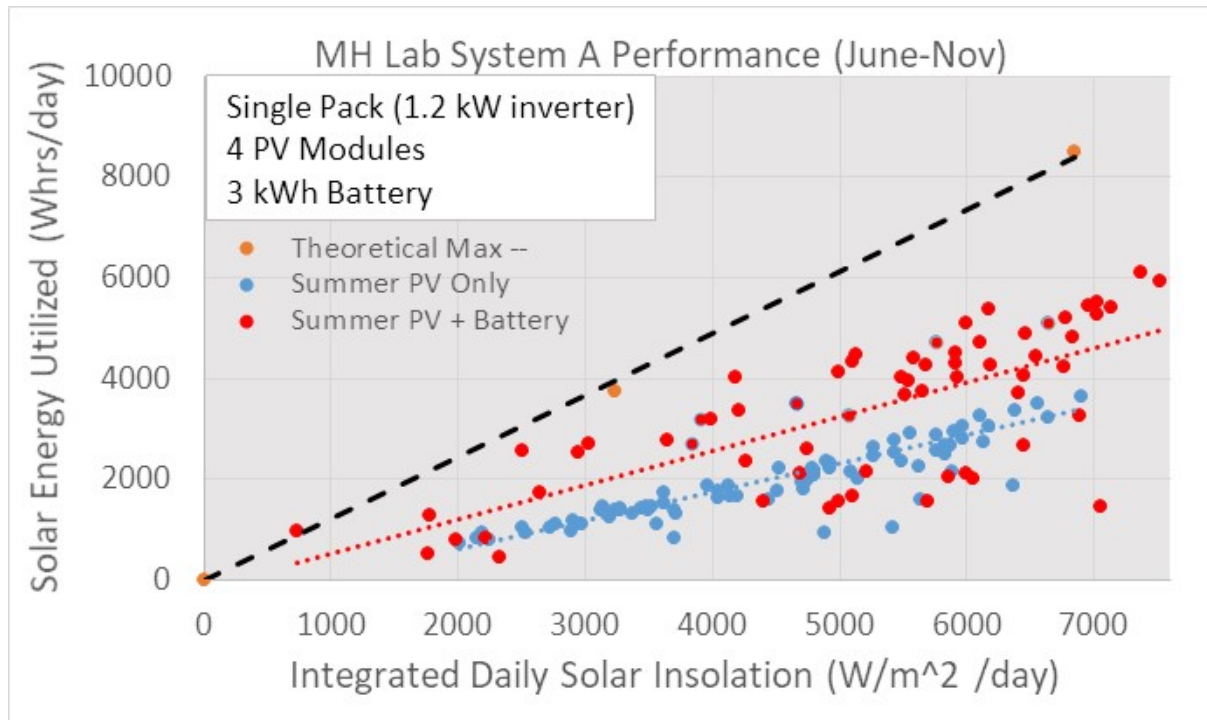
Seasonal Cooling + DHW Savings (April-Oct):

