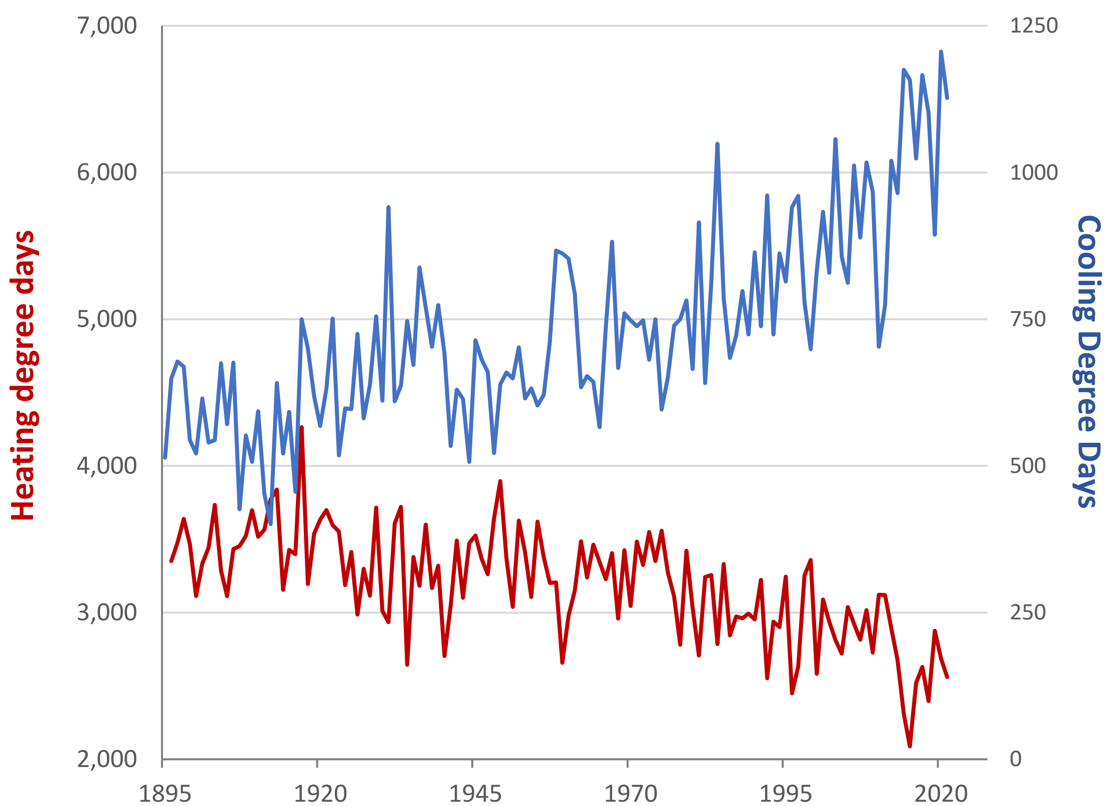
COOLING AND HEATING DEGREE DAYS

Cooling degree days and heating degree days are temperature-based metrics used to help estimate cooling and heating needs. Other things being equal, the higher the cooling degree days over a period, the more energy required to cool a building to a given temperature. Similarly, the higher the heating degree days, the less energy it takes. In California, cooling degree days have gradually increased and heating degree days have gradually decreased.

