Modeling the US buildings energy efficiency

How technological change affects the US energy use through 2050

APERC Energy Efficiency Workshop
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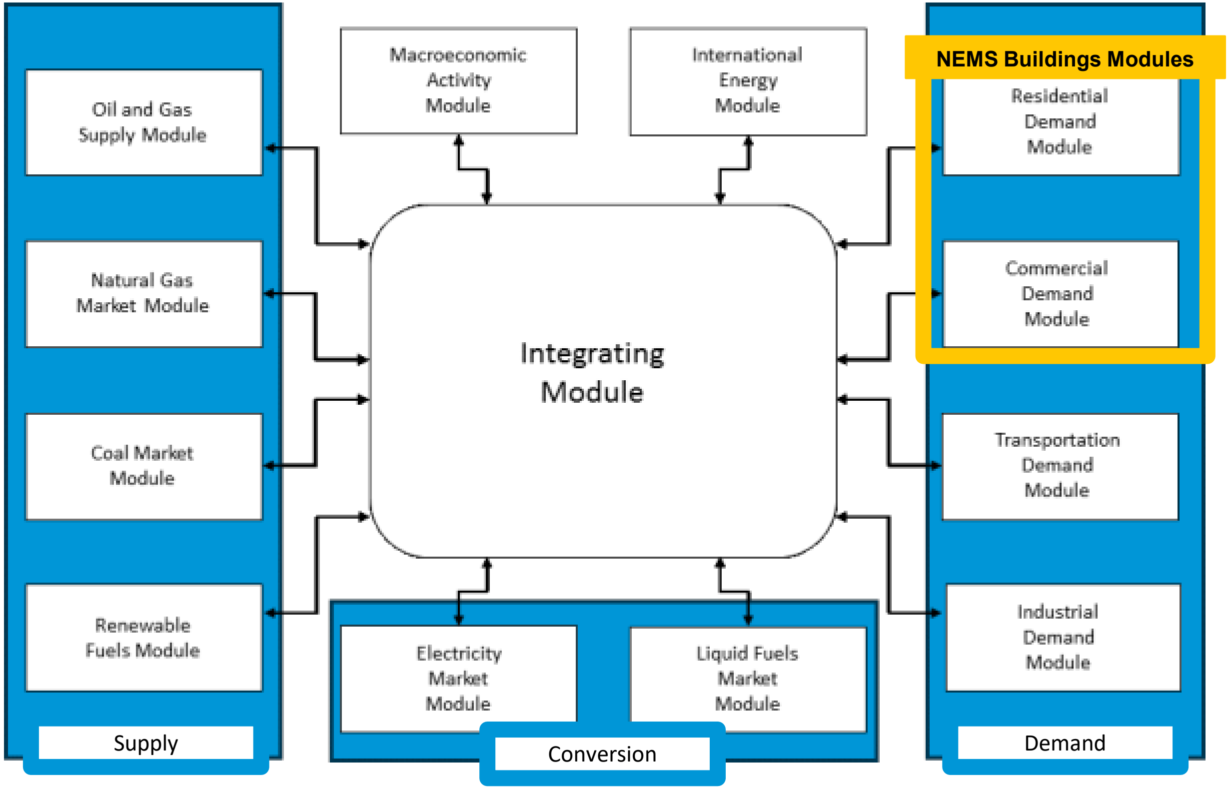
Energy efficiency

- Energy services provided per unit of energy consumption (e.g., COP), improvement driven by technological change
- In the National Energy Modeling System (NEMS): Measured at the end-use technology level, enabling projections of economy-wide changes through 2050