MSHP and HPWH only = 40%

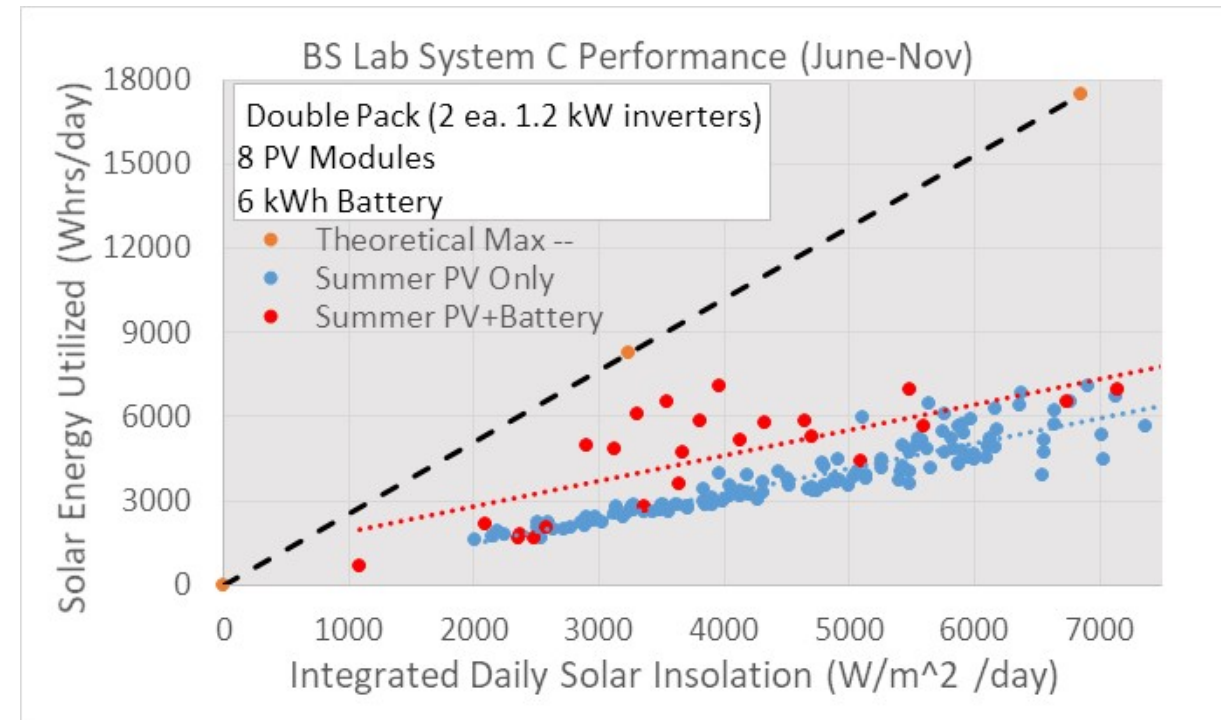
Full PV-GEMS System = 50%

Monitored performance of laboratory PV-GEMS system limited by available battery integration software and hardware.

