Homegrown Energy:
A policy blueprint for energy affordability

Technical methodology

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Energy affordability, eligible households, and upgrade scenarios

1. Defining our terms on affordability

We define "energy affordability" as a household's ability to adopt the efficient electric version of home energy upgrades at the same or lower total cost as replacing existing equipment with a new like-for-like system. We calculate this by comparing the total cost of each of the efficient electric upgrades and the like-for-like system replacements — assuming a 15- to 20-year financing term at 7% interest. Our definition accounts for both upfront and operating costs in determining whether an upgrade is affordable for a household. This metric is distinct from calculating standard annual bill savings, which primarily considers the operational savings of whole-home electrification.

We define an "affordable household" as a household for which the total annualized cost of whole-home electrification and/or whole-home electrification, solar, and storage is on par with or lower than replacing existing equipment with new like-for-like systems, before policy interventions are added.

We define an "additional affordable household" as a household where whole-home electrification and/or whole-home electrification, solar, and storage becomes affordable as a result of one or several bundled policy interventions.

We define "average lifetime savings" as the average savings an additional affordable household realizes over the life of the equipment, 15 years, when choosing an efficient electric upgrade over replacing existing equipment with new like-for-like systems.

We define "total lifetime savings" as the aggregate savings each state or the nation would realize from all additional affordable households over the life of the upgraded equipment.

2. Eligible households

In our analysis, we include the roughly 68 million occupied single-family households in the U.S. that do not currently have an existing heat pump or heating system as the “eligible households” for our upgrade scenarios. We treat all of these households as eligible for solar and storage upgrades, though in practice, some households may not be suitable for solar due to their rooftop structure, geographic orientation, tilt, or shade coverage.

3. Upgrade scenarios

Our analysis models three upgrade scenarios: like-for-like system replacements, in which a household with non-electric appliances upgrades to more energy-efficient versions of its existing appliances; whole-home electrification, in which a household with non-electric appliances upgrades its heating and cooling, water heating, clothes drying, and cooking to high-efficiency electric machines; and whole-home electrification with solar and storage, which adds solar and battery storage to the whole-home electrification scenario.

The like-for-like system replacement assumes a household upgrades its cooling system to a more efficient room or central AC, depending on the presence of ducts, regardless of whether a household previously had a cooling system. As described above, we do not include households where heating systems were not previously present.

The whole-home electrification scenario assumes a household upgrades to a ventless heat pump clothes dryer with a combined energy factor (CEF) of 5.2 if its existing dryer is non-electric; and upgrades to an induction stove if its current stove is non-electric.

We distinguish between whole-home electrification and whole-home electrification with solar and storage due to the significant difference in upfront cost requirements and long-term operational savings. While the addition of solar and battery storage substantially increases initial costs, it simultaneously greatly increases operating savings by enabling behind-the-meter generation. Therefore, we explore the effects various policy interventions can have on each pathway, given their unique financial implications and barriers to adoption.

Model specifications

Upgrade	Assumption
Like-for-like system replacement	Upgrade includes the following suite of appliances: a 96% annual fuel utilization efficiency (AFUE) gas furnace or boiler; delivered fuel furnaces ranging from 85%–95% efficiency, based on EIA standards[1]; a gas water heater with a Uniform Energy Factor (UEF) of 0.81 or greater; and an ENERGY STAR room or central AC unit.
Whole-home electrification	Upgrade existing appliances to the following: an air-source heat pump with performance characteristics similar to a centrally-ducted heat pump with Seasonal Energy Efficiency Ratio 2 (SEER2) 17.2, 8.9 Heating Seasonal Performance Factor 2 (HSPF2) or ductless system of same SEER and 9.3 HSPF2; a heat pump water heater with UEF 3.35-3.45 (dependent on the size of the water heater); a ventless heat pump clothes dryer with CEF 5.2 if dryer is non-electric; and an induction range if range is non-electric.
Whole-home electrification with solar and storage	Whole-home electrification as described above, paired with rooftop solar and battery storage. Rooftop solar capacity is modeled using building-specific scaling, capped by the more stringent of two factors: physical roof constraints or the projected electricity demand following whole-home electrification. Battery storage operates under a self-consumption dispatch strategy aimed at minimizing power imported or exported to the grid with the bank capacity of a typical battery, 12.8kWh AC, and power of 5.8 kW AC.

[1] https://www.energystar.gov/products/furnaces/key_product_criteria

Policy interventions

We apply six distinct policy interventions to our whole-home electrification and whole-home electrification, solar, and storage upgrade scenarios. First, we evaluate each policy's individual impact on household affordability, as defined above. We then model these policy interventions in various combinations — stacking them sequentially as presented below — to quantify their total aggregated benefits. For policy interventions applied to whole-home electrification with solar and storage, we assume soft cost reductions are applied before each additional intervention.

To establish a point of comparison before modeling any policy interventions, we develop a baseline scenario at both state and national levels. The baseline incorporates standard financing; we use this to quantify various affordability metrics before any interventions are applied. For any upfront costs remaining in the baseline or after policy interventions, we assume amortization schedules based on the appliance's approximate lifetime: 15 years for whole home electrification and 20 years for solar and battery storage, each financed at an annual rate of 7% interest.

