C2C: Clean Energy *to* Communities

U.S. DEPARTMENT OF ENERGY

C2C Expert Match Technical Assistance

City of Reading, Pennsylvania

Amanda Krelling – Lawrence Berkeley National Laboratory (LBNL)

June 27, 2024

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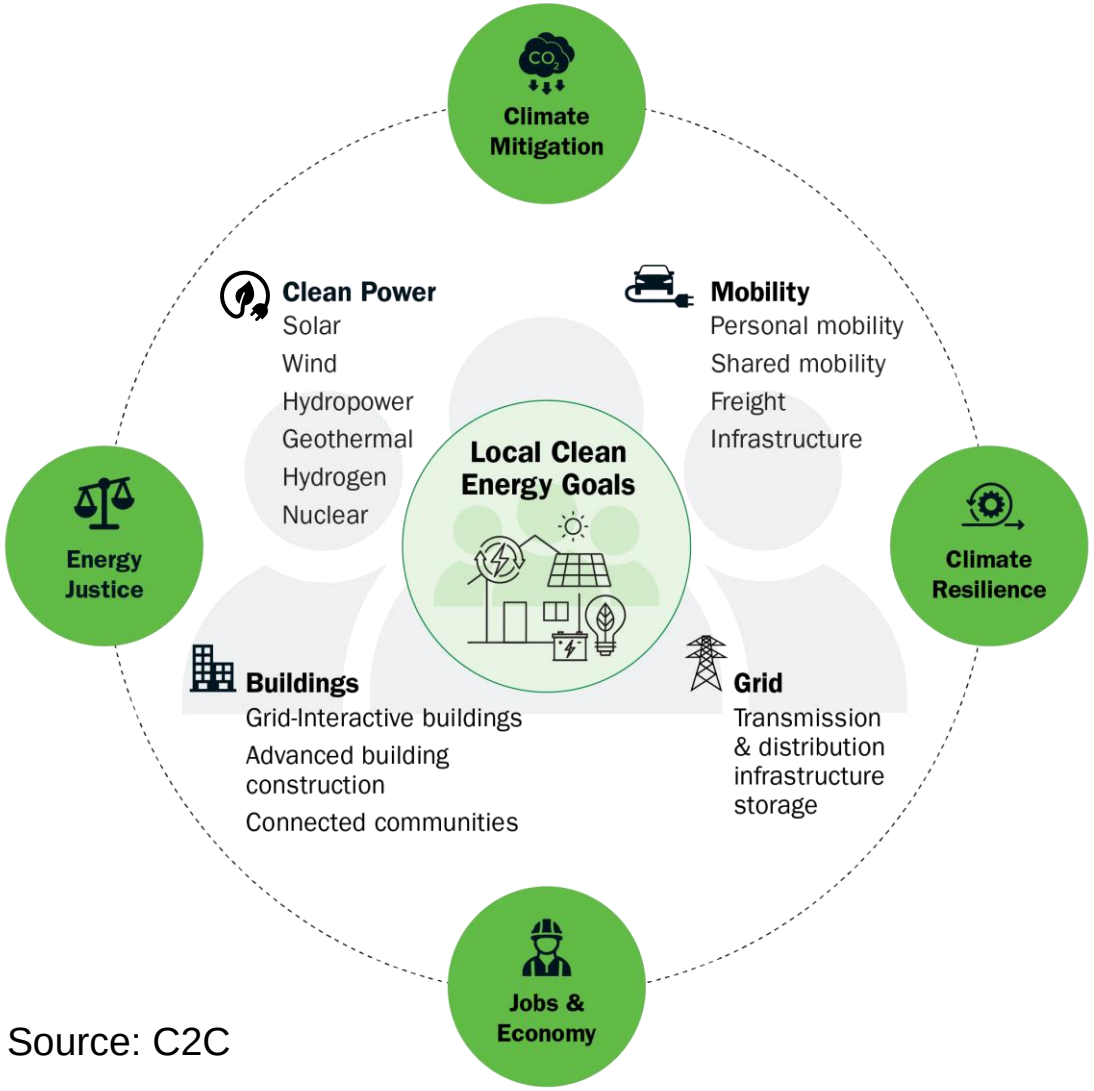
Clean Energy to Communities

Clean Energy to Communities (C2C) is an **innovative, technical program** that helps electric utilities, local governments, and community-based organizations meet their **progressive clean energy goals**.



Source: C2C

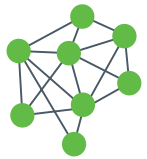
Clean Energy to Communities

In-Depth Partnerships

Multiyear partnership made up of teams (local government, community-based organizations, and electric utilities) that work alongside national lab staff to apply robust modeling and analysis tools and conduct hardware-in-the-loop testing of solutions to evaluate and test potential scenarios and strategies before full technology deployment.

~3 years
~4 communities

For more information, visit:
www.nrel.gov/c2c/indepth

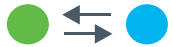


Cohorts

Multicommunity engagements to exchange strategies and best practices, learn in a collaborative environment, and workshop strategies to overcome challenges around a common clean energy transition topic. **Applications for next cohort due October 31. Includes buildings focused cohort.**

~6 months
~100 communities

For more information, visit:
www.nrel.gov/c2c/cohorts



Expert Match

Short-term, no-cost technical assistance for communities seeking to answer a near-term clean energy question.

Applications accepted on a rolling basis.

~3 months
~200 communities

For more information, visit:
www.nrel.gov/c2c/expertmatch

Source: C2C

Request and Technical Assistance (TA)

Overview of TA Request

Goal: Improve the safety, efficiency, and comfort of older rowhomes, which often use home heating oil and pose various risks to residents. Energy efficiency retrofits are a priority to enhance these conditions.

Community: Reading, Pennsylvania

The City of Reading, located in southeastern Pennsylvania, is the main city in the Greater Reading Area and the county seat of Berks County, with a population of approximately 95,112 as of 2020. Historically a disinvested manufacturing community, it has a poverty rate of around 40%, a housing stock averaging 90 years old, and an owner-occupied housing rate below 40%.

In 2019, Reading adopted a resolution to achieve 100% renewable energy by 2050. The city aims to transition residential, small commercial, and small manufacturing sectors to renewable energy for electricity and heating, bypassing natural gas.

Overview of Technical Assistance

Work Area 1. Residential Energy Modeling:

Lawrence Berkeley National Laboratory (LBNL) will develop a representative model of a typical 2–3-bedroom row home to evaluate strategies for energy efficiency and electrification retrofits.

Task 1: Gather necessary data for creating a building energy model including both technical data and feedback from Reading residents.
Task 2: Develop the representative model for a prototype home using energy modeling software tools and select 4–5 energy efficiency and electrification retrofit measures for consideration.
Task 3: Run analysis to determine potential benefits such as energy use reductions/utility bill savings, and thermal comfort improvements associated with different retrofit measures.

Deliverable: Slide deck (or memo) with notes summarizing the analysis findings.

Overview of Technical Assistance

Work Area 2. Research and Collection of Energy Efficiency Retrofit Resources:

Gather relevant case studies, reports, fliers, and other resources to gather best practices on energy efficiency, thermal resilience and electrification retrofits in Reading, Pennsylvania.

Task 1: Gather region-relevant residential energy efficiency and electrification retrofit resources.
Task 2: Summarize findings.

Deliverable: Slide deck (or memo) summarizing the research findings with embedded links to resources.

Overview of Technical Assistance

Work Area 3. Presentation to Environmental Advisory Council:

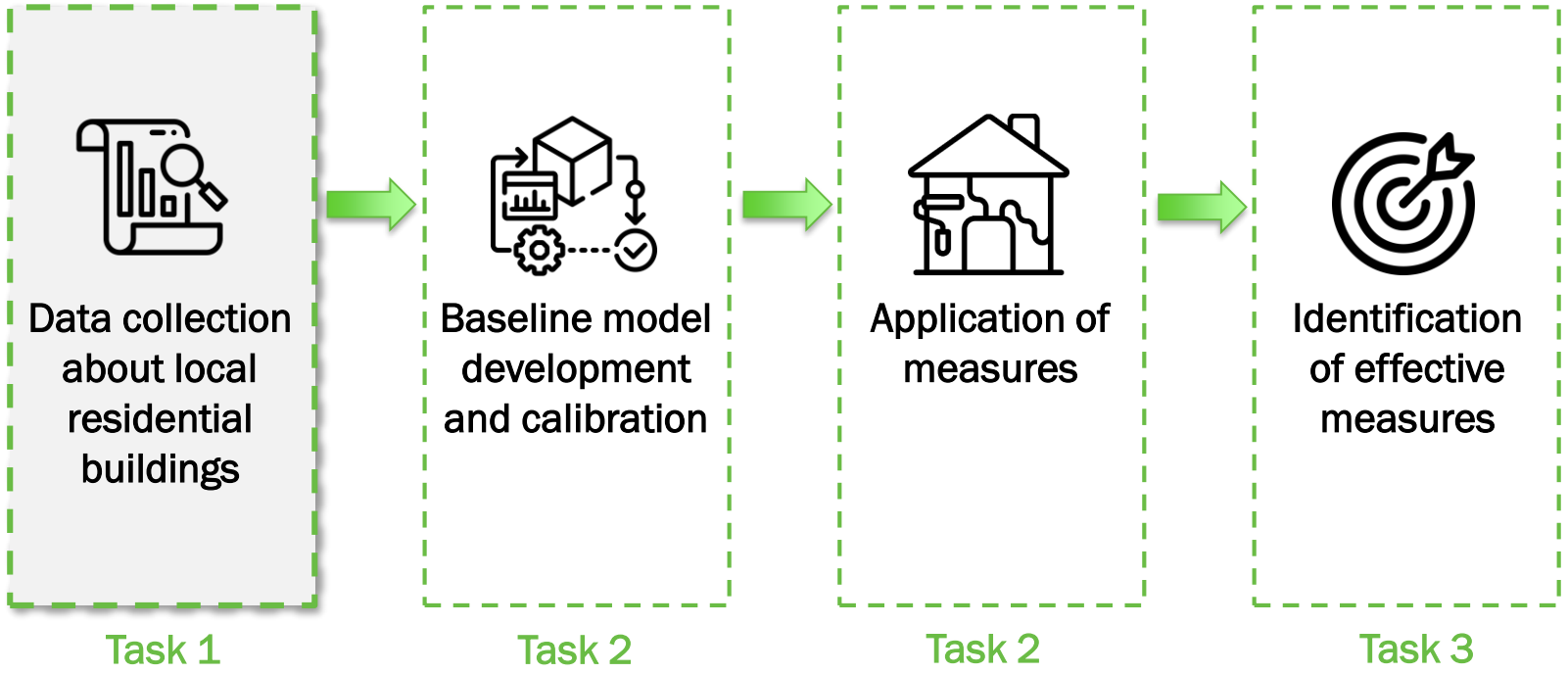
LBNL will give a presentation on the modeling findings to the Reading Environmental Advisory Council.

Task 1: Prepare slide deck for presentation.
Task 2: Present the Work Area 1 deliverable and findings to the Environmental Advisory Council during a council meeting.

Deliverable: Environmental Advisory Council Presentation (Scheduled for August 7).

Work Area 1. Residential Energy Modeling

Work Area 1: Workflow



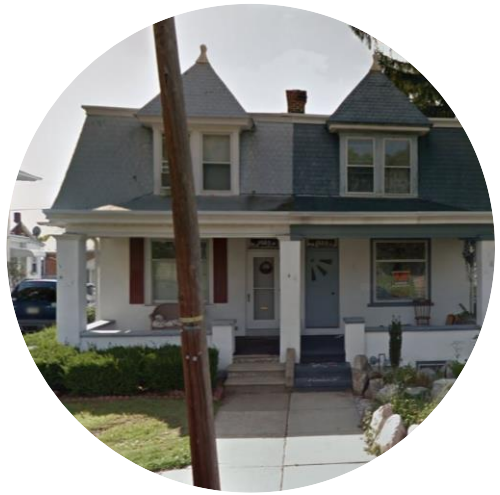
Icons: Created by Ranah Pixel Studio, Freepik, Smashicons, and Uniconlabs – Flaticon, from left to right: "data" icon (available here), "modeling" icon (available here), "paint" icon (available here), "target" icon (available here)

Available data

Data about three residential buildings, including:

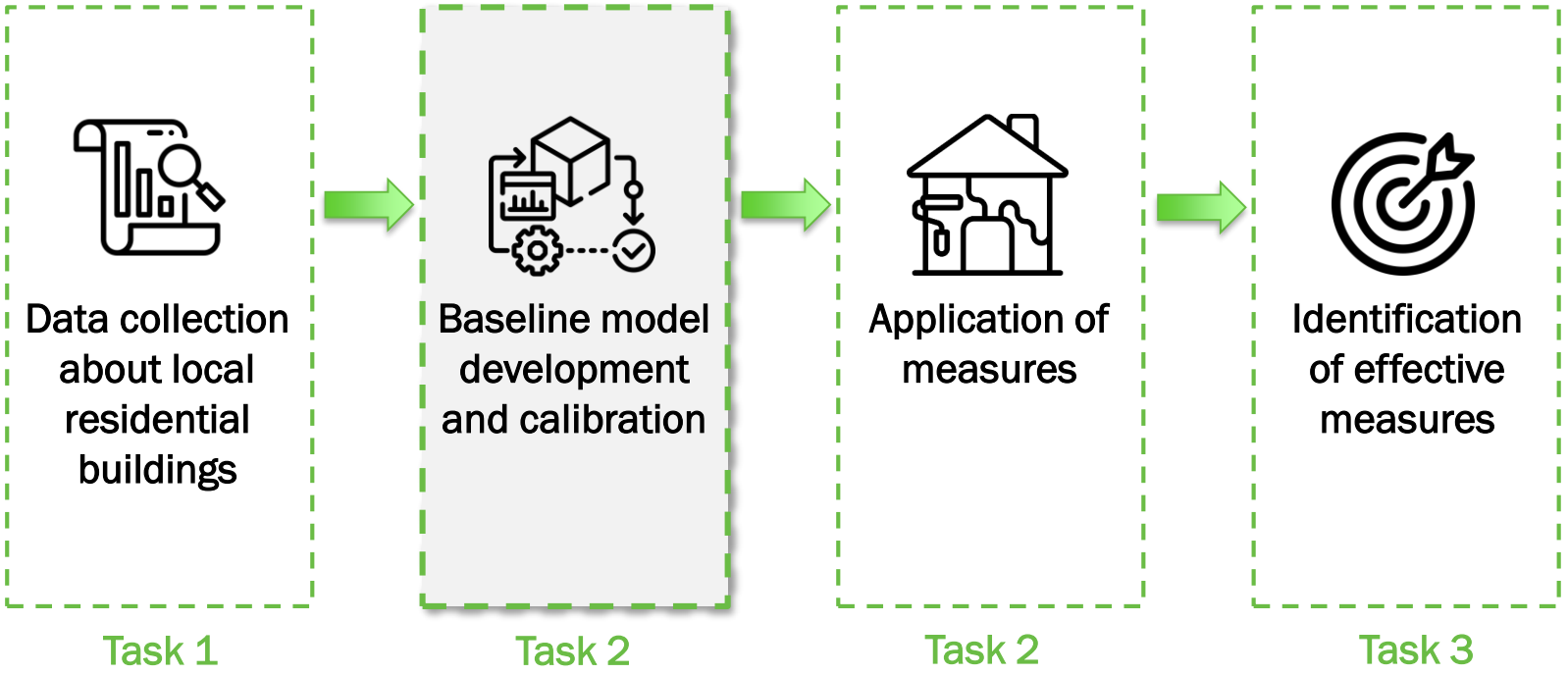
- Metered electricity consumption.
- Metered natural gas consumption.
- Description of building layout or schematic drawing.
- Pictures from Google street view.