Laboratory Results – Central Florida PV Energy Utilization

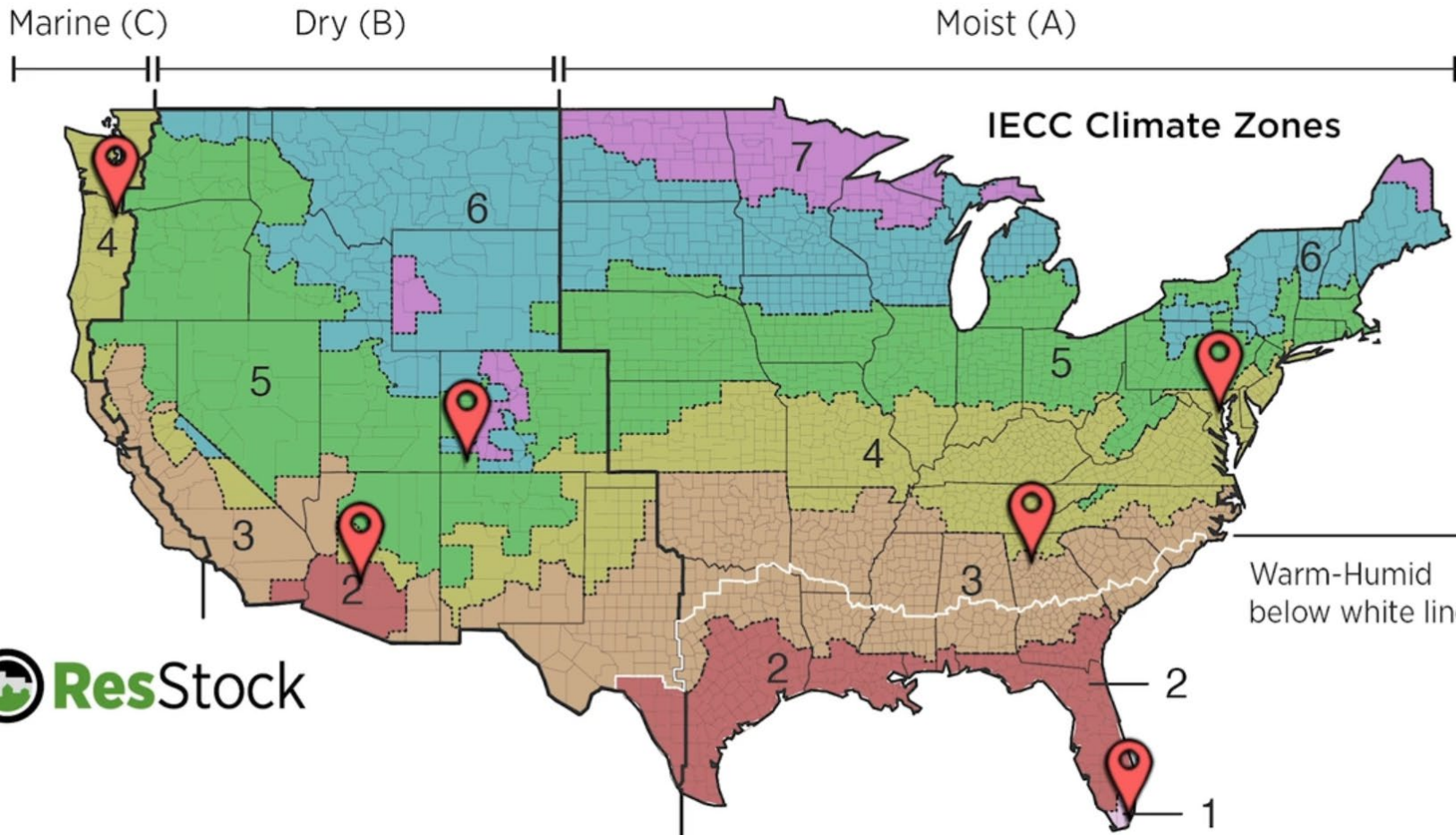


- Without battery ~ 50% PV utilization.
- With battery ~ 75% PV utilization.
- Improve PV utilization with more advanced battery integration software / hardware, and increasing match of load to solar availability.



- Improve PV utilization with additional system load – added capacity of connected space conditioning system.

EnergyPlus Simulation – Regional Building Archetypes



Created multiple baselines for each city:

Vintage

- Pre-1990 (80s)
- Post-1990 (90s)

Central Heating System

- Electric resistance
- Heat pump
- Natural gas

EnergyPlus Simulation – Shallow Retrofit Improvements

- PV-GEMS most effective when deployed with cost effective, minimally-disruptive measures.
- Reduce HVACWH energy by 4%-18%; improve control of airflow, pressures, and comfort.

Duct Sealing



80s: 15% to 10%
90s: 10% to 7.5%

Envelope Sealing



80s: 10 ACH50 to 6
90s: 8 ACH50 to 6

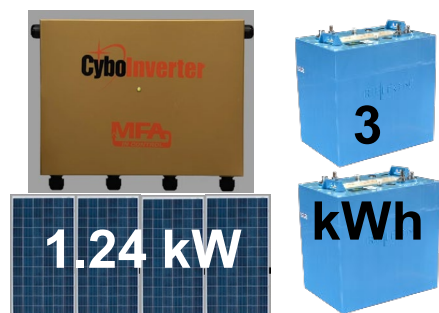
Ceiling Insulation



80s: R-19 to R-38
90s: R-30 to R-38

EnergyPlus Simulation – PV-GEMS Technology Solutions

A



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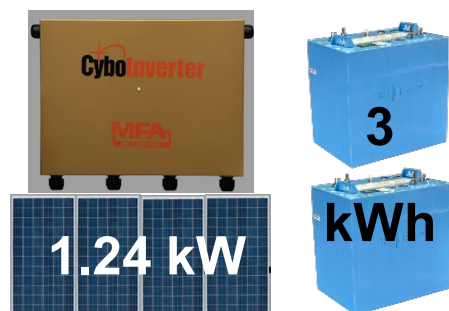


