Annual Energy Outlook 2025 Working Group Meeting

Residential and Commercial Buildings

Energy Consumption and Efficiency Modeling Team
May 8, 2024 | Virtual

Overview

- AEO2024 pause and AEO2025 enhancements
  - **Technology representation**
    - Major end-use technology updates
    - Distributed generation technology updates
    - Behind-the-meter storage characterization
  - **Policy representation**
    - Recent legislation and policy assumptions
- Changes in the residential and commercial buildings sectors
  - *Residential Energy Consumption Survey* (RECS)
  - *Commercial Buildings Energy Consumption Survey* (CBECS)

AEO2024 pause and AEO2025 enhancements

AEO2025: Enhancing long-term modeling capabilities

- The energy market is rapidly evolving, with new policies and regulations, new macroeconomic trends, and revolutionary technology change.

- We are not publishing AEO2024 to devote more development time to:
  - Introducing hydrogen representation
  - Improving carbon capture, transportation, and sequestration modeling
  - Improving electric power sector modeling
  - Improving technology representation in National Energy Modeling System (NEMS)
  - Addressing more comprehensively the existing and upcoming laws and regulations

https://www.eia.gov/pressroom/releases/press537.php
https://www.eia.gov/outlooks/aeo/resources/

Improving technology representation in NEMS residential and commercial modules

- Update distributed generation, combined-heat-and-power technology, and major end-use equipment cost and performance characteristics
- Develop representation of battery energy storage in buildings
- Characterize mini-split heat pumps in the residential sector

Improving technology representation in NEMS beyond AEO2025

- Update and regionalize residential major end-use equipment fuel and technology switching costs**
- Model thermal storage technologies: standalone, equipment-integrated, and envelope-integrated**
- Revise building envelope heating and cooling loads, residential new construction costs, and residential weatherization effects**
- Investigate effects of hydrogen blending on end-use equipment

***Depends on funding and data availability*

AEO2025 enhancements: distributed generation, combined heat and power, and battery storage

New distributed generation report characterizes solar photovoltaic (PV) paired with battery energy storage

Table 1-1. List of solar and storage technologies assessed and nominal capacity (2022)

Sector	Configuration	Technology	Technology Size Bin	Representative System Capacity
Residential	Solar PV (standalone)	Solar PV	Small	7.1 kW-DC
	Solar + Storage	Solar PV	Small	7.9 kW-DC
		Battery Storage (combined w/solar)	Small	5 kW-DC (12.5 kWh-DC)
		Battery Storage (retrofit)	Small	4.5 kW-DC (10 kWh-DC)
	Storage (standalone)	Battery Storage (standalone)	Small	6.9 kW-DC (13.5 kWh-DC)
Commercial	Solar PV (standalone)	Solar PV	Small 1	28.5 kW-DC
			Small 2	100 kW-DC
			Medium	250 kW-DC
			Large 1	500 kW-DC
			Large 2	1,000 kW-DC
	Solar + Storage	Solar PV	Small 1	28.5 kW-DC
			Small 2	100 kW-DC
			Medium	250 kW-DC
			Large 1	500 kW-DC
		Battery Storage (combined w/solar)	Small 1	20 kW-DC (40 kWh-DC)
			Small 2	60 kW-DC (120 kWh-DC)
			Medium	150 kW-DC (300 kWh-DC)
			Large 1	300 kW-DC (600 kWh-DC)
	Storage (standalone)	Battery Storage (standalone)	Small	60 kW-DC (120 kWh-DC)
			Medium	150 kW-DC (300 kWh-DC)
			Large 1	300 kW-DC (600 kWh-DC)

Note: kW-DC = kilowatt direct current; full report available at https://www.eia.gov/analysis/studies/buildings/dg_storage_chp/

Modeling behind-the-meter (BTM) battery energy storage systems in NEMS: some initial thoughts

- Focus on residential sector first, and battery storage paired with solar PV (rather than standalone batteries)
  - New versus retrofit battery system installations
  - S&P Global *Grid-Connected Energy Storage Market Tracker: H2 2023*—about 80% of BTM battery storage installations through 2030 will be residential versus commercial and industrial

- Let the current solar PV adoption choice models determine battery storage adoption
  - *Modeling Distributed Generation in the Buildings Sectors*: https://www.eia.gov/outlooks/aeo/nems/2020/buildings/
  - Fixed share of PV capacity that also adds battery storage capacity; battery system size based on average solar PV system capacity
    - Models do not differentiate between installation in new versus existing construction

Modeling behind-the-meter battery energy storage systems in NEMS: exploring cross-sector effects and market dynamics