Figure 1. Cooling and Heating Degree Days Statewide



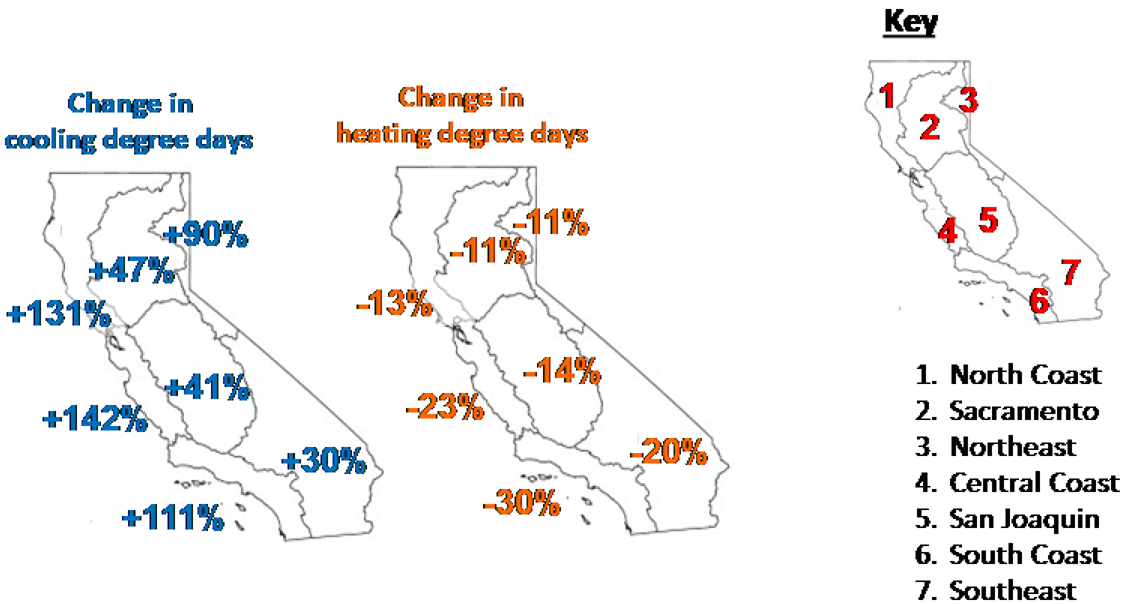
Source: NOAA 2022

Note: Degree days measure the difference between the average daily temperature and a reference temperature, in this case, 65 degrees Fahrenheit (°F). Cooling degree days measure how much the average daily temperature is higher than 65°F; heating degree days, how much it is lower than 65°F. For example, an average statewide temperature of 75°F on one day corresponds to a cooling degree day value of 10. Average is defined as the midpoint of the hourly minimum and maximum temperature for the day. Each value shown in the graph is the sum of degree days for

What does the indicator show?

Annual cooling degree days (CDD) in California increased between 1895 and 2020, while heating degree days (HDD) decreased over the same period (Figure 1). Both trends are consistent with national patterns (NOAA, 2021a) and are especially visible in the past five decades, with the past few years showing some unusually high statewide CDDs and unusually low HDDs.

California's 100 million acres encompass diverse terrains and geographies with various climates. Long-term trends in degree days show regional variations, as shown in Figures 2, 3, and 4 and Table 1 for California's seven NOAA climate divisions.[1] All seven divisions show an increase in CDD and a decrease in HDD over the last century, but to varying extents (see Figures 2-4). Coastal California shows greater percentage increases in CDD over the last century compared to inland areas of the state, partly because they had low CDDs to begin with. The Central Coast and especially the South Coast had the largest percentage declines in HDD.



Source: NOAA, 2022a

Table 1 presents these trends in terms of changes in annual cooling and heating degree days (base 65°F) for the seven climate divisions, expressed as a linear rate of change per decade. Trends are reported for two periods: 1895 to 1970, and 1971 to 2020. In each region, cooling degree days increased and heating degree days decreased over both periods. The regional rates of change for the most recent 50 years (1972-2021) are substantially higher than for the previous 77-year period (1895-1971).

[1] National Oceanic and Atmospheric Administration (NOAA) climate divisions span the contiguous United States, subdividing each state into ten or fewer climate divisions; other indicators in this report are based on data from the Western Regional Climate Center, which divides California into eleven climate regions.

Table 1. Divisional Trends in Cooling and Heating Degree Days

Trends are presented for each of California's climate divisions. Values presented are the slope of linear trends, representing the rate of change in cooling or heating degree days per year.

Climate Division	Trends, 1895-1971 (Degree Days per Decade)		Trends, 1972-2021 (Degree Days per Decade)	
	Cooling	Heating	Cooling	Heating
North Coast Drainage	+8	-32	+45	-135
Sacramento Drainage	+18	-18	+62	-119
Northeast Interior Basins	+6	-68	+27	-157
Central Coast Drainage	+16	-35	+63	-138
San Joaquin Drainage	+15	-12	+82	-135
South Coast Drainage	+27	-45	+86	-147
Southeast Desert Basins	+38	-24	+111	-98

Source: NOAA, 2021a.