EIA.gov: Buildings energy data and modeling resources

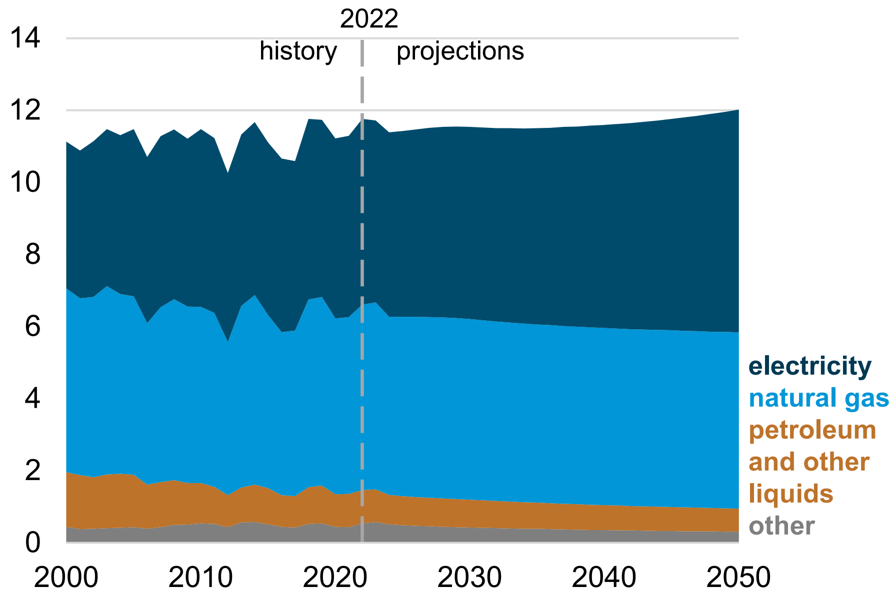
National Energy Modeling System (NEMS) structure



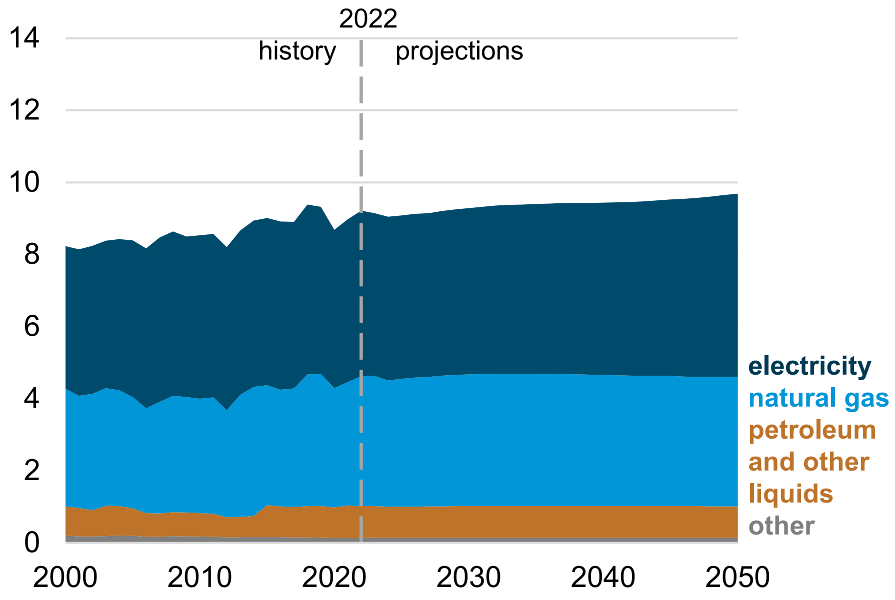
Data source: U.S. Energy Information Administration, *The National Energy Modeling System: An Overview* *(2023)*

Energy consumption does not keep pace with increases in housing and floorspace due to the role of energy efficiency

Residential delivered energy consumption by fuel
AEO2023 Reference case, quadrillion British thermal units



Commercial delivered energy consumption by fuel
AEO2023 Reference case, quadrillion British thermal units



Data source: U.S. Energy Information Administration, Annual Energy Outlook 2023 Reference case (AEO2023)

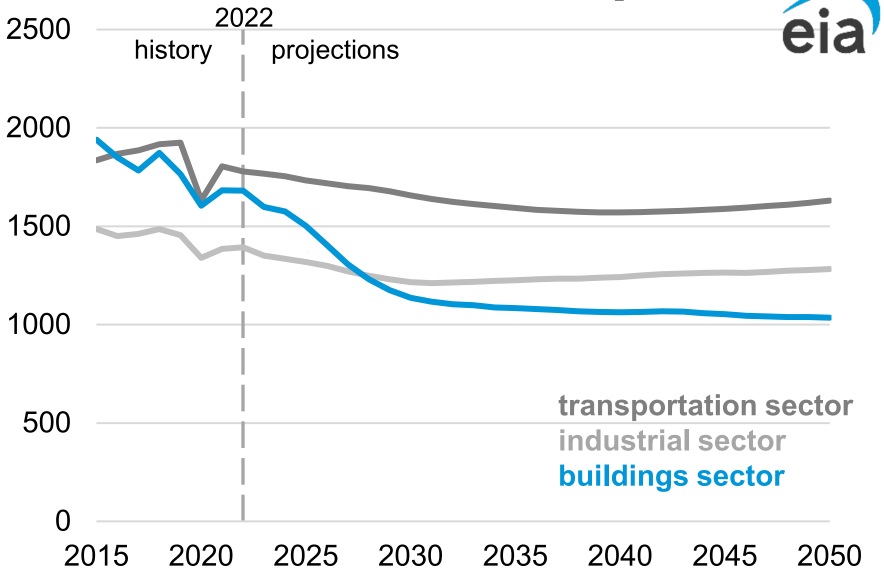
Energy-related CO2 emissions fall across all AEO2023 cases because of increased electrification and higher equipment efficiencies