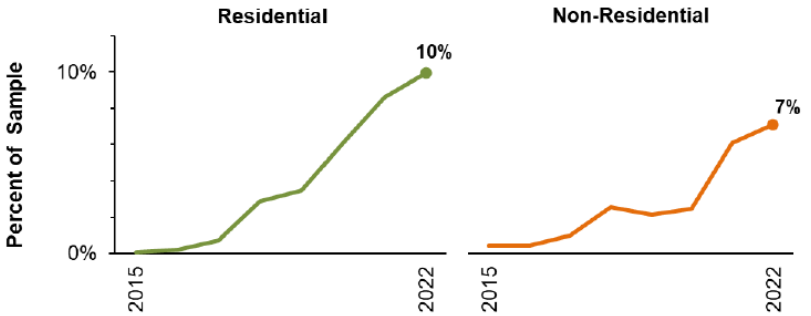
- **Use battery technology learning** across residential, commercial, transportation, and electricity supply models to drive increasing shares of PV systems coupled with battery energy storage

- **Investigate how state policies and utility power outages relate** to regional adoption of battery energy storage

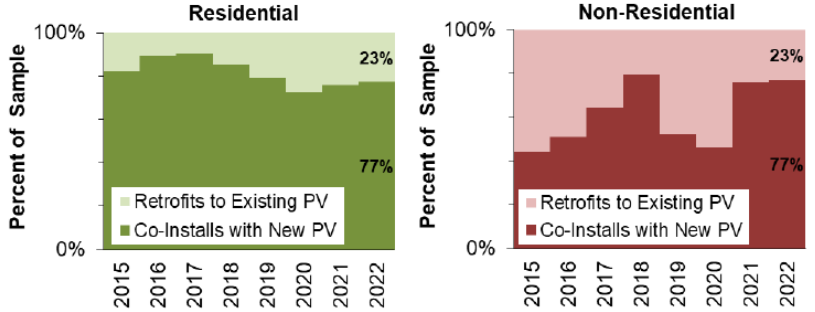
- Consider standalone battery storage in the context of **resiliency and price arbitrage**

An increasing amount of behind-the-meter battery energy storage is paired with distributed solar PV

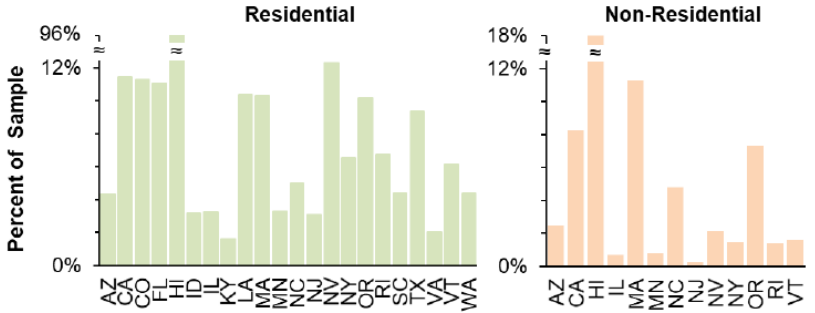
Storage Attachment Rates over Time



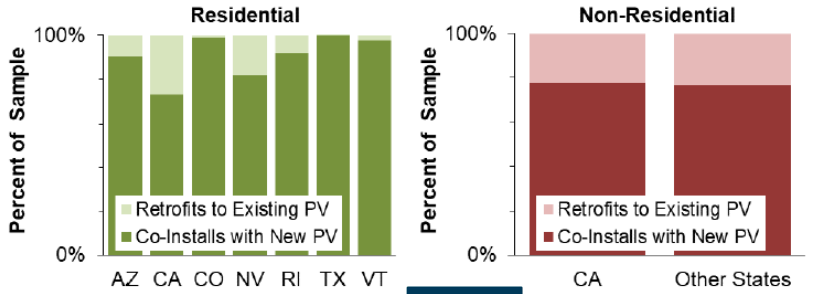
Retrofits vs. Co-Installs by Year



Storage Attachment Rates by State (2022)