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60 Gal
3 COP

B



+



+

C

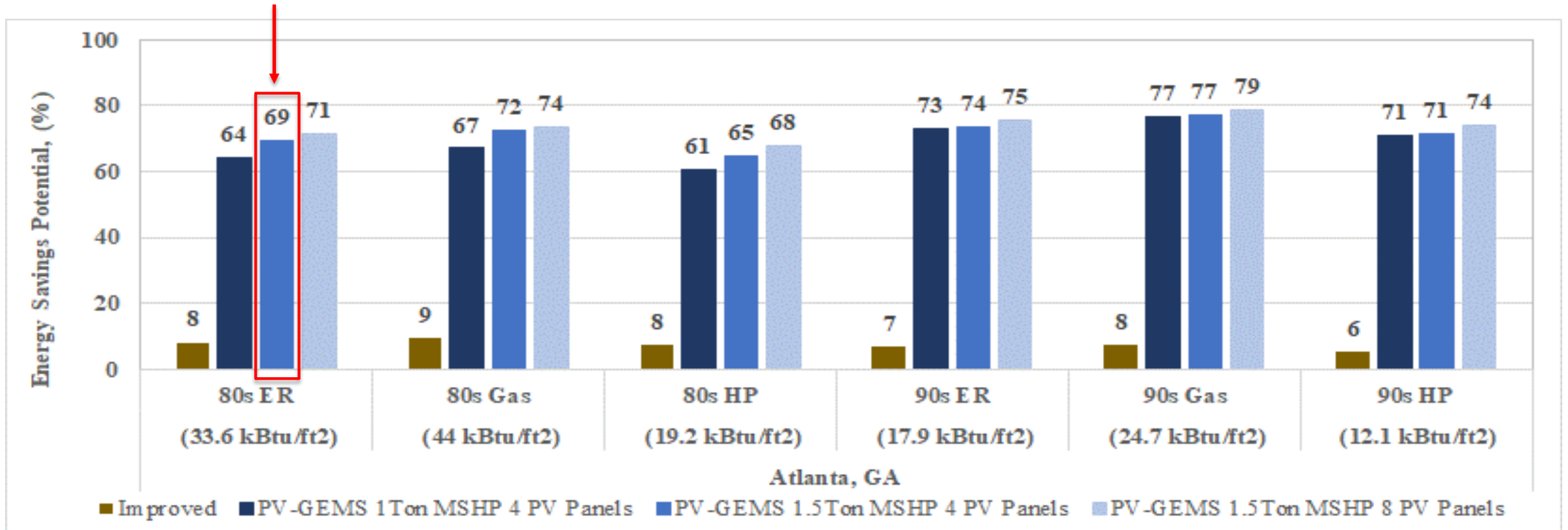


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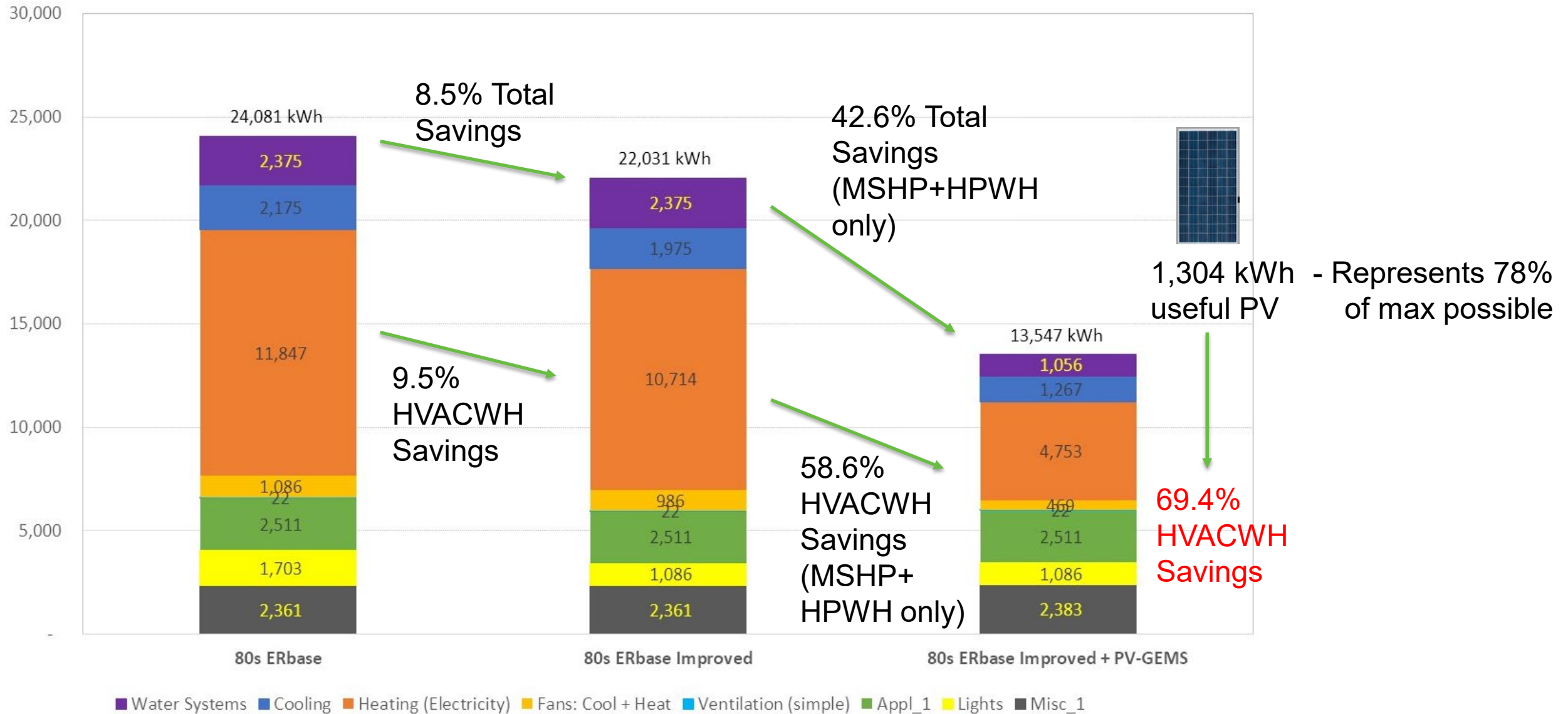