- In the residential and commercial sectors, higher equipment efficiencies and compliance with building codes extend ongoing declines in energy intensity

- Changes in the buildings fuel mix reduce energy-related CO_2 emissions, which decline faster in buildings than any other end-use sector

Energy-related carbon dioxide (CO_2) emissions by sector

AEO2023 Reference case, million metric tons CO_2



Data source: U.S. Energy Information Administration, Annual Energy Outlook 2023 Reference case (AEO2023)

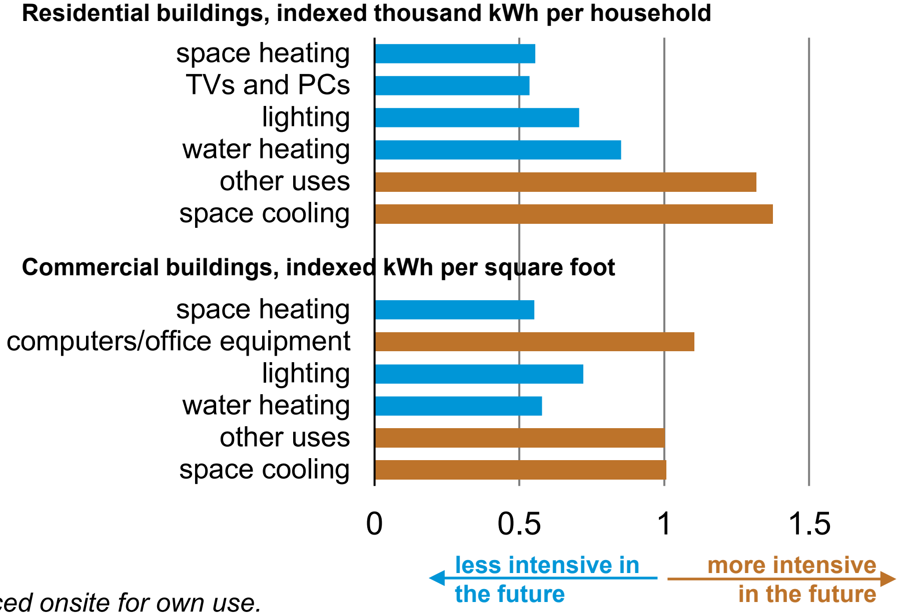
Note: Figure includes emissions associated with electric power generation. Electric power sector emissions are distributed to each end-use sector according to their share of electricity consumption.

Drivers of building electrification in the United States

- Relative efficiency of electric appliances
- Declining cost of onsite electricity generation (for example, solar photovoltaics)
- Utility energy efficiency rebates
- Stable to declining electricity prices
- Continued population shifts to warmer regions

Buildings electricity intensity by end use and sector in 2050, relative to 2022 levels

AEO2023 Reference case, kilowatthours (kWh) indexed to 2022



Note: Intensities reflect both purchased electricity and electricity produced onsite for own use.