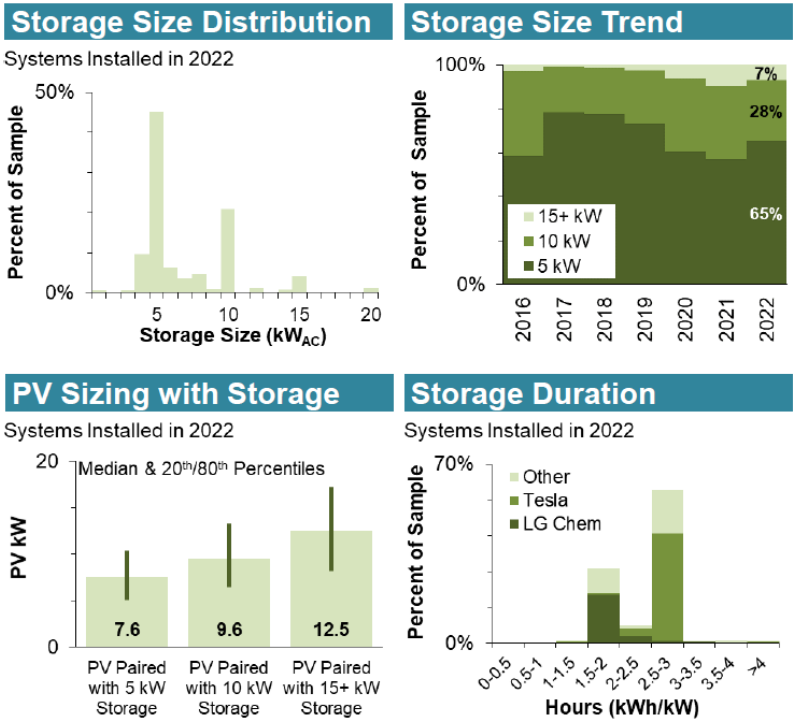
Retrofits vs. Co-Installs by State (2022)



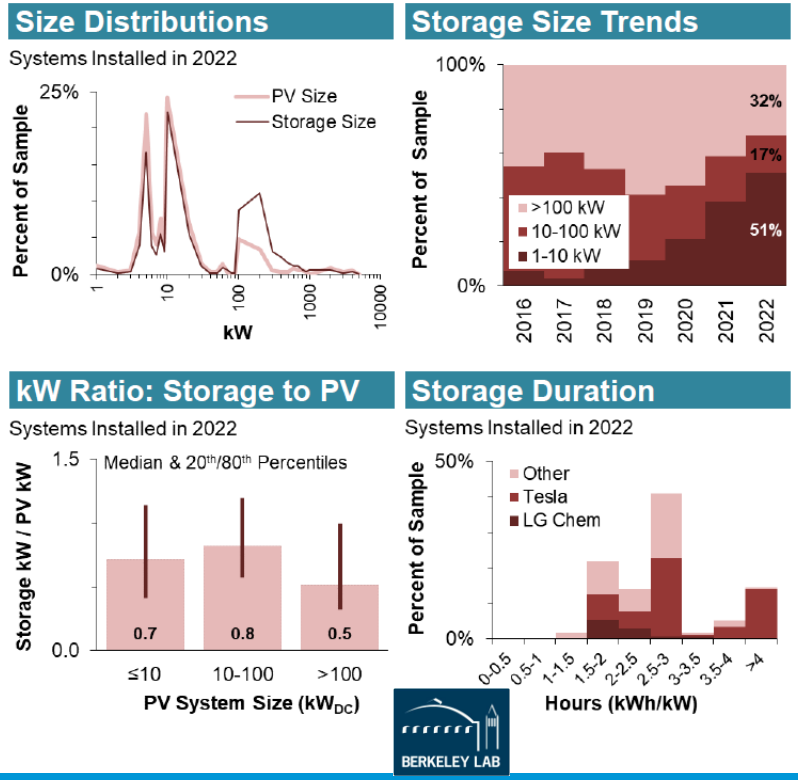
https://emp.lbl.gov/tracking-the-sun/

An increasing amount of behind-the-meter battery energy storage is paired with distributed solar PV (continued)