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EnergyPlus Simulation – Atlanta Results



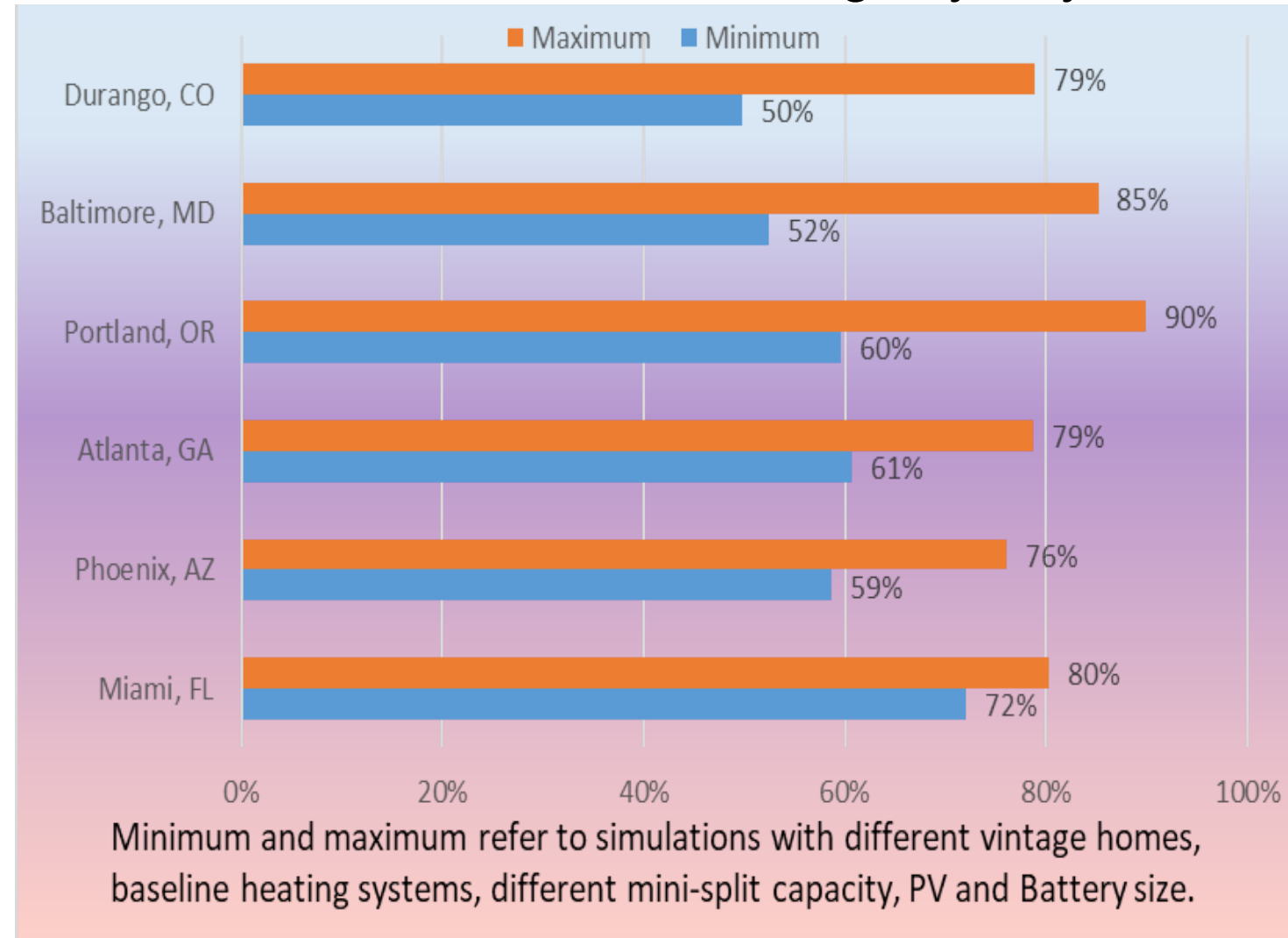
EnergyPlus Simulation – Atlanta Results, 80s, ER, System B