Pictures obtained through Google street view.

Work Area 1: Workflow



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Summary of Representative Home Features:

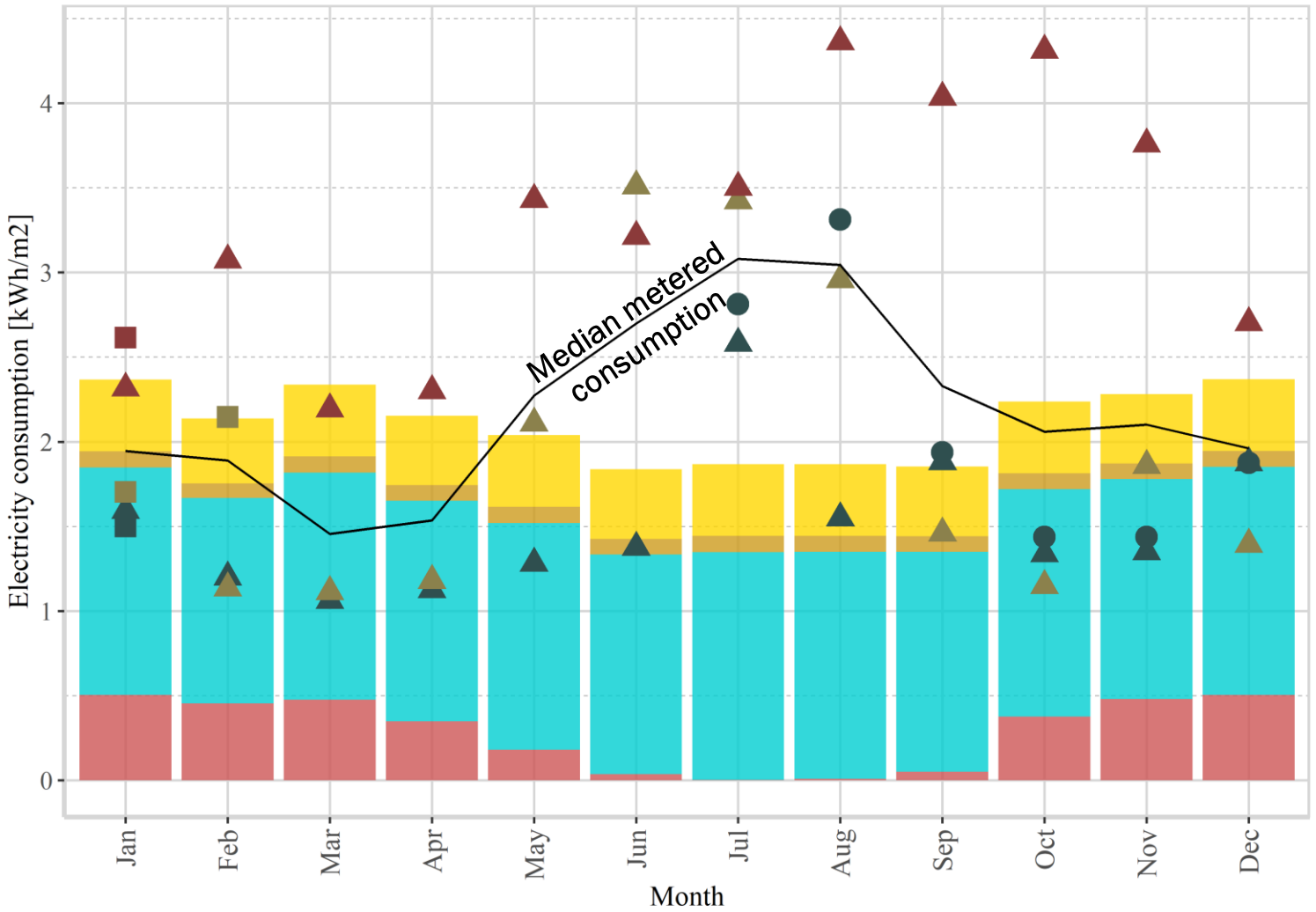
Modeling assumptions

- 2–3-bedroom rowhome (adapted from U.S. Department of Energy prototype models)
- Total Floor area: 1,500 sq. ft
- 2 floors
- 90-year-old structure
- Brick walls (beige finishing)
- Dark gray roof
- No cooling system (natural ventilation used during summer)
- Heating system (radiators) based on heating oil
- Buildings not equipped with fans
- Without shading devices
- Occupancy 24/7.

Pictures obtained through Google street view.

Baseline Model Development and Calibration

Results: Electricity consumption



Simulated electricity end-use:
- Interior lights
- Exterior lights
- Appliances
- Pumps

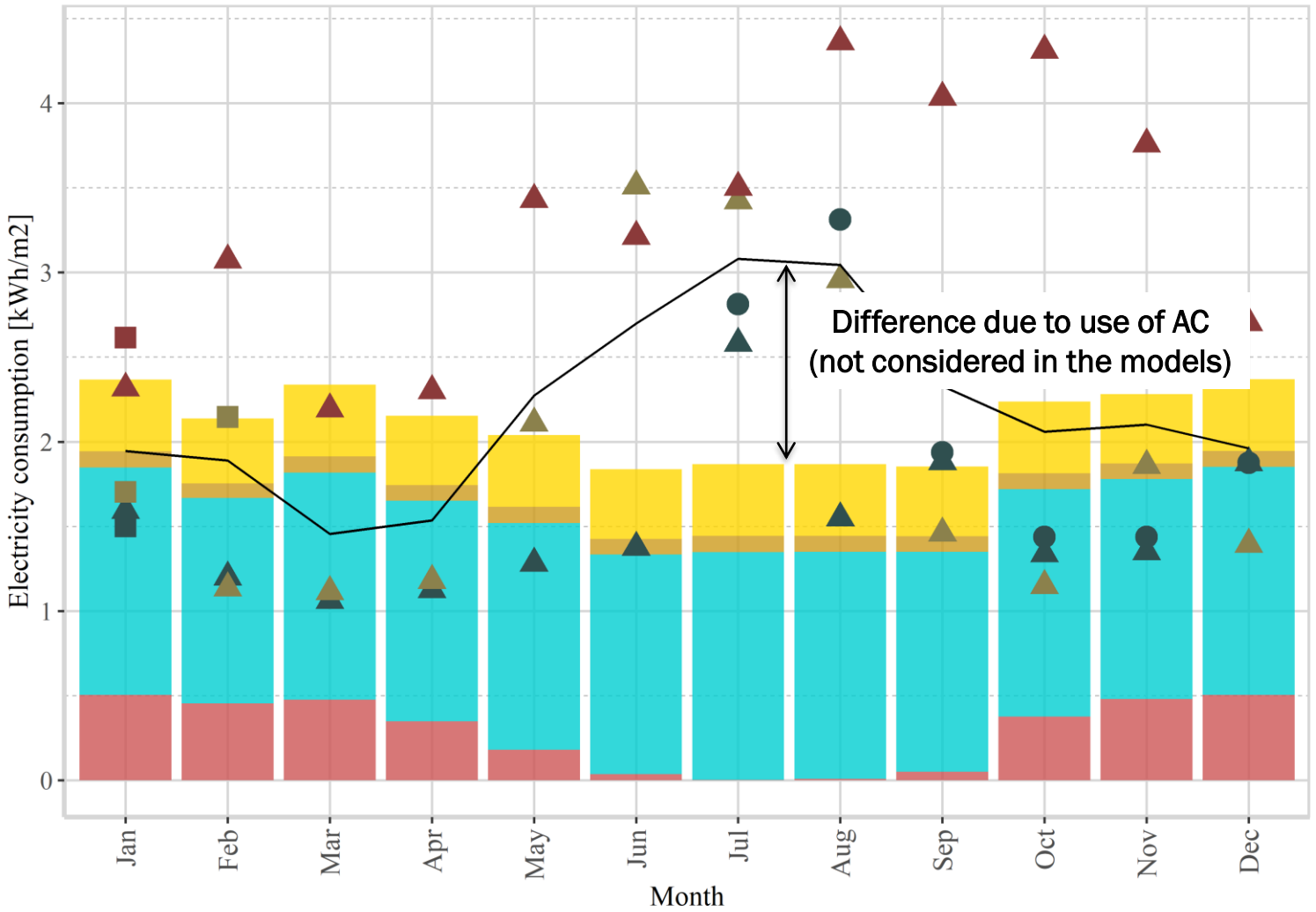
Year of metered consumption:
- 2022
- 2023
- 2024

Metered electricity consumption:
- Building 1
- Building 2
- Building 3

Pictures obtained through Google street view.

Baseline Model Development and Calibration

Results: Electricity consumption



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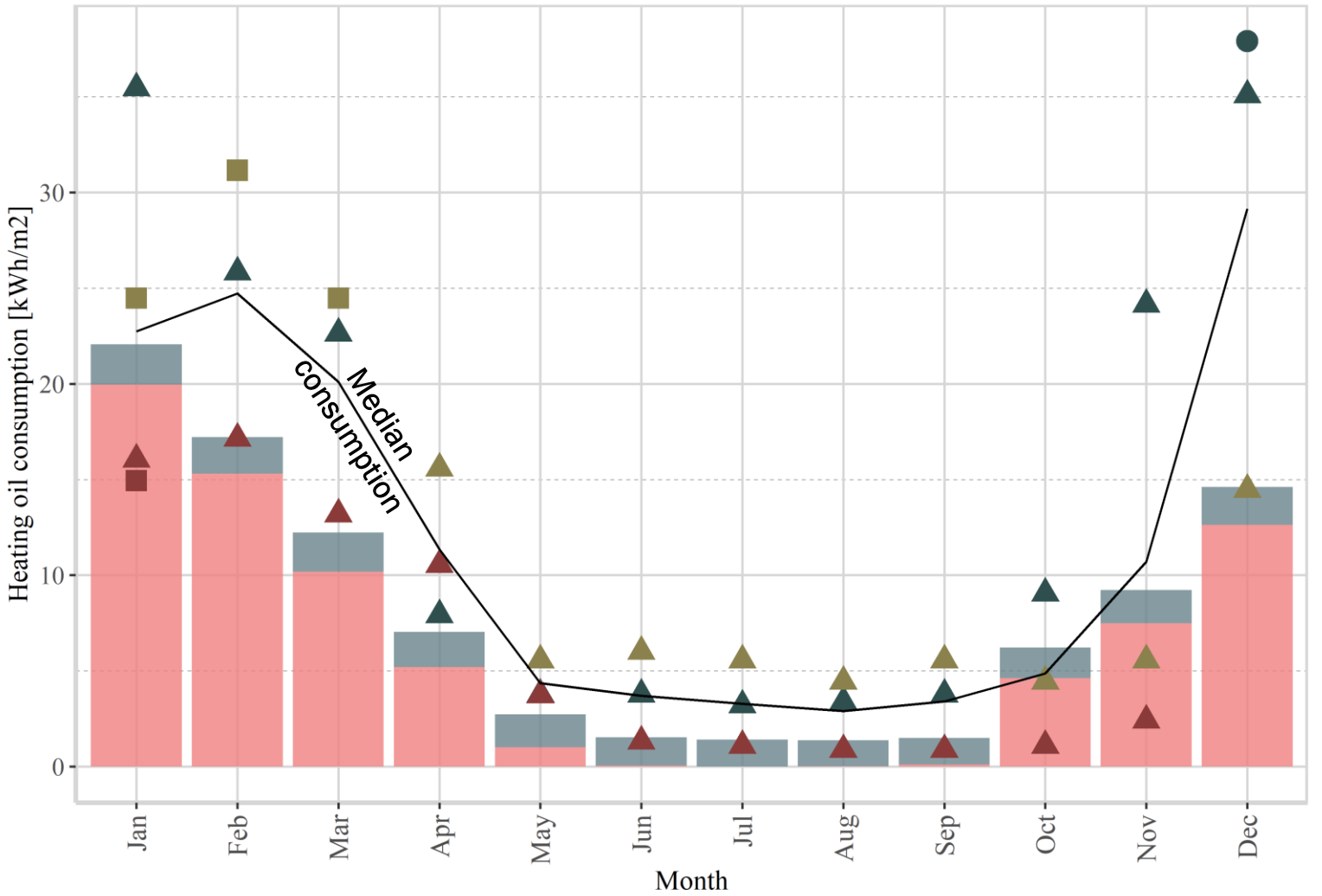
Pictures obtained through Google street view.