Residential



Non-Residential



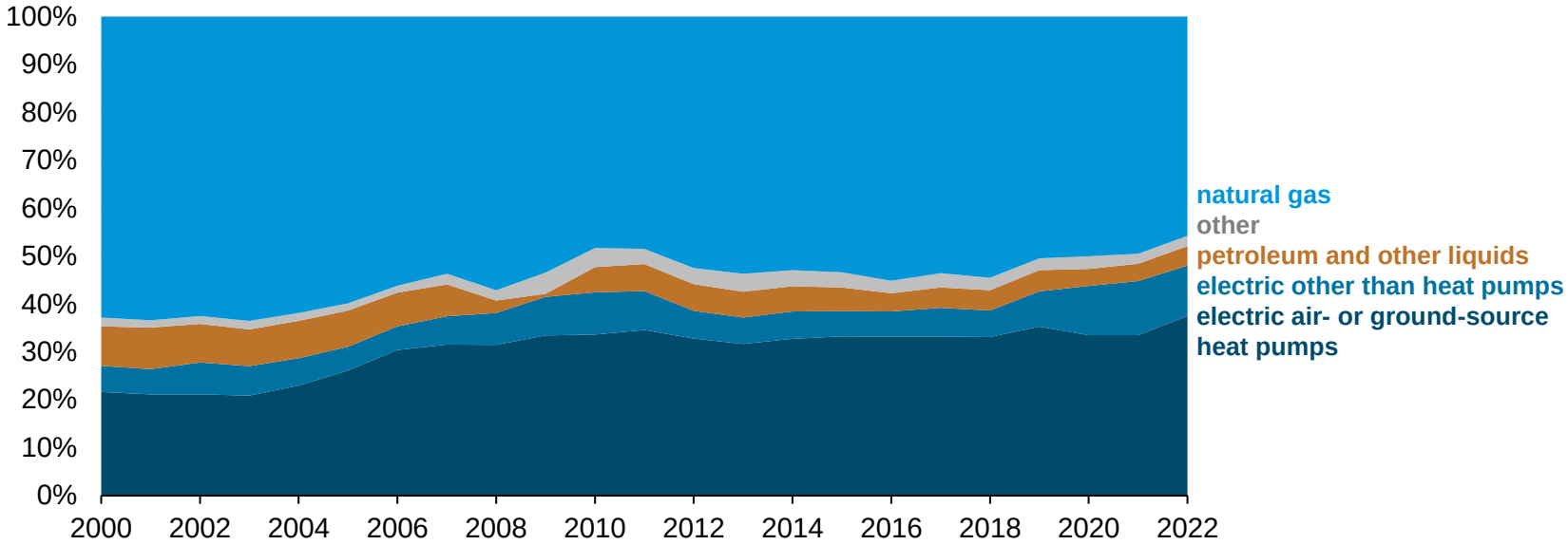
https://emp.lbl.gov/tracking-the-sun/

BERKELEY LAB

AEO2025 enhancements: major end-use equipment and standards

In 2022, nearly half of residential space heating equipment installed in *new*, single-family construction was electric

Share of equipment in new single-family homes by fuel type
percentage



Data source: U.S. Census Bureau, Survey of Construction (SOC), 2000–2022 SOC microdata files

Air-source heat pump technology continues to evolve…

Residential Air-Source Heat Pumps

LATEST REPORT

Final

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DATA	2015	2020	2022				2023				2030		2040		2050	
	Installed Base	Installed Base	Current Standard	Typical	ENERGY STAR V. 5.0	High	New Standard	ENERGY STAR V. 6.1	ENERGY STAR Cold Climate Criteria	High[4]	Typical	High	Typical	High	Typical	High
Typical Capacity (kBtu/h)	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
SEER (Cooling)[1]	13.1	15.3	14.0	15.3	15.0	22.6	15.0	16.0	NA	22.6	16.0	22.6	16.5	22.6	17.0	22.6
SEER2[2]	12.4	14.5	NA	14.5	NA	21.5	14.3	15.2	15.2	21.5	15.2	21.5	15.7	21.5	16.2	21.5
HSPF (Heating)[1]	7.9	8.6	8.2	8.6	8.5	12.4	8.8	9.2	NA	12.4	9.2	12.4	9.3	12.4	9.3	12.4
HSPF2[2]	6.7	7.3	NA	7.3	NA	10.6	7.5	7.8	8.1	10.6	7.8	10.6	7.9	10.6	7.9	10.6
Average Life (y)	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3
Retail Equipment Cost (2022$)[1]	3,290	4,270	3,970	4,270	4,110	6,740	4,110	4,380	4,380	6,740	4,380	6,740	5,000	6,740	5,100	6,740
Total Installed Cost (2022$)[1]	5,790	6,880	6,730	6,880	6,810	8,620	6,810	6,940	6,940	8,620	6,940	8,620	7,240	8,620	7,330	8,620
Annual Maintenance Cost (2022$)[3]	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150

1. Values shown are for split-system units in the 36 kBtu/h (3-ton) size class. Costs and efficiency levels are for "blower-coil" systems, meaning they include a blower. Note coil-only systems were analyzed for residential central air conditioners, which is why the "High" SEER levels are higher for heat pumps than for air conditioners.
2. In 2023, new energy conservation standards for Residential Central Air Conditioners and Heat Pumps took effect. The new standards specify different metrics for Air-Source Heat Pumps (SEER2 and heating seasonal performance factor 2 (HSPF2)). SEER to SEER2 and HSPF to HSPF2 conversions were determined using the RESNET website.
3. Annual maintenance include preventative maintenance and services provided by HVAC professionals for maintaining product operation. Examples include, calibrate and level thermostat, clean filters, clean indoor and condenser coil, flush/treat condensate drain with anti-algae, inspect condenser coil, monitor operating pressure of refrigerant, inspect fan blade, etc.
4. High costs derived from developing a cost-efficiency curve between retail/installed costs and SEER.