Legislation and policy assumptions: Inflation Reduction Act

Extend and modify energy credit (IRS 48)	Extend, modify new energy efficient home credit (IRS 45L)	Extend, 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, grid improvement property **cost recovery**

Inflation Reduction Act: Ongoing work

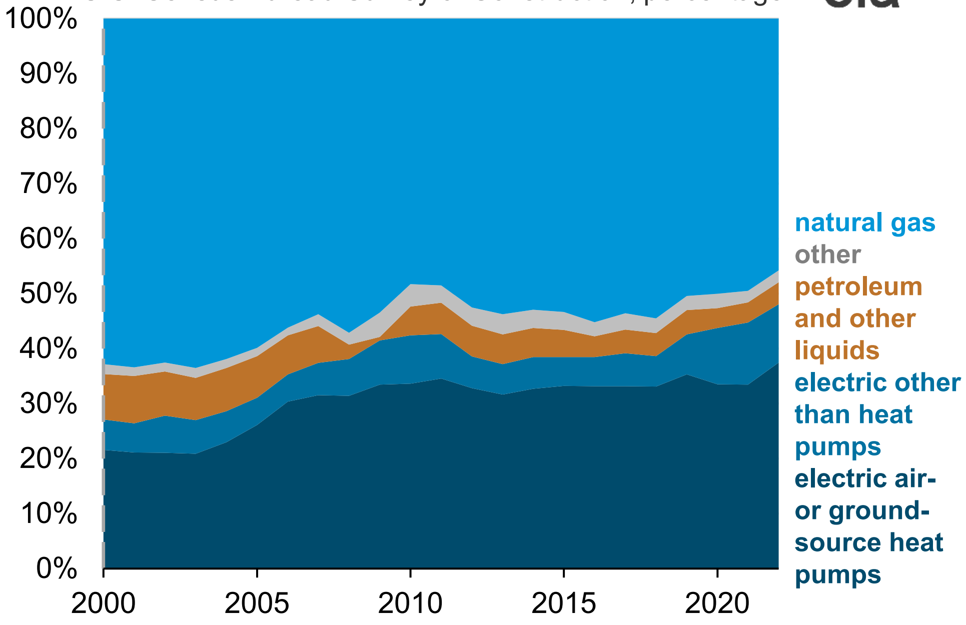
Home Owner Managing Energy Savings (HOMES) rebates	High-Efficiency Electric Home Rebate Program	Assistance for Latest and Zero Building Energy Code Adoption	Energy efficient commercial buildings deduction (IRS 179D)
investigate whole-home **retrofit savings potential**	investigate qualification criteria 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, heating and cooling use

Residential single-family new-construction equipment shares

- Despite historical growth in heat pump adoption, we project natural gas-fired heating equipment, including furnaces and boilers, will account for the largest share of energy consumption for space heating through 2050

- The average stock efficiency of natural gas-fired equipment increases over time

Share of equipment in new single-family homes by fuel type
U.S. Census Bureau Survey of Construction, percentage



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

Buildings technological improvement in NEMS

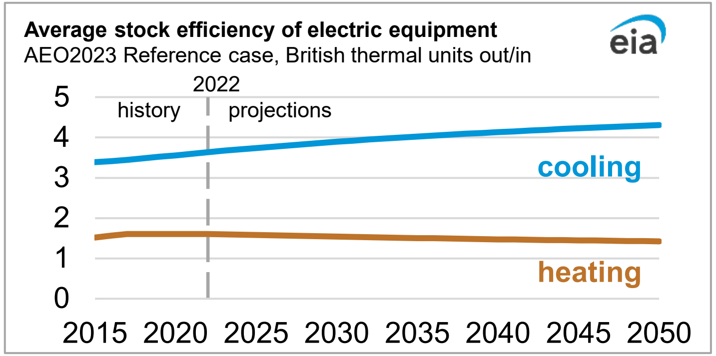
1. **Building technology reports** represent the *average* cost and performance of installed equipment in buildings

efficiency	capcst	maintcst	subcst	life	yintro	ylast	techname
3.20	380.21	3.13	0.00	14.40	2013	2062	comm_GSHP-heat 2017 current standard
3.70	396.88	3.13	0.00	14.40	2033	2062	comm_GSHP-heat 2017 typical
			194.90	14.40	2020	2022	comm_GSHP-heat 2020 typ 26% ITC
			284.51	14.40	2020	2022	comm_GSHP-heat 2020 mid 26% ITC
			292.33	14.40	2020	2022	comm_GSHP-heat 2020 high 26% ITC
			210.70	14.40	2023	2032	comm_GSHP-heat 2023 typ 30% ITC
		13	300.81	14.40	2023	2032	comm_GSHP-heat 2023 mid 30% ITC
		13	309.23	14.40	2023	2032	comm_GSHP-heat 2023 high 30% ITC

2. Model uses **technology menus** to select optimal equipment based on energy service requirements, consumer behavior rules, cost and performance **considerations**