Figure 3. Cooling degree days by Division, 1895-2021*

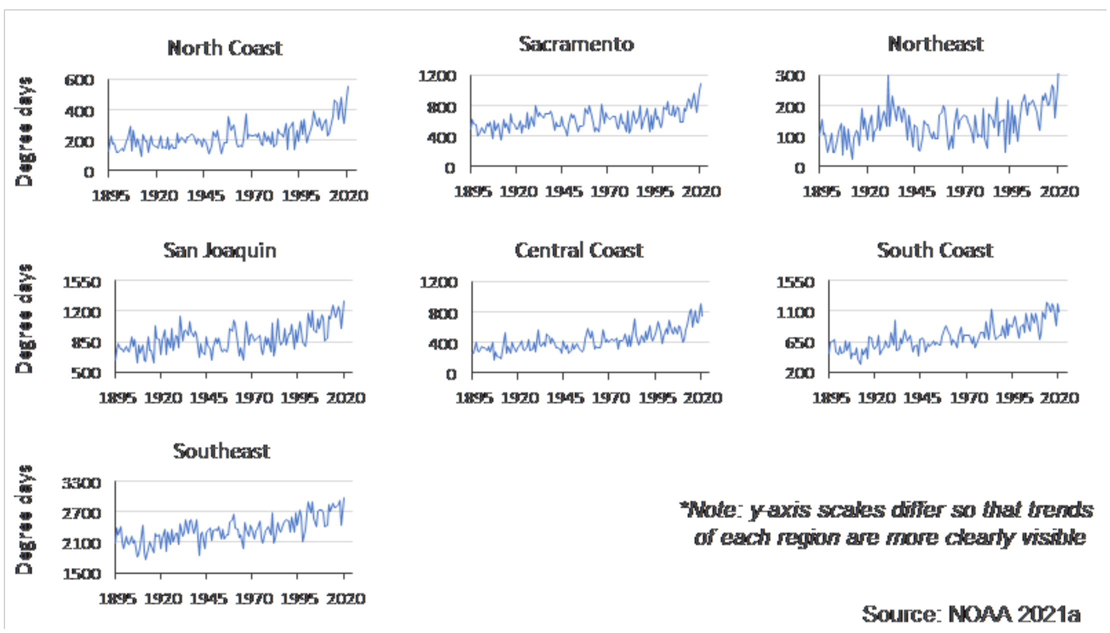
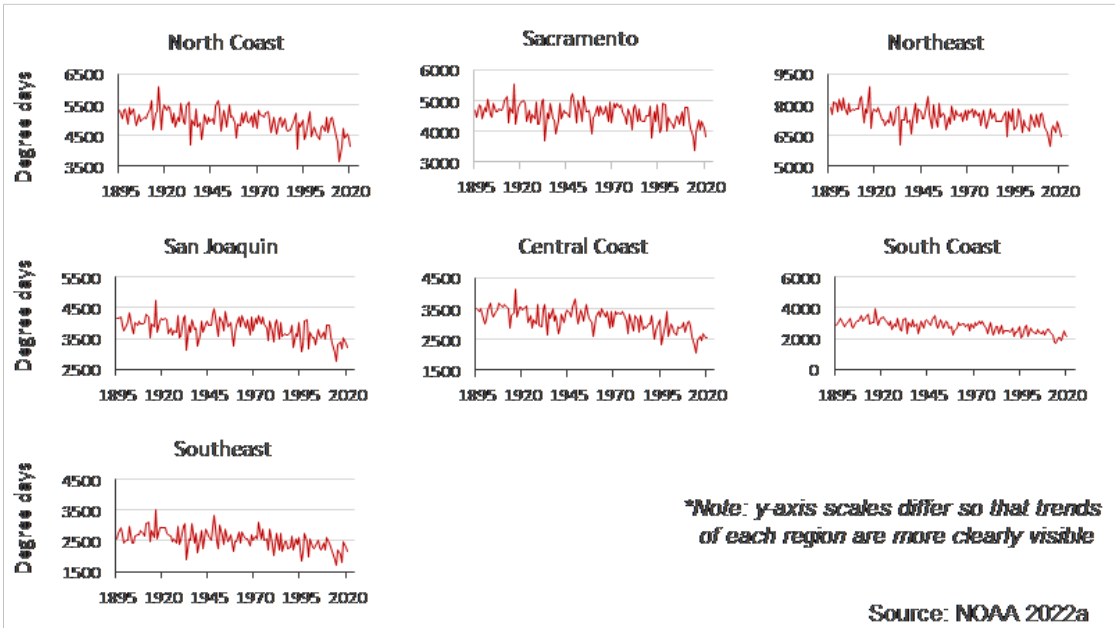


Figure 4. Heating degree days by Division, 1895-2021*



Why is this indicator important?