Note:
The previous standard went into effect in January 2015. The current standard went into effect in January 2023.
ENERGY STAR V. 5.0 went into effect in September 2015. ENERGY STAR V. 6.1 went into effect in January 2023.
Ranges represent the span of typical values for maintenance costs.
Average life is determined using a Weibull distribution characterized by the following scale (α), shape (β), and delay (θ) parameters: (15.88, 2, 1).

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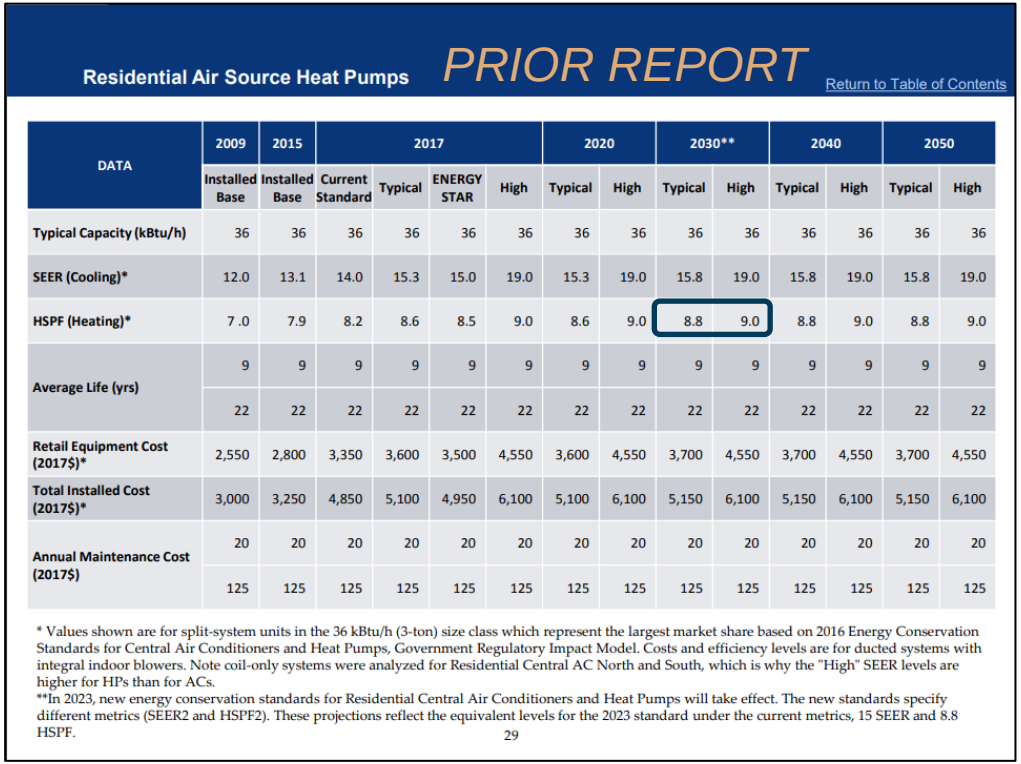
Available at https://www.eia.gov/analysis/studies/buildings/equipcosts/

…relative to prior report efficiency estimates



Residential Air Source Heat Pumps *PRIOR REPORT* Return to Table of Contents

DATA	2009	2015	2017				2020		2030**		2040		2050	
	Installed Base	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBtu/h)	36	36	36	36	36	36	36	36	36	36	36	36	36	36
SEER (Cooling)*	12.0	13.1	14.0	15.3	15.0	19.0	15.3	19.0	15.8	19.0	15.8	19.0	15.8	19.0
HSPF (Heating)*	7 .0	7.9	8.2	8.6	8.5	9.0	8.6	9.0	8.8	9.0	8.8	9.0	8.8	9.0
Average Life (yrs)	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	22	22	22	22	22	22	22	22	22	22	22	22	22	22
Retail Equipment Cost (2017$)*	2,550	2,800	3,350	3,600	3,500	4,550	3,600	4,550	3,700	4,550	3,700	4,550	3,700	4,550
Total Installed Cost (2017$)*	3,000	3,250	4,850	5,100	4,950	6,100	5,100	6,100	5,150	6,100	5,150	6,100	5,150	6,100
Annual Maintenance Cost (2017$)	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	125	125	125	125	125	125	125	125	125	125	125	125	125	125