Baseline Model Development and Calibration

Results: Heating oil consumption



Metered oil* consumption:
- Building 1
- Building 2
- Building 3

Year of metered consumption:
- 2022
- 2023
- 2024

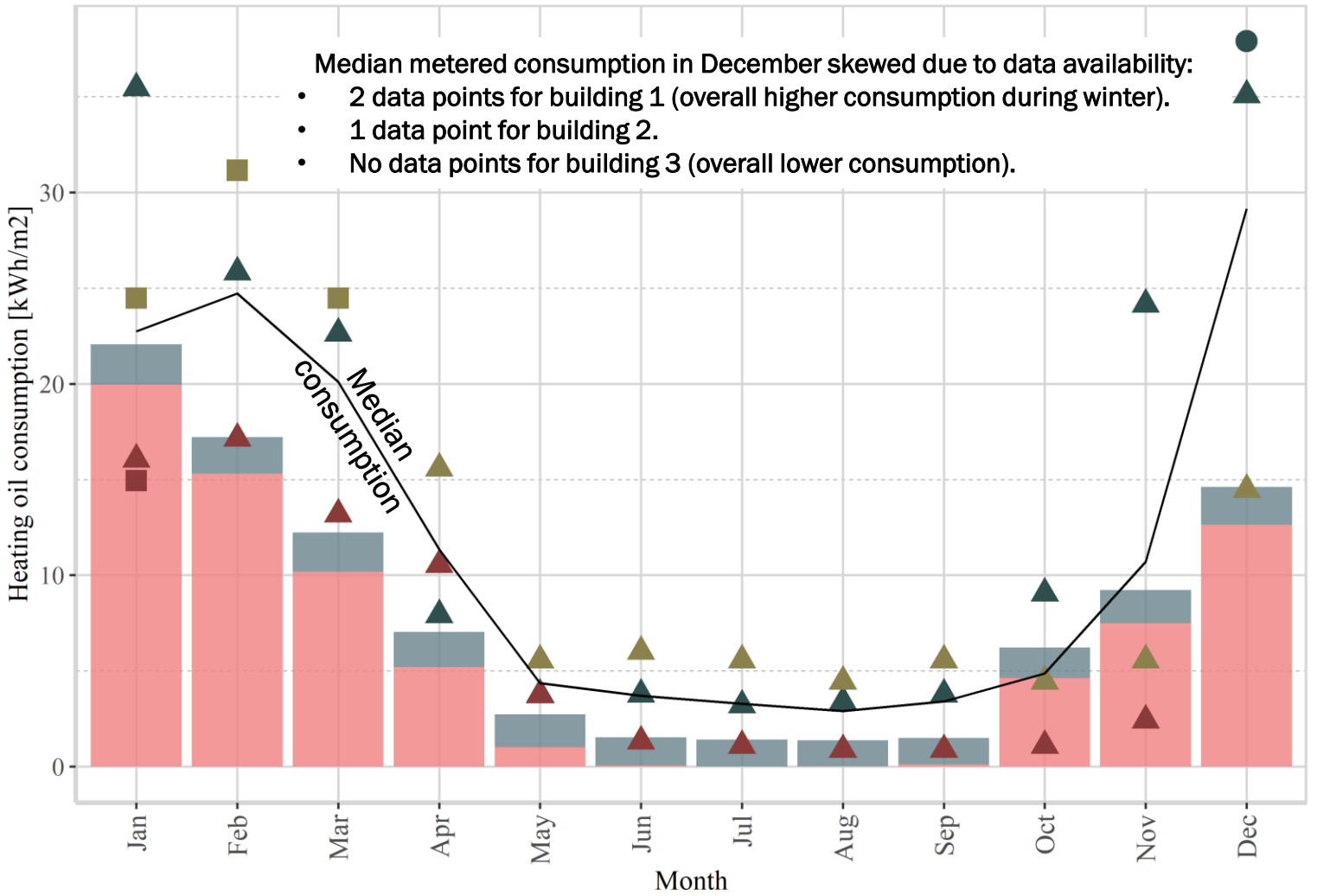
Simulated oil end-use:
- Water heating
- Space heating

*Converting consumption in natural gas to an equivalent consumption of heating oil.

Pictures obtained through Google street view.

Baseline Model Development and Calibration

Results: Heating oil consumption



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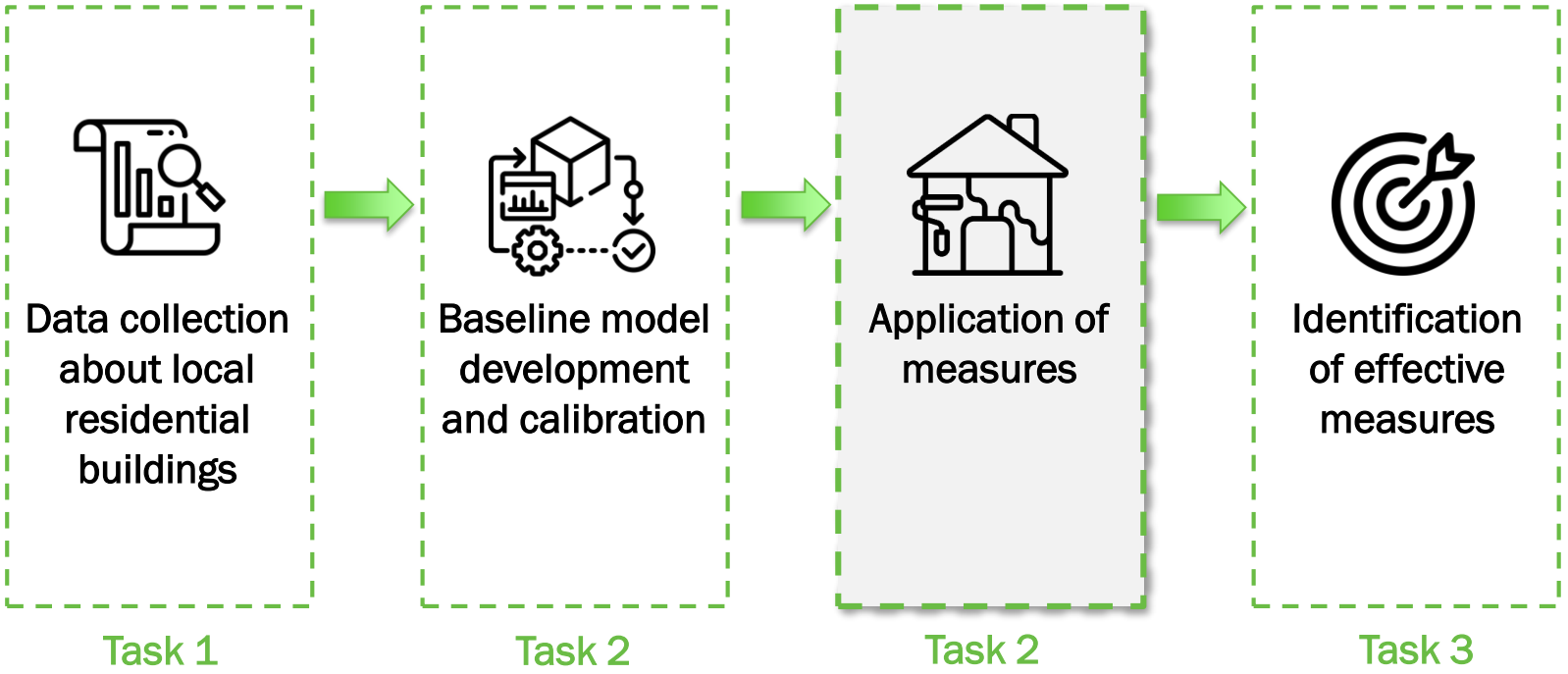

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Low-Intervention Measures

Window films

Improves comfort during the cold winter months as well as during the heat of summer. **High heat control** helps provide energy savings in the summer.

Ceiling fans

Ceiling fans improve thermal comfort in buildings by **enhancing air circulation**, which helps to distribute heat more evenly and increase the evaporation of sweat, making occupants feel cooler.

Efficient natural ventilation strategies

Increased openable area of windows for natural ventilation, and **night ventilation**.

Figures from top to bottom: LUCKYYJ Official Store (available here); secontrols (available here); Home Depot (available here).

High-Intervention Measures

Shading

Shading elements help to improve thermal comfort in buildings by **reducing solar heat gain**, keeping indoor temperatures cooler and minimizing the need for air conditioning.

Cool roofs

Cool roofs improve thermal comfort in buildings by **reflecting more sunlight** and **absorbing less heat**.

Ceiling insulation improvement

Ceiling insulation helps **minimizing heat transfer through the roof**. In winter, it prevents warm indoor air from escaping, keeping the interior warmer and reducing heating needs. In summer, it blocks external heat from penetrating into the living spaces, maintaining cooler indoor temperatures and reducing the reliance on air conditioning.

Figures from top to bottom: Summer Space (available here); Attic Man (available here); ENERGY STAR (available here).

High-Intervention Measures

Heat pump

- Heat pumps for heating, ventilation, and air conditioning (HVAC) applications offer several advantages, including high energy efficiency, reduced carbon footprint, and the ability to provide both heating and cooling.
- They are particularly effective in moderate climates and can significantly lower utility bills.
- However, they can have higher upfront costs compared to traditional systems, may require supplementary heating in very cold climates, and their efficiency can drop in extreme temperatures.
- Maintenance and installation quality are crucial for optimal performance, and there may be compatibility issues with existing ductwork in retrofitting scenarios.

Figures: Knowledge Center (available here).

Summary of Considered Measures

Measures	Description	Baseline model
Window films	Solar heat gain coefficient equal to 0.23, thermal transmittance equal to 0.84 BTU/(h.ft^2.F) (4.76 W/(m^2.K))	Solar heat gain coefficient equal to 0.436, thermal transmittance equal to 0.84 BTU/(h.ft^2.F) (4.76 W/(m^2.K))
Ceiling fans	Ceiling fans used during summer to increase indoor air velocity and avoid use of air conditioning (when available)	No ceiling fans
Efficient natural ventilation strategies	Opening area equivalent to 20% of the window area, natural ventilation used during daytime and night-time	Opening area equivalent to 10% of the window area, natural ventilation used only during daytime
Shading	6.6 ft (2 m) deep awnings in the front and back façades (1st floor)	No exterior shading elements in the façade
Cool roofs	Solar absorptance equal to 0.29	Asphalt shingles with solar absorptance equal to 0.85
Ceiling insulation improvemenent	Ceiling thermal transmittance equal to 0.021 BTU/(h·ft²·°F) (0.119 W/(m2.K)) (added R-30 insulation)	Ceiling thermal transmittance equal to 0.052 BTU/(h·ft²·°F) (0.298 W/(m2.K))
Heat pump	Single-speed air-source heat pump for heating and cooling	Radiators for heating

Metrics Evaluated

- **Energy consumption:**
    - Kilowatt-hours (kWh) for electricity consumption.
    - Gallons for heating oil consumption.

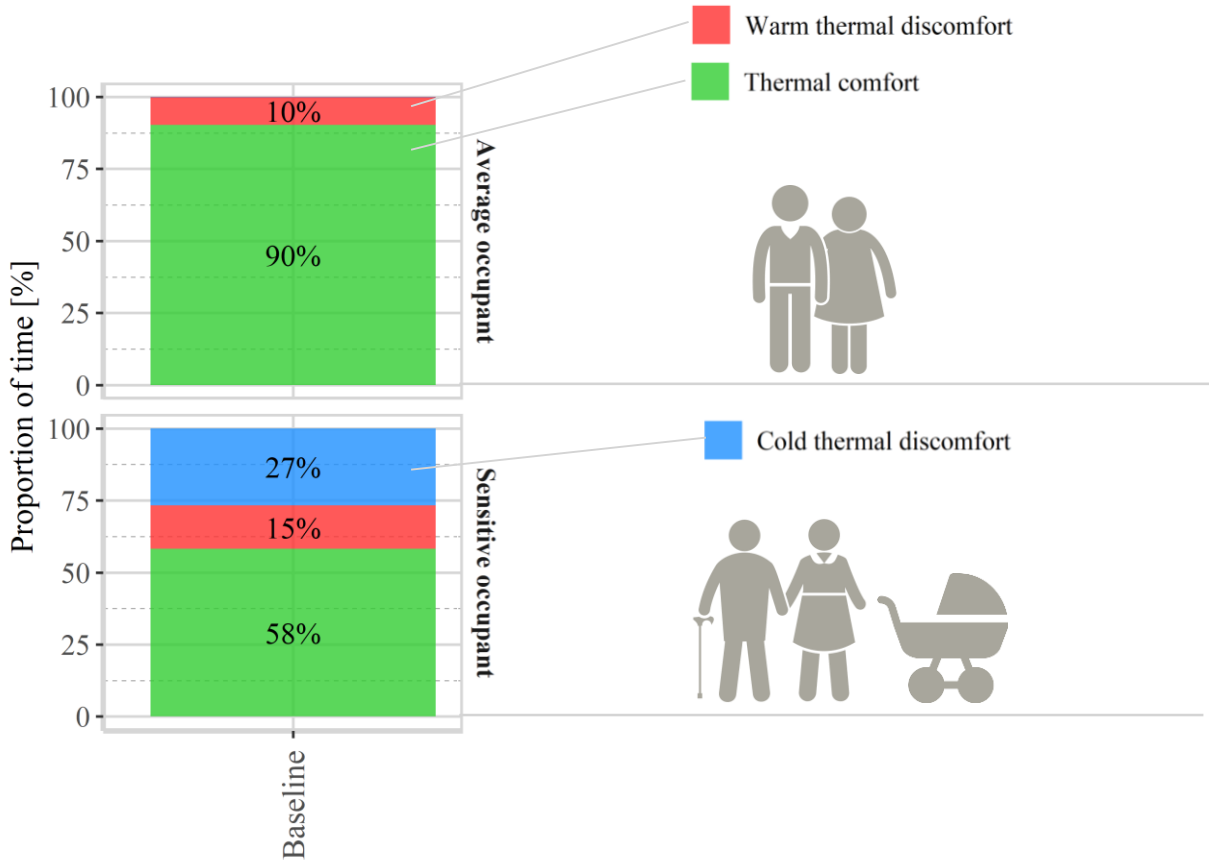
- **Energy bill ($) using utility costs of:**
    - $ 0.165/kWh of electricity.
    - $ 3.869/gallon of heating oil.

- **Thermal comfort*:**
    - Percentage of time throughout the year that occupants are comfortable indoors, considering:
        1. Thermal comfort acceptability for average/less sensitive population.**
        2. Thermal comfort acceptability for sensitive population.***

*Operative temperature used to calculate the percentage of time in thermal comfort and discomfort.
**Considering ASHRAE 55 (2023) thermal comfort thresholds for the adaptive comfort model with 80% acceptability.
***Considering ASHRAE 55 (2023) thermal comfort thresholds for the adaptive comfort model with 90% acceptability.

Thermal Comfort Results

Baseline building



These graphs represent the proportion of time throughout a year, with 100% being equivalent to all hours in 365 days.

Examples

90% of thermal comfort indicates that an **average occupant** would consider the building comfortable for 328.5 days in a year.

10% of warm discomfort indicates that an **average occupant** would consider the building too warm for 36.5 days in a year.

27% of cold discomfort indicates that a **sensitive occupant** would consider the building cold for 98.6 days in a year.

Icons: Created by Freepik, Leremy and Prosymbols Premium – Flaticon, from top to bottom: "adult" icon (available here), "elderly" icon (available here), "stroller" icon (available here).

Thermal Comfort Results

Baseline building compared to packages of low and high intervention

All cases are equipped with:

- Radiator for heating.
- No cooling system.

Influenced by low mean radiant temperatures due to uninsulated heavy exterior walls during winter.