3. **Technologies *compete*** to meet service demand in each US census division and building type

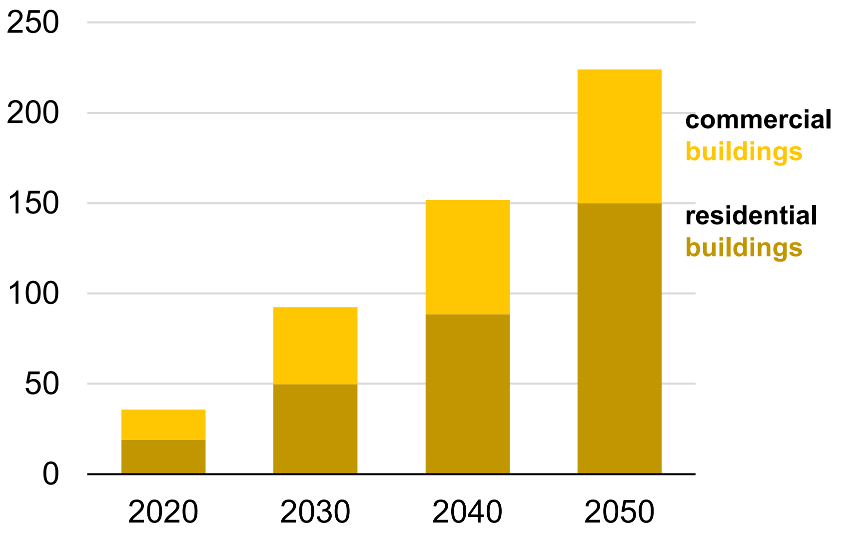
4. NEMS projects **average stock** and **purchased stock efficiency**, by end use and region, over time



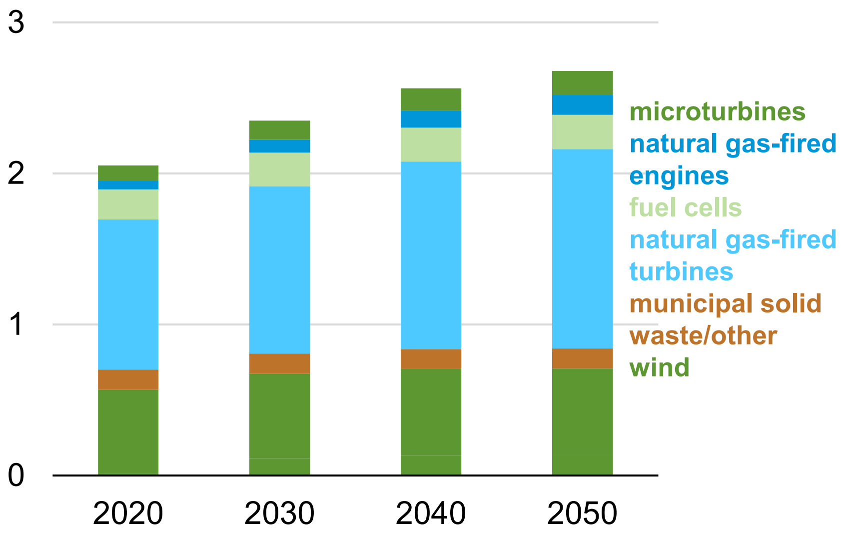
Additional data

The US distributed generation capacity in commercial and residential buildings

Buildings distributed solar photovoltaic capacity
AEO2023 Reference case, gigawatts direct current



Buildings non-solar distributed generation capacity
AEO2023 Reference case, gigawatts direct current



Note: Excludes utility-scale electricity generation.