* Values shown are for split-system units in the 36 kBtu/h (3-ton) size class which represent the largest market share based on 2016 Energy Conservation Standards for Central Air Conditioners and Heat Pumps, Government Regulatory Impact Model. Costs and efficiency levels are for ducted systems with integral indoor blowers. Note coil-only systems were analyzed for Residential Central AC North and South, which is why the "High" SEER levels are higher for HPs than for ACs.
**In 2023, new energy conservation standards for Residential Central Air Conditioners and Heat Pumps will take effect. The new standards specify different metrics (SEER2 and HSPF2). These projections reflect the equivalent levels for the 2023 standard under the current metrics, 15 SEER and 8.8 HSPF.

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As an example of evolving efficiency estimates, for 2030, the previous technology report showed a *high efficiency* heat pump with a lower heating seasonal performance factor (HSPF) than the latest report *typical* unit.

Available at https://www.eia.gov/analysis/studies/buildings/equipcosts/

More comprehensively addressing existing and upcoming laws and regulations

- Incorporate latest federal minimum energy efficiency standards and ENERGY STAR specifications for end-use equipment in buildings
  - https://www.energy.gov/eere/buildings/standards-and-test-procedures
  - https://www.energystar.gov/products/products_list
  - **Examples of updated equipment standards since AEO2023:**

Gas furnaces	Electric motors and blower fans
Water heaters	Air cleaners
Refrigerators and freezers	Microwaves
Conventional cooking products	Pool pumps and heaters
Dishwashers	Distribution transformers

New gas furnace standards would exceed current ENERGY STAR minimum specifications

Residential Gas-Fired Furnaces (Rest of Country) LATEST REPORT

Final

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DATA	2015	2020	2022				2030		2040		2050	
	Installed Base	Installed Base	Current Standard	Typical	ENERGY STAR (ROC) V. 4.1	High	Typical	High	Typical	High	Typical	High
Typical Input Capacity (kBtu/h)	80	80	80	80	80	80	80	80	80	80	80	80
AFUE (%)	80	80	80	90	90	99	95	99	95	99	95	99
Electric Consumption (kWh/y)[1]	279	279	386	636	636	725	631	725	631	725	631	725
Average Life (y)[2]	16	16	16	16	16	16	16	16	16	16	16	16
	25	25	25	25	25	25	25	25	25	25	25	25
Retail Equipment Cost (2022$)	1,260	1,260	1,080	1,200	1,200	1,390	1,220	1,390	1,220	1,390	1,220	1,390
Total Installed Cost (2022$)	2,380	2,380	3,690	4,130	4,130	4,320	4,150	4,320	4,150	4,320	4,150	4,320
Annual Maintenance Cost (2022$)	40	40	120	130	130	130	130	130	130	130	130	130

1. Electric consumption accounts for the electricity consumption of components such as the furnace fan, draft inducer, and the ignitor. In some high efficiency products, this component also includes auxiliary equipment, such as condensate pumps and heat tape.
2. In the Residential Furnaces EERE 2022 NOPR, an average lifetime of 21.5 years is calculated for gas-fired furnaces (Rest of Country). Lifetime range was calculated using the Weibull Distribution in the Residential Furnaces EERE 2022 NOPR.

Note:
Models on the market can be either weatherized or non-weatherized. The majority (74%) are non-weatherized, and the values in the table use only non-weatherized data.
Electric consumption and cost values for 2022 and beyond are for a national sample and use the Residential Furnaces EERE 2022 NOPR LCC spreadsheet.
Electric consumption and costs for the 2030, 2040, and 2050 high values are estimated based on the maximum-efficiency level analyzed in Residential Furnaces EERE 2022 NOPR, which is 98% AFUE.
The current standard went into effect in November 2015.
ENERGY STAR V. 4.1 went into effect in February 2013.
The range for average life represents the span of typical values.

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Available at https://www.eia.gov/analysis/studies/buildings/equipcosts/

Recent legislation and policy assumptions

How do assumptions about energy efficiency incentives affect energy use projections?