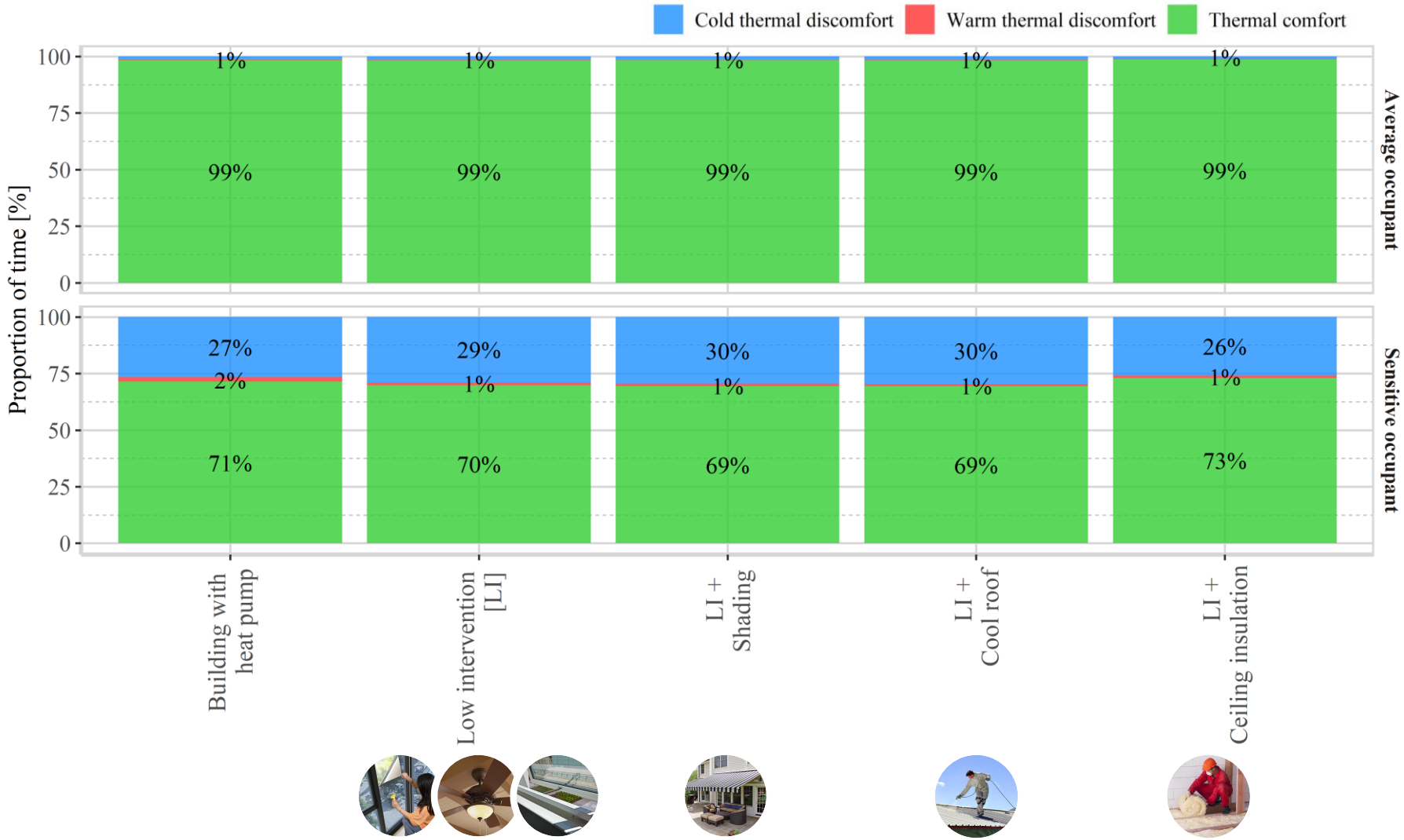
By installing a package of low-intervention measures together with a shading device, the proportion of time in **thermal comfort increases by 8%**, which means **29 extra days** in a year for an **average occupant.**

Sensitive occupants are exposed to **36 days** fewer days of warm discomfort.

Figures from left to right: LUCKYYJ Official Store (available here); secontrols (available here); Home Depot (available here); Summer Space (available here); Attic Man (available here); ENERGY STAR (available here); Knowledge Center (available here).

Thermal Comfort Results

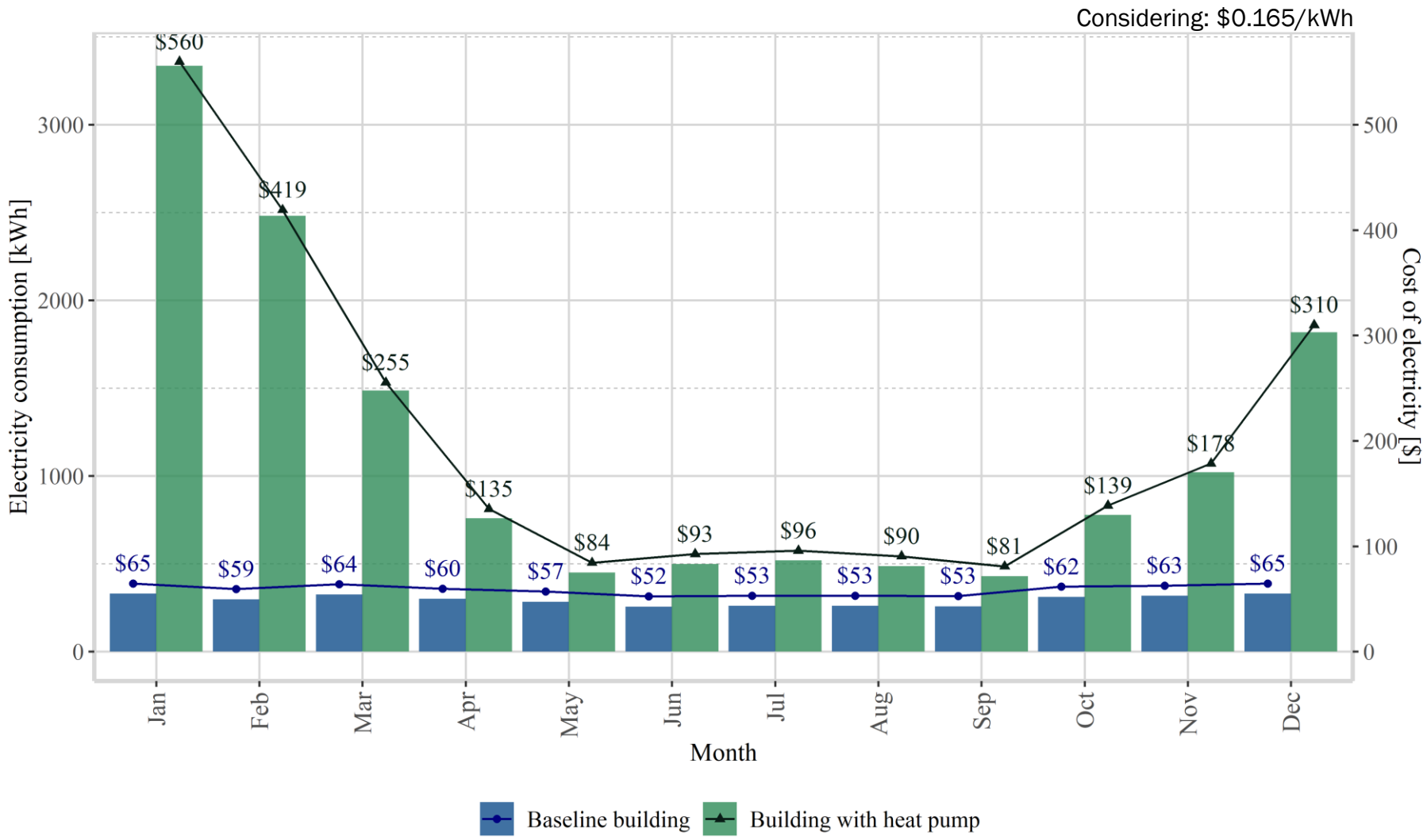
Buildings equipped with heat pumps compared to packages of low and high intervention



All cases are equipped with heat pumps for heating and cooling.

Figures from left to right: LUCKYYJ Official Store (available here); secontrols (available here); Home Depot (available here); Summer Space (available here); Attic Man (available here); ENERGY STAR (available here); Knowledge Center (available here).

Electricity Consumption and Cost Results



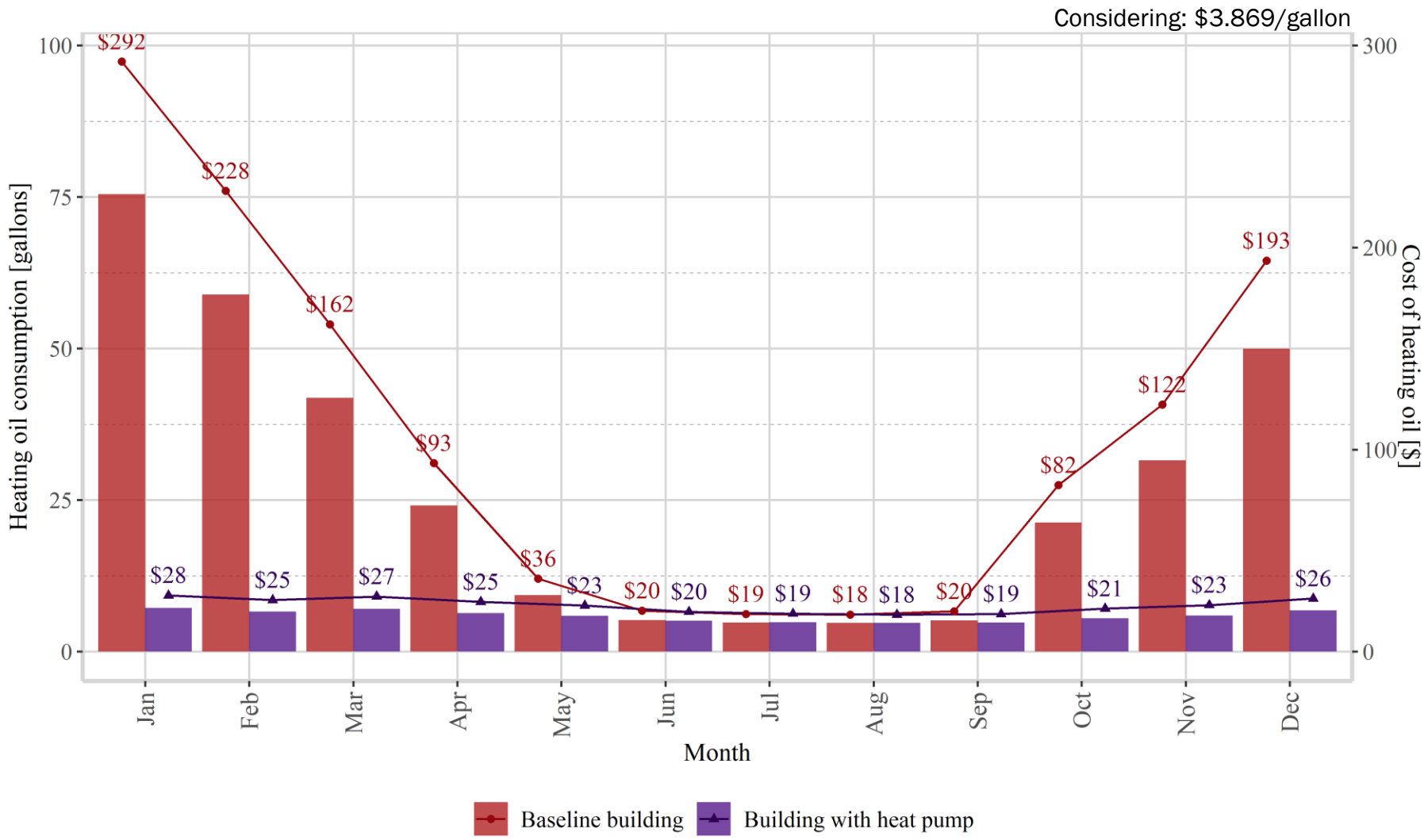
"Baseline building" equipped with:

- Radiator for heating.
- No cooling system.

"Building with heat pump" equipped with:

- Heat pump for heating and cooling.
- No other measure applied.

Heating Oil Consumption and Cost Results



"Baseline building" equipped with:

- Radiator for heating.
- No cooling system.

"Building with heat pump" equipped with:

- Heat pump for heating and cooling.
- No other measure applied.

Total Energy Cost Results

Considering: $0.165/kWh of electricity, and $3.869/gallon of heating oil

"Baseline building" equipped with:

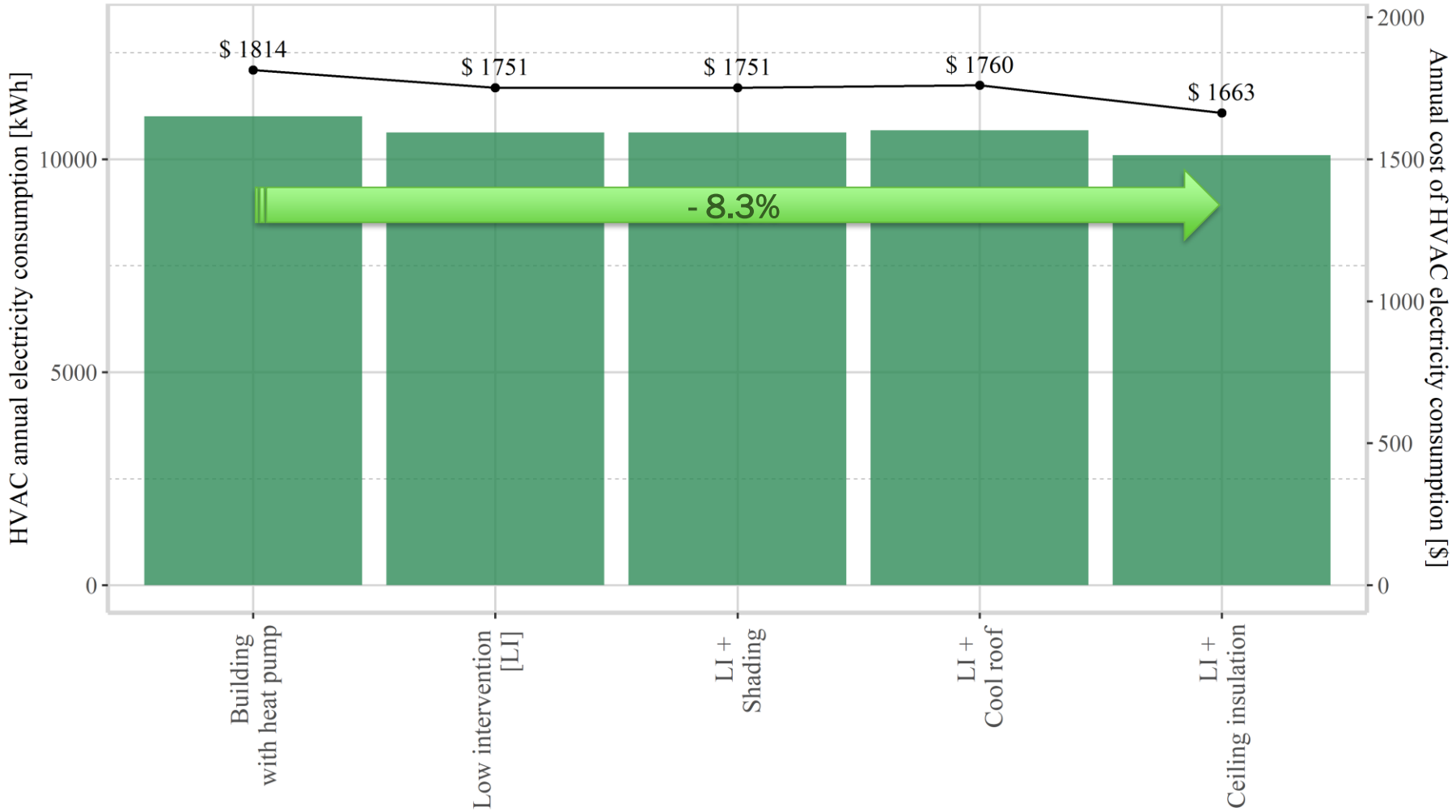
- Radiator for heating.
- No cooling system.

"Building with heat pump" equipped with:

- Heat pump for heating and cooling.
- No other measure applied.