EnergyPlus Simulation – Results Summary

- Savings for HVACWH range from 50%-90%.
- At least 1 case in each climate >75% savings.
- Higher % savings in newer homes, but greater EUI savings in older homes.
- Larger, 1.5 ton MSHP more beneficial in cold climates.
- Doubling PV Array from 4 to 8 modules increases PV utilization by 16%-42%.

Annual HVACWH Savings by City



PV-GEMS Economic and Market Opportunities

Economics for 80's, ER+HP, System B case

System B PV-GEMS component + shallow retrofit cost = \$8,955

Add shed + install + other costs = \$17,215

Subtract incentives = **\$12,215**

Average savings of HP and ER cases except Miami which is 100% ER (kWh)		EIA rate Sep-2021 \$/kWh	Annual Savings (\$)	Simple Payback (yrs)	15 year mortgage, 30 year analysis			
					Life Cycle Savings	Life Cycle Costs	Net Present Value	Savings to Investment Ratio
Durango	17557	0.129	\$ 2,256	5.7	\$83,278	\$25,067	\$58,211	3.32
Portland	16652	0.113	\$ 1,878	6.9	\$59,908	\$25,067	\$34,841	2.39
Baltimore	14099	0.127	\$ 1,793	7.2	\$59,808	\$25,067	\$34,741	2.39
Atlanta	9295	0.126	\$ 1,172	11.1	\$33,960	\$25,067	\$8,893	1.35
Phoenix	8067	0.125	\$ 1,008	12.9	\$31,418	\$25,067	\$6,351	1.25
Miami	5925	0.119	\$ 702	18.5	\$19,180	\$25,067	-\$5,887	0.77

Market Opportunities

- Optimize system to increase PV utilization and improve cost effectiveness.
- Develop PV-GEMS option that offers central system HVAC replacement.
- Integrate functionality for demand response and resiliency to increase value.
- Develop manufacturing, distribution, and installation plans for pre-packaged delivery model.
- Consider targeting specific single-family housing sectors for PV-GEMS technology transition plans, such as manufactured housing.



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Thank You

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Link to PV-GEMS Video
<https://vimeo.com/655024096>