Selected rebates as a percentage of installed cost by residential end use

percent, AEO2023 Reference case

Technology	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
Air-source heat pumps	26%	8%	6%	8%	5%	1%	38%	7%	13%
Ground-source heat pumps	21%	11%	5%	5%	2%	0%	1%	4%	2%
Clothes washers	11%	3%	2%	2%	3%	0%	1%	2%	7%
Electric-heat-pump water heaters	31%	30%	11%	9%	15%	6%	24%	10%	24%

Data sources: U.S. Energy Information Administration (EIA), *Northeast Regional Energy Efficiency Database (REED) 2019 data update*; EIA, *Northeast Regional Energy Efficiency Database (REED), Program and Measure Data: Report on Results of Investigations*, May 2020; EIA, *Assessing Existing Energy Efficiency Program Activity*, June 2018; ENERGY STAR Summaries of Programs; Consortium for Energy Efficiency (CEE) Program Summaries
Note: We apply rebates to all projection years unless noted otherwise.

For more information, see AEO2023 assumptions: https://www.eia.gov/outlooks/aeo/assumptions

Legislation and policy assumptions: Inflation Reduction Act

Extend and modify energy credit (IRS 25D) (IRS 48)	Extend and modify new energy efficient home credit (IRS 45L)	Extend and modify non-business energy property credit (IRS 25C)	Extend *Modified Accelerated Cost Recovery System* (IRS 167)
renewables and combined heat and power investment **tax credits** (ITC)	newly constructed, high efficiency residential housing packages **tax credits**	residential energy efficiency **tax credits**	commercial qualified facilities, qualified property and grid improvement property **cost recovery**

For more information on IRA assumptions, see https://www.eia.gov/outlooks/aeo/narrative/index.php#Appendix

Inflation Reduction Act: Ongoing work

Home Owner Managing Energy Savings (HOMES) rebates	High-Efficiency Electric Home Rebate Program	Assistance for Latest and Zero Building Energy Code Adoption	Energy-efficient commercial buildings deduction (IRS 179D)
investigate whole-home **retrofit savings potential**	investigate qualification criteria and estimate **share of eligible homes** and **equipment**	investigate potential for **increases in** regional building **energy code adoption**	investigate potential impact on **building code compliance** in new construction and heating and cooling use

Changes in the residential and commercial buildings sectors

EIA's energy consumption surveys are major inputs to the National Energy Modeling System (NEMS)

- The *Residential Energy Consumption Survey* (RECS) and the *Commercial Buildings Energy Consumption Survey* (CBECS) are the primary data sources that define the buildings sectors in NEMS

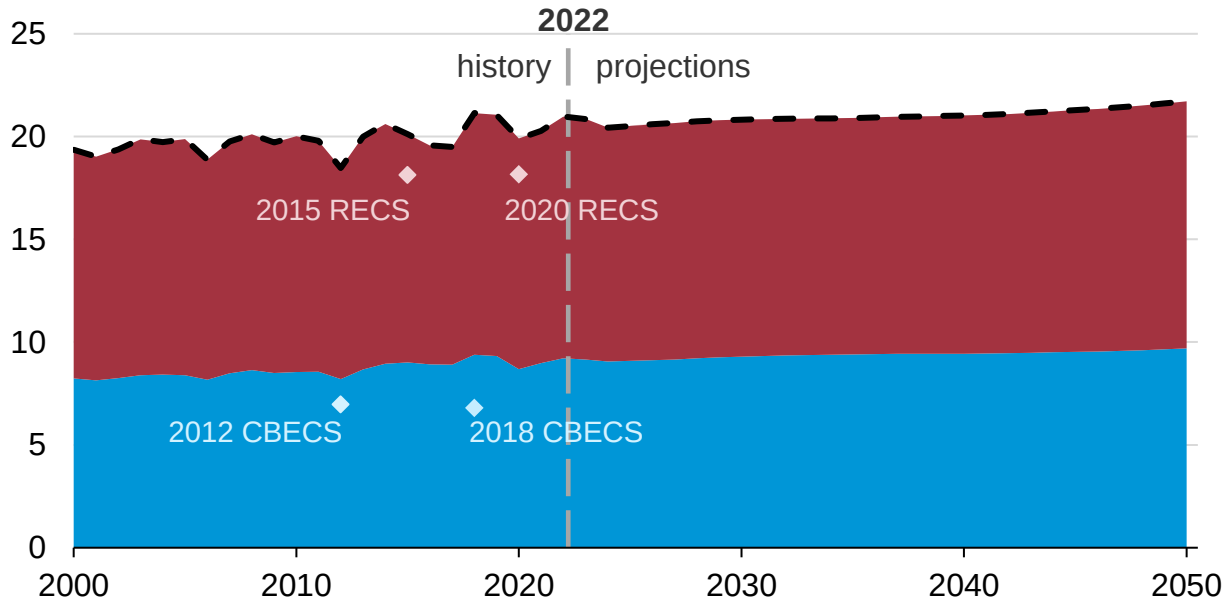
Annual Energy Outlook	*RECS used*	*CBECS used*
AEO2023	2015	2012
AEO2025	2020	2018

https://www.eia.gov/consumption/residential/
https://www.eia.gov/consumption/commercial/