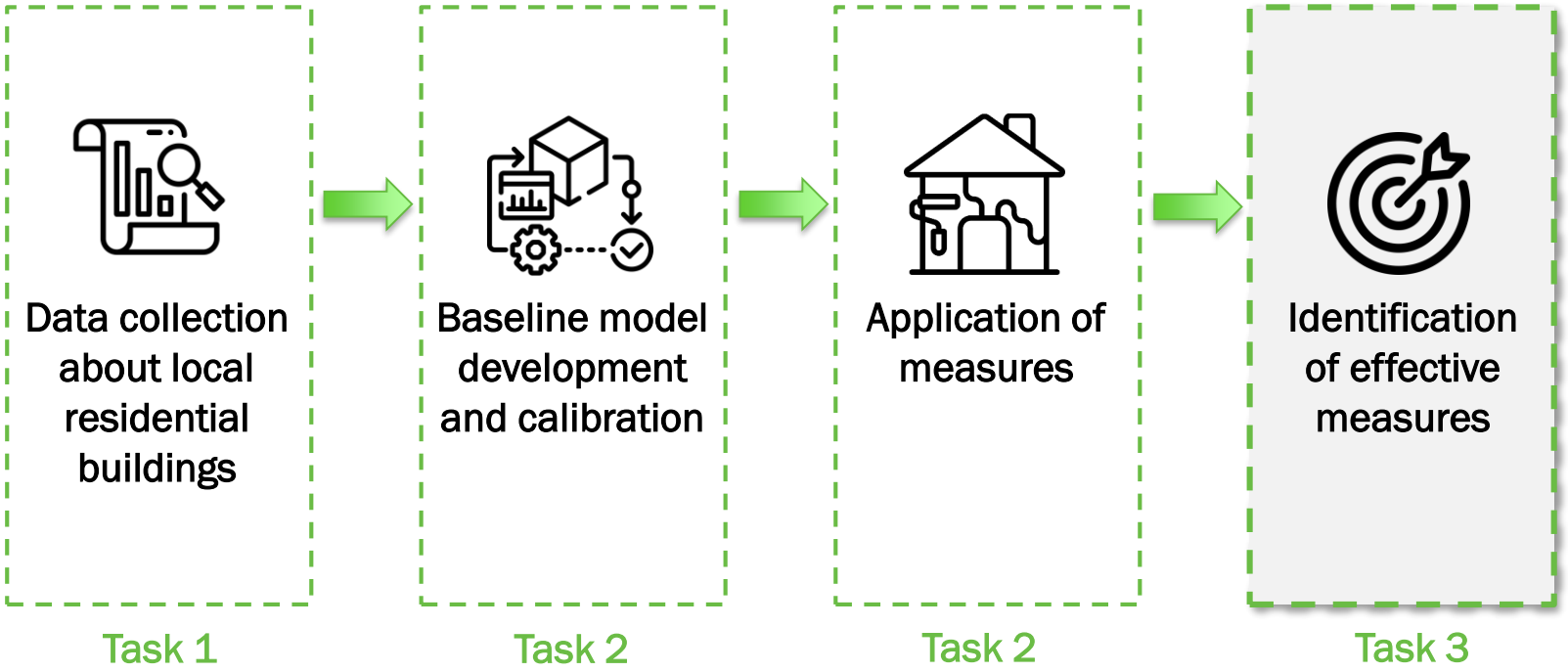
HVAC Annual Electricity Consumption and Cost Results

Building with heat pump and additional measures



All cases are equipped with heat pumps for heating and cooling.

Work Area 1: Workflow



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Effective Measures

- Simple measures with low intervention can enhance thermal comfort by:
  - Adding **25 days** of comfort for both average and sensitive (vulnerable) occupants.
  - Decreasing **33 days** of warm discomfort for sensitive (vulnerable) occupants.

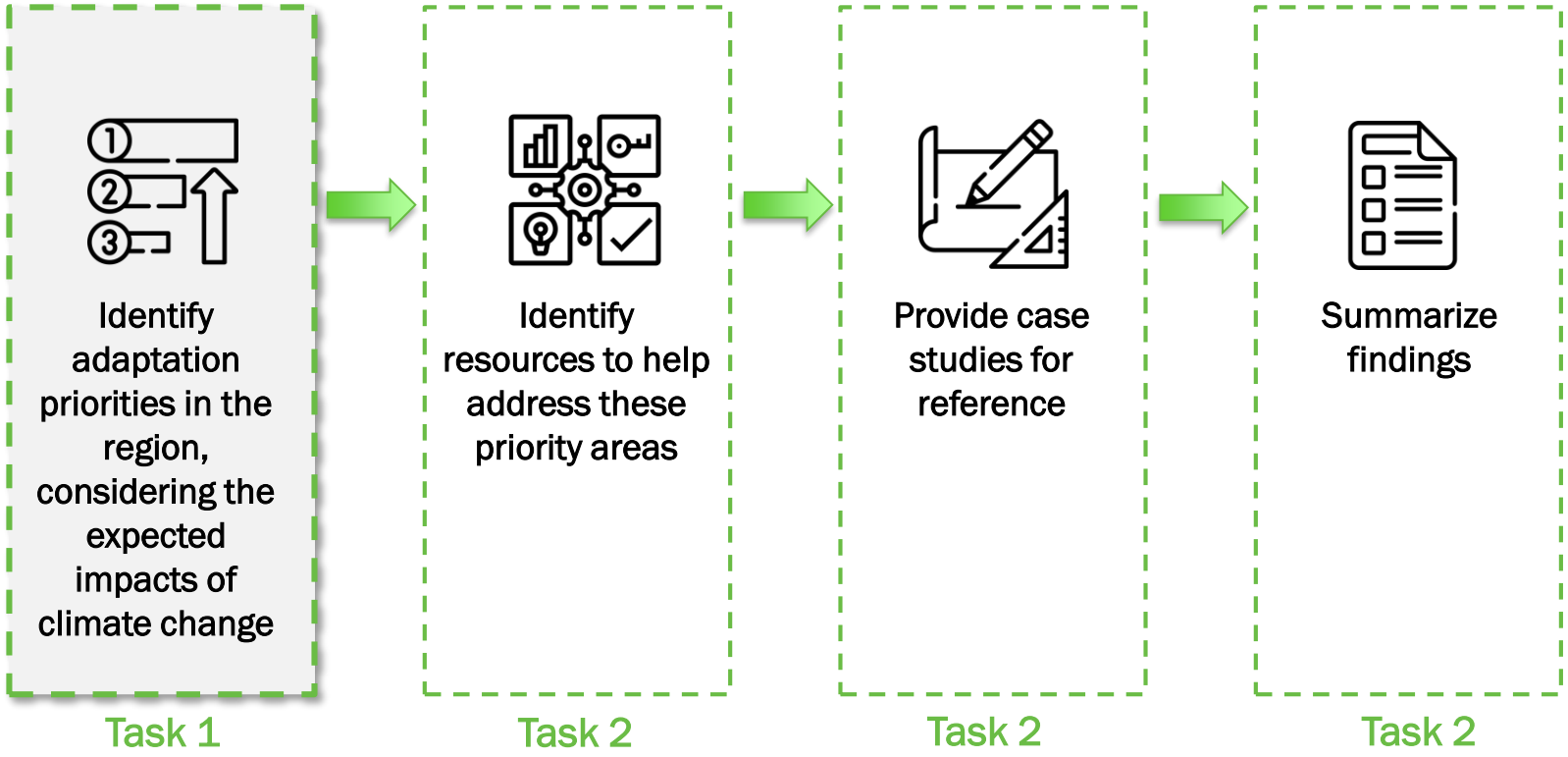
- A combination of low-intervention measures with one high-intervention measure (e.g., shading through awnings) can improve thermal comfort even further by:
  - Adding up to **29 days** of comfort for average occupants.
  - Decreasing up to **36 days** of warm discomfort for sensitive occupants.

- A heat pump can nearly eliminate warm thermal discomfort, but with potentially significant energy burden.

- Further strategies are necessary to reduce energy consumption during winter to make heat pumps more feasible.

Work Area 2. Research and Collection of Energy Efficiency Retrofit Resources

Work Area 2: Workflow



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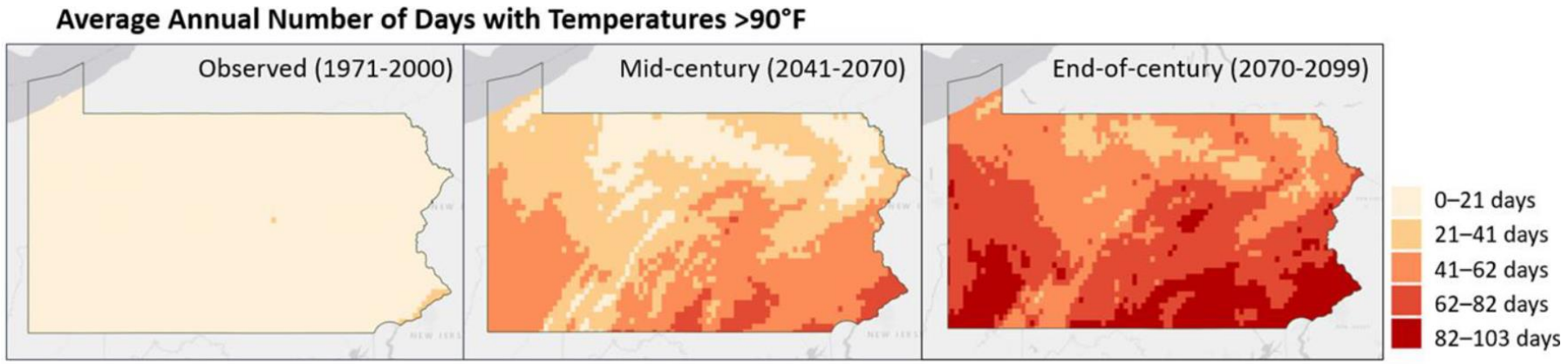
Impacts of Climate Change in Pennsylvania

The 2021 Pennsylvania Climate Impacts Assessment [1] outlines the latest anticipated impacts and risks of climate change in the commonwealth. By midcentury, the following changes are expected, compared to the 1971–2000 baseline:

- The average annual temperature statewide is projected to rise by 5.9°F (3.3°C).
- Extreme heat events will become more frequent and intense. For instance, temperatures of at least 90°F are expected on 37 days per year, up from 5 days during the baseline period, with more days reaching temperatures above 95°F and 100°F.
- The growing season will continue to change, increasing the number of days people need cooling for their homes and workspaces while reducing the number of days heating is required.



[1] Department of Environmental Protection (DEP). Pennsylvania Climate Impacts Assessment 2021 (available here)
Figure: Department of Environmental Protection (DEP). Pennsylvania Climate Impacts Assessment 2021 (available here)

Adaptation Priorities in Pennsylvania

According to the 2021 Pennsylvania Climate Impacts Assessment [1], without action, Pennsylvania will face severe climate impacts. To avoid and mitigate the consequences of climate change, the commonwealth must prioritize climate adaptation. The risk assessment identifies the following key considerations related to the built environment to reduce risks:

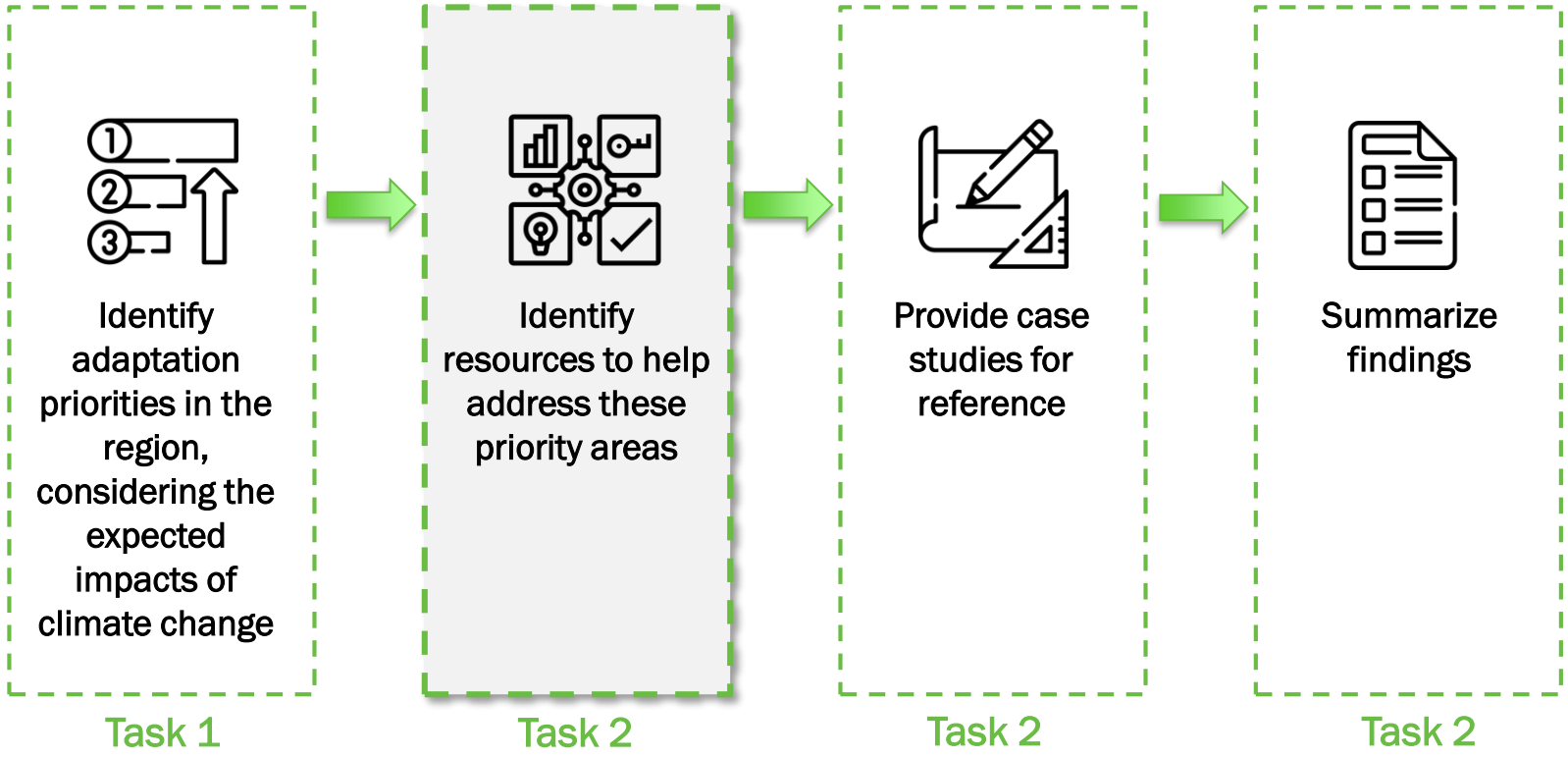
1. Reduce extreme heat risks to human health, particularly for vulnerable populations.
2. Support key sectors in the transition to a warmer climate.
3. Help low-income households cope with potential increased energy burden.