Commercial Ground-Source Heat Pumps

Example from technology report

Final

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DATA	2012	2018	2022			2030		2040		2050	
	Installed Base	Installed Base	Current Standard	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBtu/h)	48	48	48	48	48	48	48	48	48	48	48
COP (Heating)[1]	3.1	3.7	3.2	3.5	3.6	3.5	3.6	3.5	3.6	3.5	3.6
EER (Cooling)[2]	12.7	17.4	14.1	17.0	21.6	17.0	21.6	17.0	21.6	17.0	21.6
Average Life (y)	8	8	8	8	8	8	8	8	8	8	8
	21	21	21	21	21	21	21	21	21	21	21
Retail Equipment Cost (2022$)	10,470	6,470	5,590	6,470	7,880	6,470	7,880	6,470	7,880	6,470	7,880
Total Installed Cost (2022$)	19,760	18,230	17,350	18,230	19,650	18,230	19,650	18,230	19,650	18,230	19,650
	44,820	26,520	25,580	26,520	27,880	26,520	27,880	26,520	27,880	26,520	27,880
Total Installed Cost (2022$/kBtu/h)	673	466	447	466	495	466	495	466	495	466	495
Annual Maintenance Cost (2022$)	180	180	180	180	180	180	180	180	180	180	180
Annual Maintenance Cost (2022$/kBtu/h)	4	4	4	4	4	4	4	4	4	4	4

1. COP values listed are assessed at a "ground loop" test condition, which is representative of closed loop GSHP operating conditions. However, DOE sets standards at a "water loop" test condition. The AHRI directory lists COP ratings at both sets of test conditions and is used to convert between them where necessary.
2. EER values listed are assessed at a full-load "ground loop" test condition, which is representative of closed loop GSHP operating conditions. However, DOE sets standards at a full-load "water loop" test condition. The AHRI directory lists EER ratings at all sets of test conditions and is used to convert between them where necessary.

Note:
Residential and commercial GSHPs are very similar - the main difference in data presented is the different capacity (3-ton vs. 4-ton) and slightly higher installation costs for commercial GSHP. DOE does not distinguish between residential and commercial units in its regulations.

Data source: U.S. Energy Information Administration *https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/full.pdf*

View our data online

- Interactive graphs available as part of our online data table browser

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- Excel spreadsheets for Reference and side cases

  www.eia.gov/outlooks/aeo/tables_ref.php

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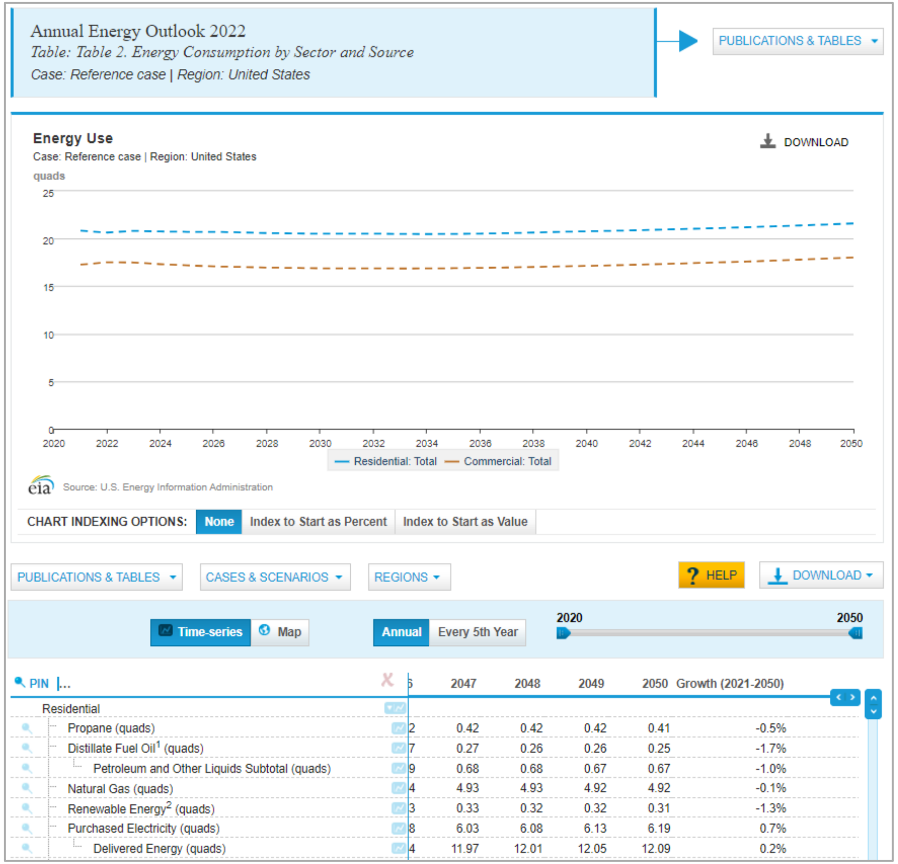

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Buildings Working Group materials | www.eia.gov/outlooks/aeo/workinggroup/buildings

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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

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