EIA consumption surveys do not represent the *entirety* of the residential and commercial buildings sectors

Buildings delivered energy consumption

quadrillion British thermal units

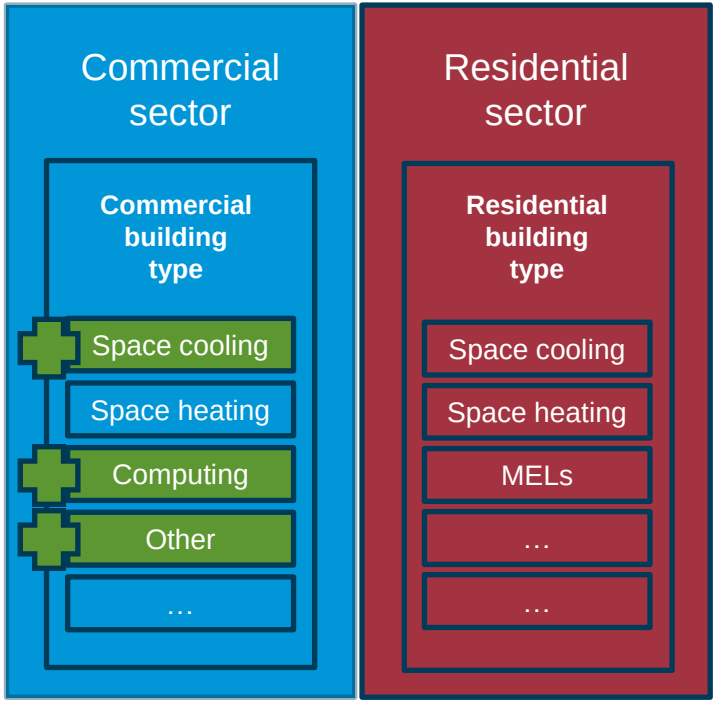


Data source: RECS; CBECS; AEO2023 Reference case

AEO2025 considerations for modeling energy-intensive computing in NEMS

We must be certain to **avoid double counting incremental increases in computing** consumption.

Although most on-premise data center floorspace is in large offices, **other building types have data centers**, too.



Note: MELs refers to miscellaneous electric loads

For more buildings information

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For more information

U.S. Energy Information Administration homepage | www.eia.gov

Annual Energy Outlook 2025 Resources | www.eia.gov/outlooks/aeo/resources

Annual Energy Outlook Working Group materials | www.eia.gov/outlooks/aeo/workinggroup

Today in Energy | www.eia.gov/todayinenergy

Annual Energy Outlook | www.eia.gov/aeo

Short-Term Energy Outlook | www.eia.gov/steo

State Energy Data System | www.eia.gov/state/seds

Monthly Energy Review | www.eia.gov/mer

Residential Energy Consumption Survey | www.eia.gov/recs

Commercial Building Energy Consumption Survey | www.eia.gov/cbecs

International Energy Portal | www.eia.gov/international

Questions or comments?

Bonus slides

Buildings hydrogen use research

- No explicit hydrogen representation in buildings by AEO2025
- How would the Commercial Demand Module (CDM) and Residential Demand Module (RDM) interact with upcoming Hydrogen Module?
  - What do we need to know from the supply sectors to work with demand sectors?
  - What technologies are being implemented?
  - Are there any current pilot programs we can investigate?
- RDM and CDM would not be demanding hydrogen, just reacting to what is provided by the supply side.

Buildings energy data and modeling resources

Use our data, reports, and studies

- 2020 Residential Energy Consumption Survey (RECS)
- 2018 Commercial Buildings Energy Consumption Survey (CBECS)
- Repository of buildings reports and studies

Learn about our assumptions

- Documentation of the National Energy Modeling System (NEMS) Modules
- Assumptions to the *Annual Energy Outlook 2023*
- Updated Buildings Sector Appliance and Equipment Costs and Efficiency
- Analysis and Representation of Miscellaneous Electric Loads (MELs) in NEMS
- Distributed Generation System Characteristics and Costs in the Buildings Sector
- Modeling Distributed Generation in the Buildings Sectors
- Trends in Commercial Whole-Building Sensors and Controls
- Price Elasticities for Energy Use in Buildings of the United States

Contact our staff

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Source: https://www.eia.gov/consumption/workshop/resources.php