Resources to guide the community in these priority areas are provided in the following slides. Also, in line with national decarbonization and electrification goals, a fourth priority area was included:

4. Encourage energy-efficient electrified buildings.

[1] Department of Environmental Protection (DEP). Pennsylvania Climate Impacts Assessment 2021 (available here)

Work Area 2: Workflow



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1. Reduce extreme heat risks to human health.

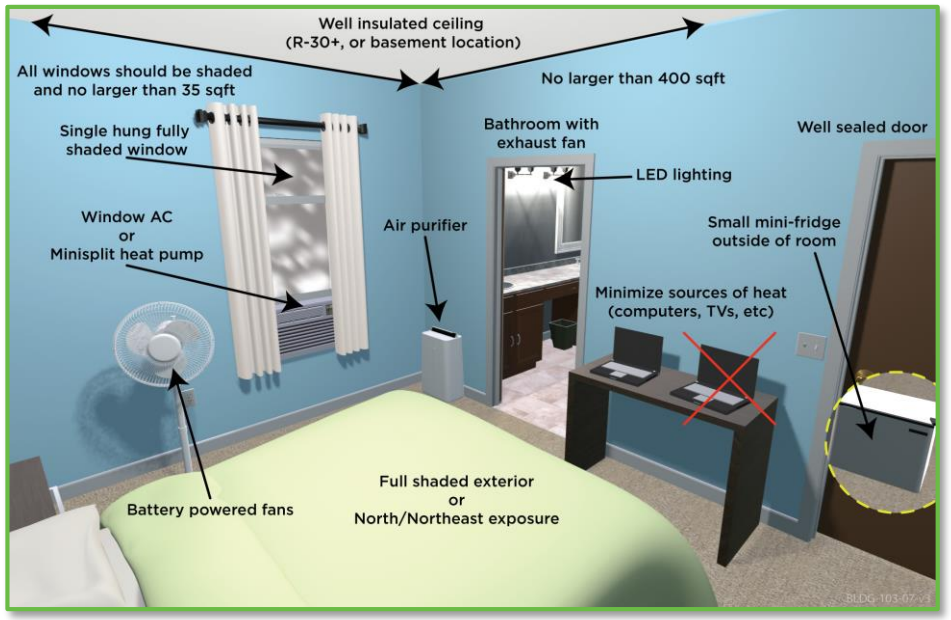
“Design for Extreme Heat” guide from the U.S. Department of Energy’s (DOE’s) Building America Program (available here):

This guide is intended to provide basic concepts and strategies for designing homes to be safer during extreme heat events. Covered topics are the following, which include important definitions and relevant strategies:

- Design considerations
- Design approach
- Minimizing heat gain
- Emergency cooling
- Backup power systems
- Communications, accessibility, and indoor air quality
- Cool rooms.

1. Reduce extreme heat risks to human health.

“Creating a Cool Room for Extreme Heat Events” guide from the DOE’s Building America Program (available here): This guide is intended to provide instructions on how to create a “cool room” or space within the home to shelter from extreme heat.



Browse through the tabs to find relevant information about the strategy, including key considerations for a successful application and training resources.

Figures: DOE, “Creating a Cool Room for Extreme Heat Events” guide (available here)

2. Support key sectors in the transition to a warmer climate.

“Building Components” guide from the DOE’s Building America Program (available here):
The Building Components tool can assist you in finding guides for both new and existing homes. Each category (shown below) contains a list of guides:

Figures: “Building Components” guide from the DOE’s Building America Program (available here)

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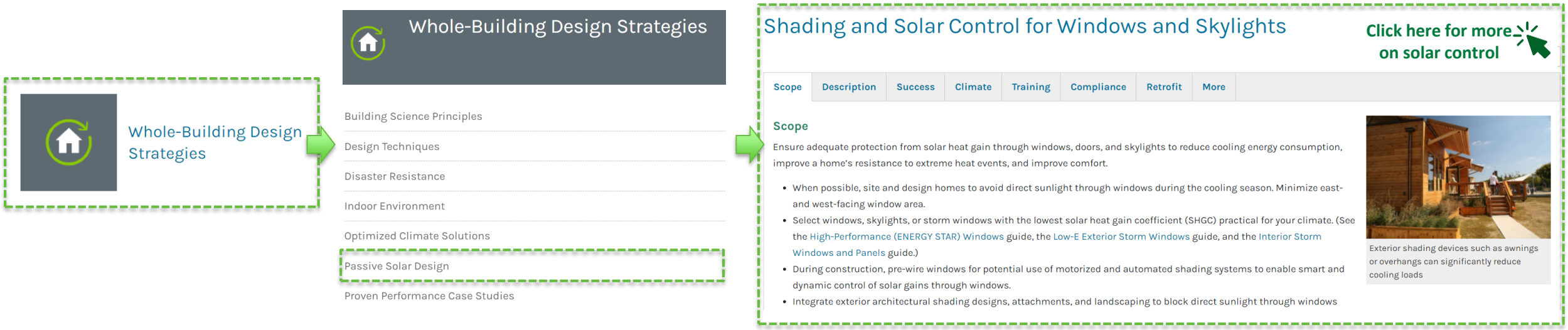

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Icons: “click” icon created by Freepik – Flaticon (available here)

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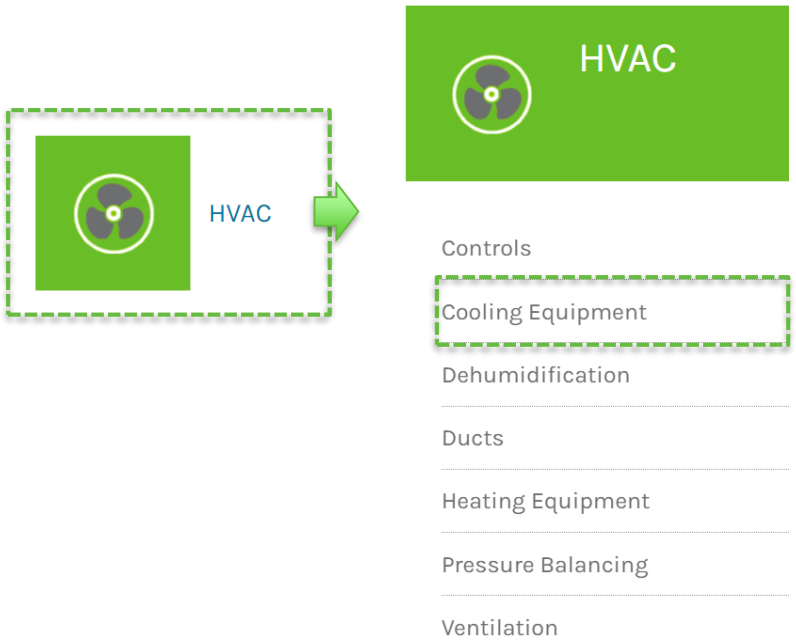

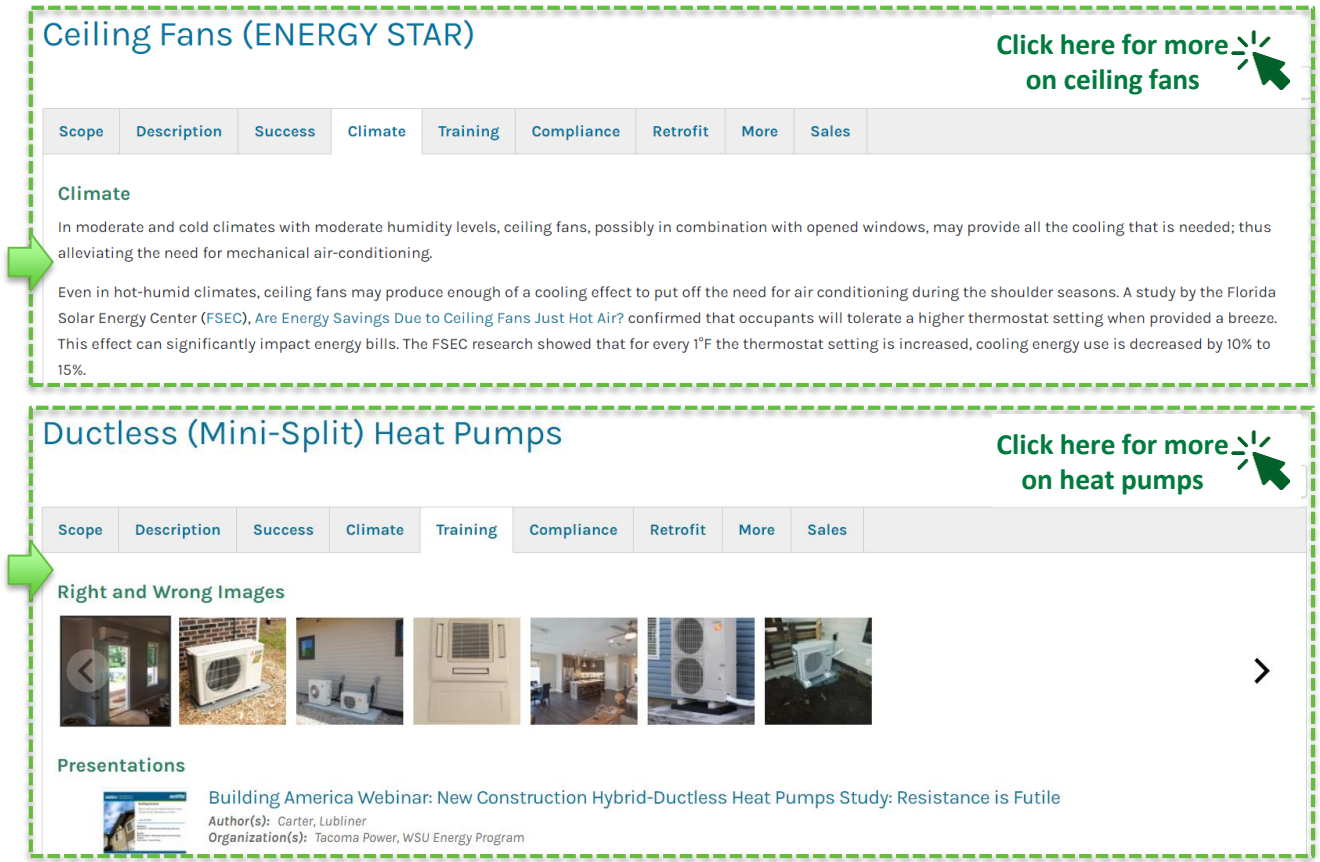

Browse through the tabs to find relevant information about the strategy, including key considerations for a successful application and training resources.

Figures: "Building Components" guide from the DOE's Building America Program (available here)
Icons: "click" icon created by Freepik – Flaticon (available here)

2. Support key sectors in the transition to a warmer climate.

“Building Science-to-Sales Translator” tool from the DOE’s Building America Program (available here):
The goal of this Building Science-to-Sales Translator is to provide a new glossary of sales themes that can be used across the industry to consistently reinforce the value of high-performance homes. Below are the themes covered by this tool:

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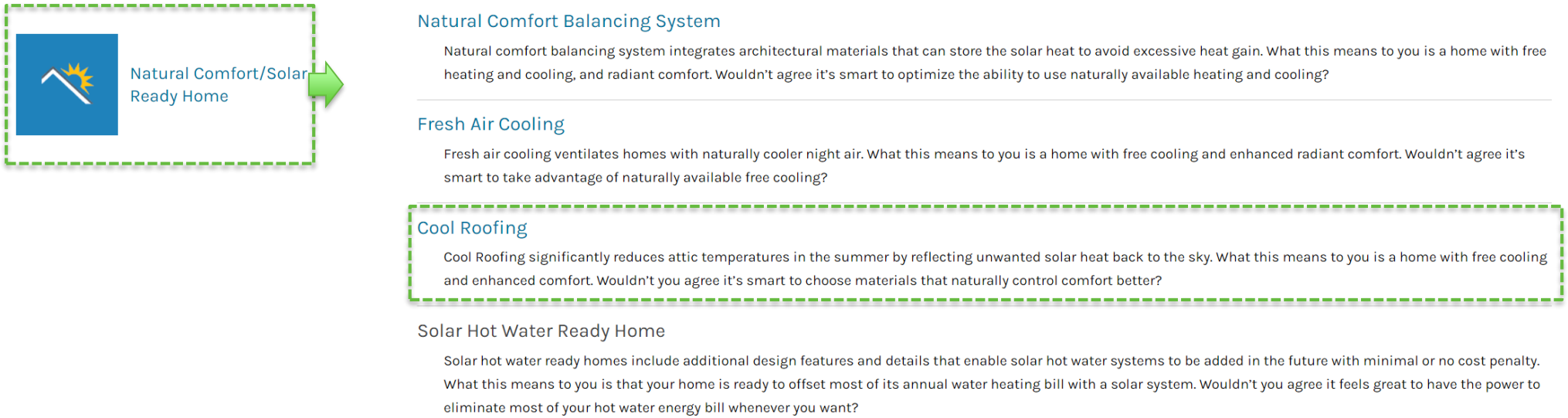

Provides simple definitions and relevant resources.

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Example:

Natural Comfort/Solar Ready Home

BUILDING SCIENCE-TO-SALES TRANSLATOR

Cool Roof = Cool Roofing

TECHNICAL DESCRIPTION

Cool roofing maintains lower attic temperatures by reflecting sunlight similar to how light-colored clothing helps you feel cooler on a sunny day. Standard or dark roofs can reach temperatures of 150°F or higher in hot climates. A cool roof under the same conditions could stay more than 30°F cooler. Cool roofing materials certified under the ENERGY STAR program include metal, tile, and asphalt shingles. They incorporate light colors and/or reflective materials that help meet minimum criteria for solar reflectance and reliability criteria.

Alternate Terms

- Energy-Saving Cool Roofing
- Cool Roofing Technology

Click here for more on cool roofs

Cool Roofing Sales Message

Cool Roofing significantly reduces attic temperatures in the summer by reflecting unwanted solar heat back to the sky. What this means to you is a home with free cooling and enhanced comfort. Wouldn't you agree it's smart to choose materials that naturally control comfort better?

Figures: "Building Science-to-Sales Translator" tool from the DOE's Building America Program (available here)
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2. Support key sectors in the transition to a warmer climate.

“National Residential Efficiency Measures Database” from the National Renewable Energy Laboratory (NREL) (available here):

The purpose of this tool is to provide a national unified database of residential building retrofit measures and associated costs. Home performance contractors and manufacturers of residential materials and equipment may find this information useful. The database offers the following types of retrofit measures:

- Appliances
- Domestic hot water
- Enclosure
- Heating, ventilation, and air conditioning (HVAC)
- Lighting
- Miscellaneous.

A measure consists of a typical “before-component” and “after-component” state for a certain type of retrofit activity. Each measure will have components, costs, and possibly references associated with it.

Note: The costs provided are national averages and may need some adjustment to factor in regional variations.

2. Support key sectors in the transition to a warmer climate.

“National Residential Efficiency Measures Database” from NREL (available here):

Example:

- Appliances
- Domestic Hot Water
- **Enclosure → Windows & Doors → Windows**
- Heating, ventilation, and air conditioning (HVAC)
- Lighting
- Miscellaneous.