Intervention	Assumption
Soft cost reductions	Solar and storage upfront costs are discounted by 40%.*†
Electrification-friendly rate design	Electric heating costs are discounted by 20%.
Data centers pay	Total whole-home upfront costs are discounted by 50% for households with electric resistance heating. Solar and storage upfront costs are discounted by 30%.*
Non-pipeline alternatives	Total whole-home upfront costs are discounted by 40% for households with gas heating.
Inclusive utility investment	Utilities cover the upfront cost of home energy upgrades for households with expected bill savings and recover those costs over 15 to 20 years (depending on expected bill savings) at a 4 percent rate. Recovery is capped at 80 percent of the estimated bill savings. Any remaining portion of the upfront cost that cannot be recovered through bill savings is paid by the household up front.
Virtual power plants	We do not model VPPs as a standalone intervention because much of their household affordability benefits are captured in the "data centers pay" pathway.

* Does not apply to whole home electrification without solar and storage
† All subsequent interventions assume soft cost reductions have already been applied

Household energy consumption

Residential energy loads are calculated using the National Renewable Energy Laboratory (NREL)'s publicly available ResStock tool.[2] ResStock consists of 550,000 sampled residential buildings that statistically represent the U.S. residential housing stock, conforming to known distributions of various housing characteristics such as location, square footage, primary heating fuel, and housing typology. Each sample building represents approximately 252 real-world households. In addition to modeling the baseline energy consumption of the US housing stock, NREL uses EnergyPlus to model the energy consumption of the U.S. housing stock under several electrification and efficiency retrofit scenarios, such as installation of air source heat pumps, heat pump water heaters, and induction stoves. We supplement these scenarios with our own modeled scenarios.

We model hourly solar generation for each ResStock building using the PVWatts module from NREL's SAM[3]. We model the hourly battery dispatch for each ResStock building, given the hourly electric load and solar generation using SAM's battery model[4].

Operating costs

We calculate gas and electric volumetric charges by taking the 2024 revenues and sales volumes reported by utilities to the U.S. Energy Information Administration (EIA)[5,6] and subtracting out the fixed charges. RMI provides us with state-level gas fixed charges, and we obtain utility-level electric fixed charges from NREL's Utility Rate Database[7]. Electricity and gas rates are projected from 2024 to 2025, reflecting a 5% increase in electric rates[8] and a 19% increase in gas rates[9]. This change accounts for the difference between 2024 rates and present-day rates, and better represents 2025 commodity prices, which align more closely with EIA-projected out-year commodity costs. We use state-level EIA data for propane and fuel oil volumetric rates. We do not model time of use or seasonal rates, which likely results in an underestimate of electricity bill savings, particularly for utilities with existing winter heating rates.

[2] https://resstock.nlr.gov/datasets
[3] https://nrel-pysam.readthedocs.io/en/main/modules/Pvwattsv8.html
[4] https://nrel-pysam.readthedocs.io/en/main/modules/Battery.html
[5] Form EIA-86, "Annual Electric Power Industry Report"
[6] Form EIA-176, "Annual Report of Natural and Supplemental Gas Supply and Disposition"
[7] https://openei.org/wiki/Utility_Rate_Database
[8] https://www.eia.gov/outlooks/steo/data/browser/#/?v=8
[9] https://www.eia.gov/naturalgas/annual/pdf/nga24.pdf

To calculate annual energy bills, volumetric charges are applied to each building model's estimated annual fuel consumption along with fixed charges. We assume gas disconnection and thus no gas fixed charges for homes undergoing whole-home electrification.

For states with mandatory solar-buy-back programs, we assume 1:1 net metering, where excess electricity is sold back to the grid at full retail cost, and exports cannot exceed the imports annually. In states with reduced net metering or net billing, where excess electricity is sold back to the grid at a lower rate or avoided-cost rate, this assumption results in an underestimate of electricity bills, and thus an overestimate of the total benefits of solar and storage. For states without mandatory solar buy-back policies, we assume the household cannot sell any excess electricity back to the grid, which can result in an overestimate of electricity bills for customers whose utility decides to offer a non-mandated solar buy-back program.

Upfront cost

To estimate upfront costs, we use a combination of internal modeling and market research. These figures represent total project costs, including both equipment and installation. Where applicable, we normalize these estimates to represent present-day national averages, adjusting for inflation and location-specific materials & labor costs. On average, a like-for-like system replacement is estimated at $15,000, whole-home electrification at $25,000, and whole-home electrification with solar and storage at $64,000.

Modeled estimates

To estimate heat pump costs, we leverage extensive installation datasets from Massachusetts' residential air-source heat pump and whole-home pilot programs[10], as well as the TECH Clean California[11] program. We train a model to predict heat pump total installed costs based on the home's size, heat pump efficiency and size, the presence of ducts, installation date, and location. We then use the trained model to predict heat pump costs for each household in ResStock.

[10] https://www.masscec.com/public-records-requests
[11] https://techcleanca.com/heat-pump-data/download-data/

Heat pump water heater estimates are derived from the TECH Clean California dataset, encompassing over 1,200 installations. Estimated costs are based on the median and quartile costs for households switching from a fossil fuel water heater to a heat pump water heater.

To estimate the cost of residential rooftop solar, we use a dataset from the Lawrence Berkeley National Laboratory[12] on solar installations from 2002 to 2024. We then predict costs based on home square footage, which determines both energy demand and rooftop size. To estimate the upfront cost of a residential battery, we multiply EnergySage's[13] average price for a Tesla Powerwall system ($1,018/kWh) by a modeled capacity of 12.8 kWh.

Market research

All remaining appliance costs are estimated using market research, third-party reports, and a Google Shopping web scraper to identify the most frequently available and highly-rated models across multiple retailers. We use this data to determine an approximate lower bound for project costs, acknowledging that some households may opt for equipment with higher price points.

[12] https://emp.lbl.gov/tracking-the-sun
[13] https://www.energysage.com/energy-storage/how-much-do-batteries-cost/