Here you will find the data for window measures available in the National Residential Efficiency Measures Database.

Cost drivers:

- Prevailing local wages
- Access
- Presence of hazardous materials
- Drive time
- Existing construction and materials
- Extent of preparation
- Local code requirements
- Moisture issues present.

2. Support key sectors in the transition to a warmer climate.

"National Residential Efficiency Measures Database" from NREL (available here):

Each measure consists of a **before-component**, an **after-component**, and the estimated cost to implement the measure. Where multiple costs are indicated, they must be combined to obtain total measure cost (e.g., fixed ($) and normalized ($/sf) costs).

Example:

- Appliances
- Domestic Hot Water
- **Enclosure → Windows & Doors → Windows**
- Heating, ventilation, and air conditioning (HVAC)
- Lighting
- Miscellaneous.

I'd like to:

Replace Window

Before Component: Clear, Single, Metal

EXPORT TO CSV

Before Component	Properties	Performance Standards	Window Lifetime	Storm Lifetime	Film Lifetime
Clear, Single, Metal	▪ Frame Material: metal ▪ Glazing Type: clear ▪ Panes: 1 ▪ SHGC: 0.76 ▪ U-Value: 1.16 Btu/h-ft^2-R		30 Years		

After Components	Properties	Performance Standards	Window Lifetime	Storm Lifetime	Film Lifetime	Cost [$/ft^2 Window]
Low-E, Double, Insulated, Air, H-Gain	▪ Frame Material: insulated ▪ Gas Fill: air ▪ Glazing Type: high-gain low-e ▪ Panes: 2 ▪ SHGC: 0.56 ▪ U-Value: 0.32 Btu/h-ft^2-R	▪ meets IECC 2012 (4C, 5A, 5B, 5C, 6A, 6B, 6C, 7, 8) ▪ exceeds IECC 2009 (4C, 5A, 5B, 5C, 6A, 6B, 6C, 7, 8, 4A, 4B)	30 Years			44
Low-E, Double, Insulated, Air, L-Gain	▪ Frame Material: insulated ▪ Gas Fill: air ▪ Glazing Type: low-gain low-e ▪ Panes: 2 ▪ SHGC: 0.31 ▪ U-Value: 0.29 Btu/h-ft^2-R	▪ exceeds IECC 2009 (4C, 5A, 5B, 5C, 6A, 6B, 6C, 7, 8, 4A, 4B) ▪ exceeds Energy Star 2010 (Northern, North-Central) ▪ exceeds IECC 2012 (4A, 4B, 4C, 5A, 5B, 5C, 6A, 6B, 6C, 7, 8)	30 Years			46

Figures: "National Residential Efficiency Measures Database" from NREL (available here)

3. Help low-income households cope with potential increased energy burden.

The "Energy Saver Do-It-Yourself (DIY) Savings" Projects offer easy, step-by-step instructions to home energy efficiency improvements that will save you energy and money **(available here)**.

Examples of projects:

- **Water heating:** Insulate water heater tank and hot water pipes, lower water heating temperature.
- **Weatherization:** Use caulk to seal air leaks, air seal windows and doors with weatherstripping.
- **Windows:** Install exterior storm windows to reduce heat loss through windows.
- **In the kitchen:** Clean the refrigerator for health and efficiency.

Figures: DOE "Energy Saver Do-It-Yourself (DIY) Savings" Projects (available here)

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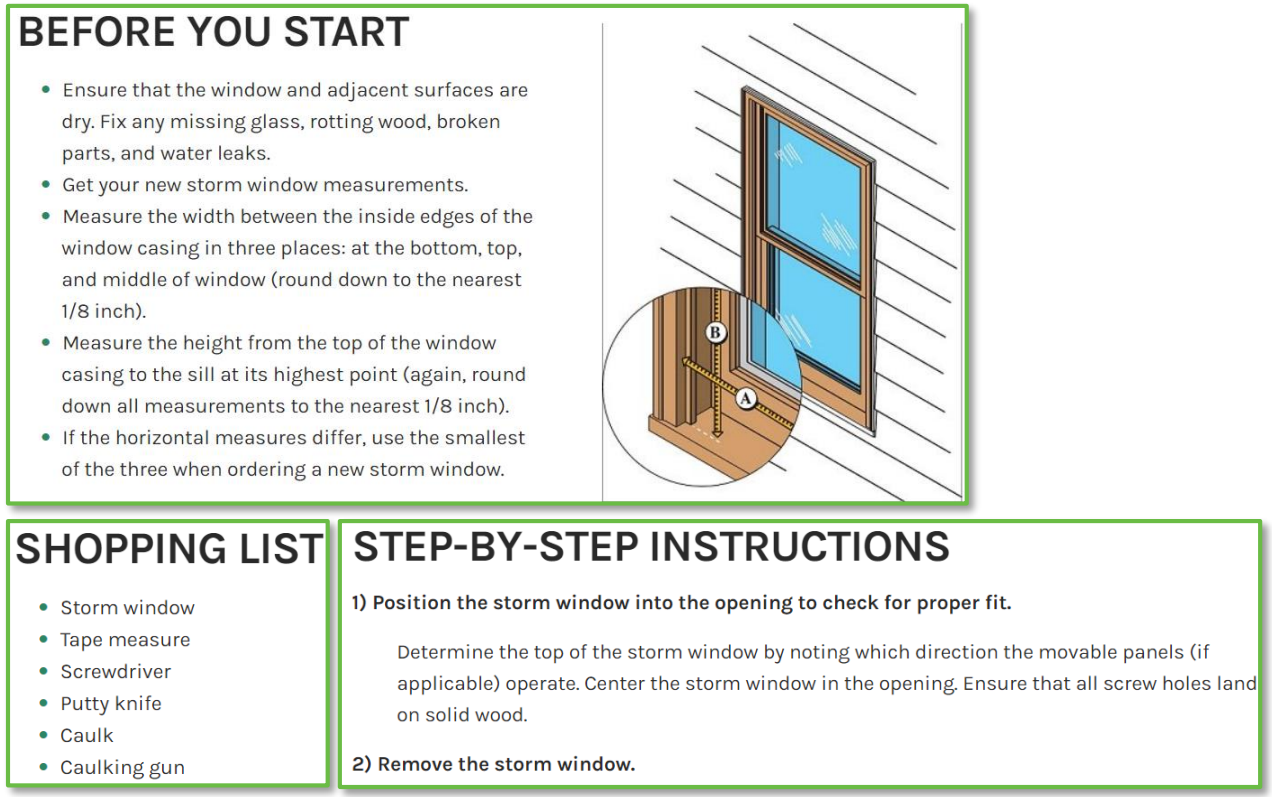

BEFORE YOU START

- Ensure that the window and adjacent surfaces are dry. Fix any missing glass, rotting wood, broken parts, and water leaks.
- Get your new storm window measurements.
- Measure the width between the inside edges of the window casing in three places: at the bottom, top, and middle of window (round down to the nearest 1/8 inch).
- Measure the height from the top of the window casing to the sill at its highest point (again, round down all measurements to the nearest 1/8 inch).
- If the horizontal measures differ, use the smallest of the three when ordering a new storm window.

SHOPPING LIST

- Storm window
- Tape measure
- Screwdriver
- Putty knife
- Caulk
- Caulking gun

STEP-BY-STEP INSTRUCTIONS

1) Position the storm window into the opening to check for proper fit.

Determine the top of the storm window by noting which direction the movable panels (if applicable) operate. Center the storm window in the opening. Ensure that all screw holes land on solid wood.

2) Remove the storm window.

Examples of projects:

- **Water heating:** Insulate water heater tank and hot water pipes, lower water heating temperature.
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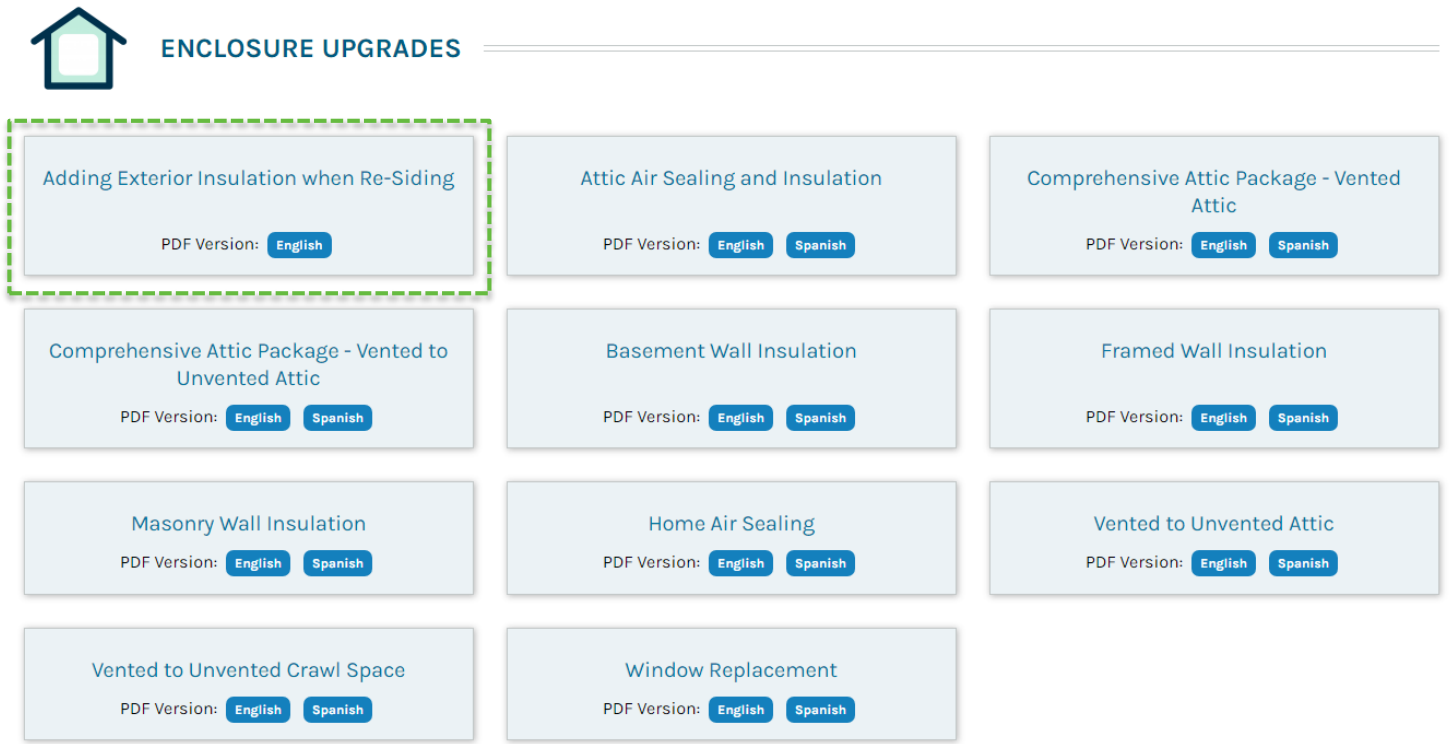
3. Help low-income households cope with potential increased energy burden.

The "Home Improvement Expert™ Checklists" provides actionable fact sheets and a "Contractor Checklist" to help over 80 million American homeowners ensure high-quality home improvements (**available here**). Available upgrade categories are:

- Enclosure upgrades
- Heating and cooling
- Fresh air system
- Water heating.



Figures: DOE "Home Improvement Expert™ Checklists" (available here)

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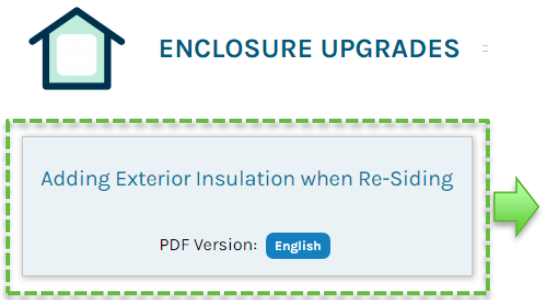


Adding Exterior Insulation when Re-Siding

Re-siding of an existing home presents an excellent opportunity to install continuous rigid insulation over the walls while the old siding is pulled off and before the new siding is installed.

PDF Version: English

Checklist

This U.S. Department of Energy checklist includes important specifications that can contribute to a complete and quality installation. All work shall comply with these specifications, all relevant codes and standards, and all manufacturer installation instructions. The contractor shall check each box on the checklist below and sign and date at the bottom to certify the work is completed.

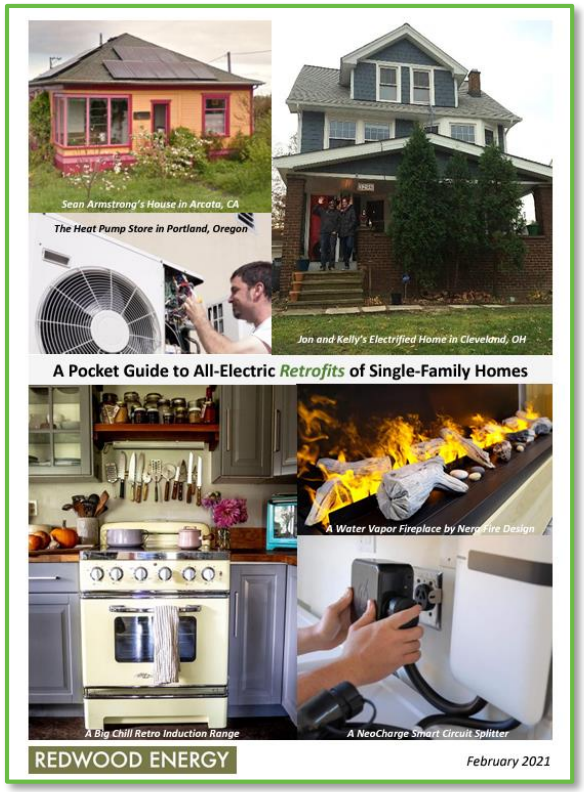
Preparation
☐ The walls shall be inspected for any evidence of bulk water penetration, knob and tube wiring, or moisture or pest damage, and a list of any potential problems shall be provided to the homeowner before proceeding with the work so remediation can be fully addressed within the scope of the siding replacement.
☐ Inspect the walls and note architectural features, window and door trim projections, hose bibs, light fixtures, and other features that may be impacted by the addition or exterior insulation.

Installation: Continuous Exterior Insulation
☐ Existing wall cladding and trim shall be removed.
☐ The wall sheathing shall be free of any protruding nail heads, screws, or irregularities to ensure a smooth surface for installing the air/water control membrane.
☐ All exposed cracks and penetrations at sheathing, rim areas, and top and bottom plates shall be air sealed with sealant compatible with the surface.
☐ If foam plastic insulation sheathing (FPIS) like XPS or foil-faced polyiso is used for the exterior rigid insulation, tape the foam with a compatible tape to serve as the air and water control layers. If other exterior insulation products are used, install a liquid-applied weather-resistant barrier product or house wrap with all of the seams taped.
☐ Flashing for windows and doors shall be integrated with the WRB to protect the wall assembly from bulk moisture.
☐ If the existing windows and doors are replaced and frames are replaced as well, new head, jamb, and sill flashing shall also be installed and properly integrated with the insulation and weather-resistant barrier layers.
☐ Insulation shall be installed in accordance with the R-value specified for the wall assembly under the contract agreement for this work.
☐ Furring strips, draining house wrap, or other spacing material shall be installed to provide an air gap behind lap siding, or brick or stone veneer. Wall cladding and trim shall be attached to the furring strips or through the air gap material to the studs. Where vinyl siding is used, the furring strips are not required.

Figures: DOE "Home Improvement Expert™ Checklists" (available here)

4. Encourage energy-efficient electrified buildings.

"A Pocket Guide to All Electric Retrofits of Single Family Homes" developed by Redwood Energy. This booklet is a simple "how-to" guide to help homeowners, home renters, and utilities and policymakers who want to replace existing gas appliances with efficient electric alternatives **(available here)**.

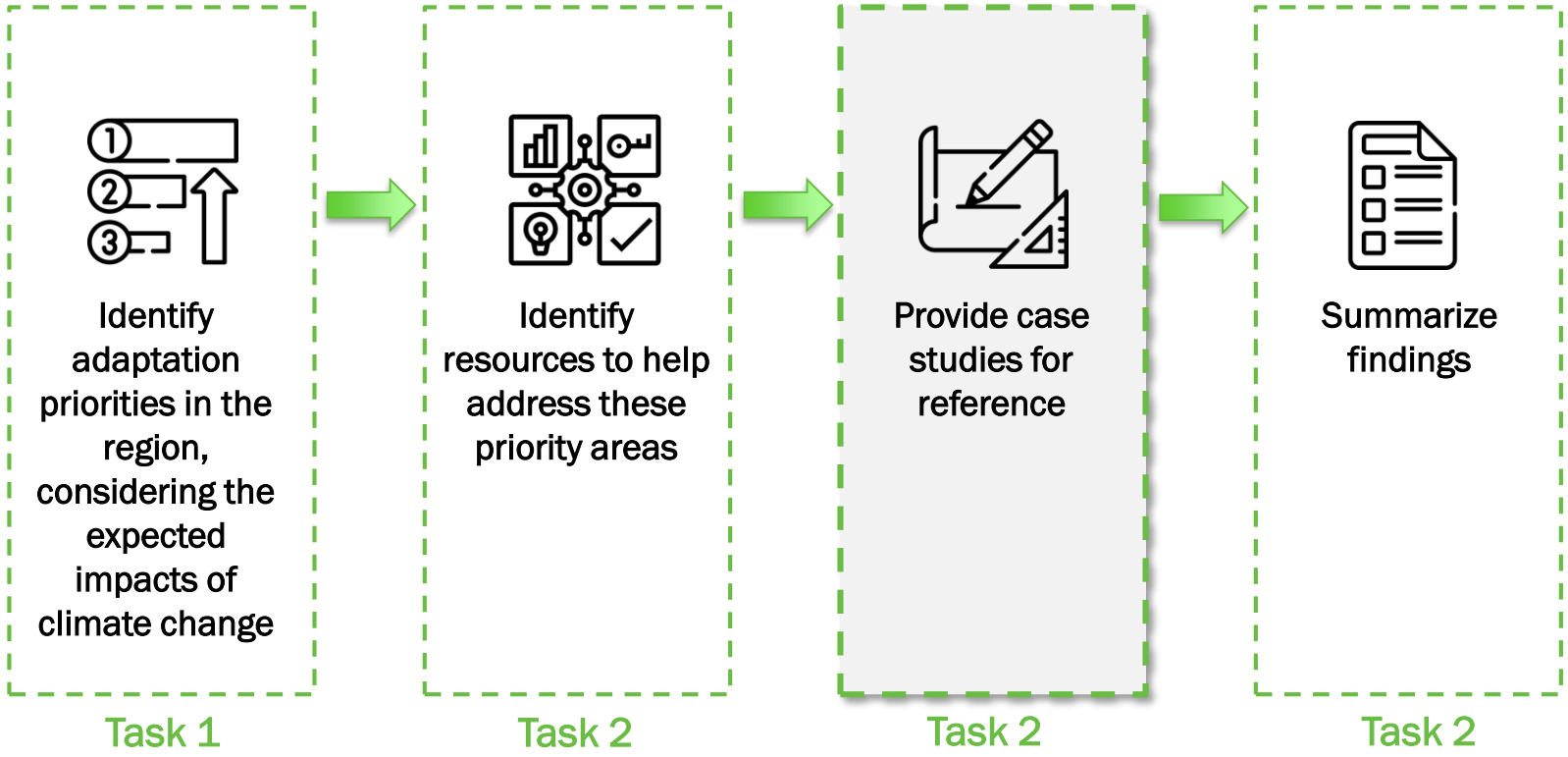


A few topics discussed are:

- The benefits of an all-electric home retrofit.
- Design factors when electrifying homes.
- Costs related to electrification.
- Case studies of complete electrification retrofits.

Figures: "A Pocket Guide to All Electric Retrofits of Single Family Homes" developed by Redwood Energy (available here)

Work Area 2: Workflow



Icons: Created by Freepik and Eucalyp – Flaticon, from left to right: "priority" icon (available here), "knowledge" icon (available here), "sketch" icon (available here), "report" icon (available here)

Case Study 1: Asdal Builders, LLC - Pittsburgh, PA

Comprehensive energy retrofit (available here).

Pittsburgh home pre-retrofit

Asdal Builders achieved a HERS* score of 65 and cut energy use by 80% with a gut-rehab of this 1930s-era Pittsburgh home.

Key Energy-Saving Features

- Basement walls insulated to R-5 rigid XPS plus R-15 fiberglass batt.
- Walls insulated with 4-inch blown cellulose plus Crane Smartcore siding with rigid polystyrene.
- Ceiling insulation – vaulted 10-inch blown cellulose, flat 12-inch blown cellulose.
- Band joist areas air sealed with spray foam and rigid foam.
- Windows – double-pane vinyl-framed.
- Doors insulated fiberglass.
- Power-vented gas boiler for heating and domestic hot water with electric tankless back up water heating.
- Ventilation from two energy recovery ventilators, timer-controlled bathroom fans and ceiling fans.
- ENERGY STAR lighting and appliances.

**HERS: Home Energy Rating System*
Photos from Asdal Builders (available here)

Case Study 2: 56th and Walnut - Philadelphia, PA

A gut rehab development (available here).

Post-implementation and test-out, energy modeling analysis for multiple sample dwellings yielded performance improvements ranging from 45% to 47%.

Key Energy-Saving Features

- 95% annual fuel utilization efficiency condensing furnace.
- 1.5 ton seasonal energy efficiency ratio 16 AC.
- 2 in. of closed cell spray polyurethane foam (ccSPF) applied against stone foundation.
- 3 in. of polyisocyanurate above roof deck covered with white TPO membrane. 3 in. of ccSPF on underside of roof deck.
- Reframed interior 2 × 4 steel stud wall at 16 in. o.c. spaced 1 in. from brick wall and filled with 3.5 in. of ccSPF.
- Double-pane, low-e, vinyl windows.
- Tightly sealed house.
- 62% compact fluorescent lights/13% linear fluorescent lamps.
- ENERGY STAR refrigerator.
- Premium natural gas tank water heater (0.67 EF).

Photo from the retrofit report: 56th and Walnut: A Philly Gut Rehab Development (available here)

Case Study 3: High-Performance Home - Gettysburg, PA

An example of a new high-performance home – DOE Zero Energy Ready Home 2016 Winner (available here).

Projected Annual Energy Cost Savings (vs home built to 2009 IECC): Without PV $842, with PV $2,145.

Added Construction Cost: Without PV $32,500, with PV $45,500.

Key Energy-Saving Features

- **Walls:** R-23 6.5" SIPs above grade, 4.5“ SIP at band joist plus 1” closed-cell foam; R-19 batt in floor joists; house wrap, stone or stucco siding.
- **Roof:** Composite shingle over 15# felt, ice-and-water shield in valleys and at eaves, kick-out and 5" sidewall flashing; all down spouts drain to 10’ pipe with pop-ups.
- **Attic:** R-53 vented attic with 1" closed-cell spray foam + R-49 blown cellulose.
- **Foundation:** Basement with 2" R-10 XPS under slab, poured concrete walls insulated on inside with 0.5" EPS and advanced framed with R-15 batts. Walkout basement walls are 10.25” R-37 SIPs.
- **Windows:** Double-pane low-e, argon filled.
- **HVAC:** Geothermal heat pump, 5.6 COP, 20.3 EER; all ducts in conditioned space.
- **Hot water:** 50-gal desuperheater on geo heat pump + 93 EF 50-gal electric water heater.
- **Lighting:** 50% LED, 50% CFL.
- **Appliances:** ENERGY STAR dishwasher, refrigerator, and bath fans.
- **Solar:** 7.2-kW photovoltaic (PV) shingles.
- **Energy Management System:** Internet energy monitoring of HVAC and solar.

Photos from the retrofit report: High-performance home - Gettysburg, PA (available here)

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Photos and figure from the retrofit report: High-performance home - Gettysburg, PA (available here)

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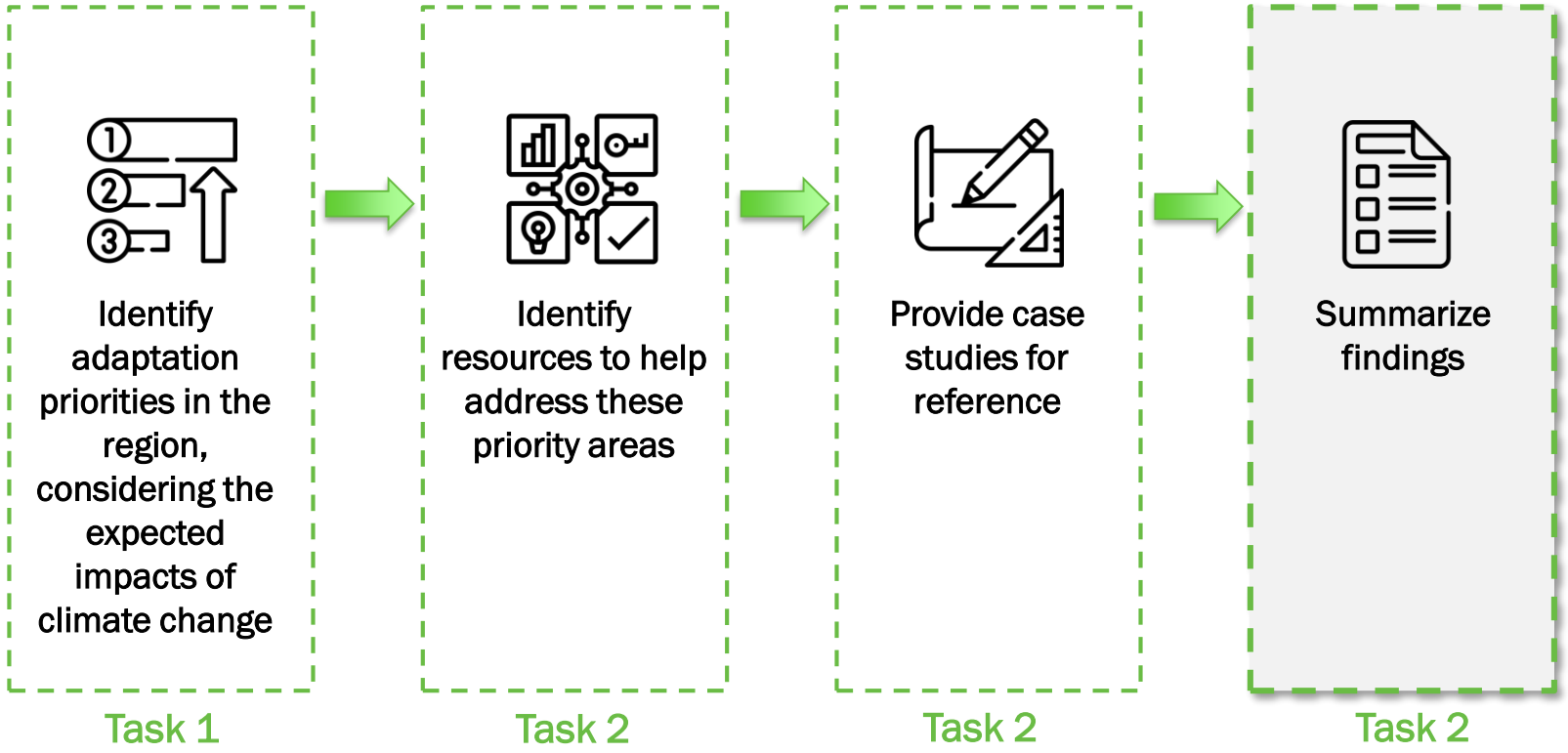

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Summary of Findings

The table below summarizes the identified resources.

Priority area	Resource	Goal	Main audience	Link
1. Reduce extreme heat risks to human health, particularly for vulnerable populations.	"Design for Extreme Heat"	Provide basic concepts and strategies for designing homes to be safer during extreme heat events.	Architects and engineers	https://basc.pnnl.gov/information/design-extreme-heat
	"Creating a Cool Room for Extreme Heat Events"	Provide instructions on how to create a "cool room" or space within the home to shelter from extreme heat.	Architects and engineers	https://basc.pnnl.gov/resource-guides/creating-cool-room-extreme-heat-events
2. Support key sectors in the transition to a warmer climate.	"Building Components" guide	Finding guides for both new and existing homes.	Architects and engineers	https://basc.pnnl.gov/building-components
	"Building Science-to-Sales Translator" tool	Provide a new glossary of sales themes that can be used to consistently reinforce the value of high-performance homes.	Across the industry, including applying this new language consistently to all consumer-facing materials used by government programs and industry alike	https://basc.pnnl.gov/sales-tool
	"National Residential Efficiency Measures Database"	Provide a national unified database of residential building retrofit measures and associated costs.	Home performance contractors and manufacturers	https://remdb.nrel.gov/about
3. Help low-income households cope with potential increased energy burden.	"Energy Saver Do-It-Yourself (DIY) Savings" Projects	Offer easy, step-by-step instructions to home energy efficiency improvements.	Homeowners	https://www.energy.gov/energysaver/do-it-yourself-energy-savers-projects
	"Home Improvement Expert™ Checklists"	Provide actionable fact sheets and a "Contractor Checklist" to help homeowners ensure high-quality home improvements.	Homeowners	https://basc.pnnl.gov/home-improvement-expert/checklists
4. Encourage energy-efficient electrified buildings.	"A Pocket Guide to All Electric Retrofits of Single Family Homes"	Provide simple "how-to" guide to help replacing existing gas appliances with efficient electric alternatives.	Homeowners, home renters, and utilities and policymakers	https://www.redwoodenergy.net/research/a-pocket-guide-to-all-electric-retrofits-of-single-family-homes

C2C: Clean Energy *to* Communities

U.S. DEPARTMENT OF ENERGY

Expert Match

Thank you

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.