Since the 1930s, degree days have been used as a proxy for the energy needed to cool or heat homes and buildings, to benchmark building performance, and to inform utility planning and construction decisions (Marston, 1935; Meng and Mourshed, 2017; NOAA, 2005; USGCRP, 2020), as well as in estimating changes in biological systems such as in agriculture. The relationship between degree days and building heating and cooling energy use is approximate and depends on many factors that vary by building and over time. These include building construction and thermal characteristics (such as building size, ventilation, insulation, and number, placement and energy efficiency rating of windows and doors), building type and function (single-family residential, multi-family residential and the myriad of commercial and industrial uses), the type and efficiency of cooling and heating technologies, and cooling and heating practices (for example, based on occupancy, tolerance for heat or cold, and use of heat-generating appliances and equipment) (Meng and Mourshed, 2017; US EPA, 2016). Compressor-based air conditioning was not introduced into U.S. homes until the middle of the 20th century (Cooper, 1998). Prior to that, home cooling did not use much energy; other such changes can be expected as energy use and technology evolve.

As the climate continues to warm, heating needs will likely decline, and energy consumption is expected to shift from cooler months to warmer months (CEC, 2015) due to increased cooling energy use from expanded presence of air conditioning and higher levels of use. In 2019, 58% of California households had central cooling, while in

2003 only 44% did (DNV, 2021).[2] That is, in 2019, California homes were 32% more likely to have central cooling than in 2003. Meeting a growing demand for cooling creates specific challenges for new energy generation and distribution infrastructure, including encouraging higher levels of load flexibility to manage peak demand and system reliability (CEC, 2020; US EPA, 2016). At the same time, warming temperatures, sea level rise, and wildfires can negatively impact the operation or the efficiency of power plants, transmission networks, and natural gas facilities (CEC, 2009, 2012, 2020; Patrick and Fardo, 2009; US EPA, 2016). Climate change can also affect renewable energy, given its dependence on natural resources like water, wind, biomass and available incoming solar radiation, which are all influenced by climate variations (CEC, 2009).

For lower-income households, heating and cooling costs represent a bigger fraction of household income than for higher-income households (CalEPA, 2010). The impact of increased summer heat is disproportionate across households and communities. Lower-income households are less likely to own well-functioning efficient air conditioners or even any air conditioners at all (Chen et al., 2020; Fernandez-Bou et al., 2021), which potentially makes them more vulnerable to health effects of summer heat extremes.

What factors influence this indicator?

Since heating and cooling degree days reflect trends in temperature, factors that influence temperature affect this indicator. These factors are discussed in the *Annual air temperature* indicator.

Technical considerations

Data characteristics

The values for degree days are downloaded from NOAA's Climate at a Glance website (NOAA, 2021c). They are derived by NOAA using daily temperature observations at major weather stations in the United States with NOAA's Climate Divisional Database (nClimDiv). nClimDiv uses a 5 km gridded approach to compute temperature, precipitation, and drought values for United States climate divisions. A mean daily temperature (average of daily maximum and minimum temperatures) of 65˚F serves as the reference temperature for degree day calculations for this data set. Cooling degree days are calculated by summing the positive differences between the mean daily temperature and the 65˚F reference temperature. Heating degree days are calculated by summing the negative differences between the mean daily temperature and 65˚F.

Strengths and limitations of the data

The nClimDiv dataset is an improved version of an older climate dataset from NOAA, benefitting from additional quality assurance reviews and temperature bias adjustments

[2] This comparison pertains only to households served by California's three investor-owned utilities (Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric) or LADWP, which are the utilities surveyed in both the 2003 and 2019 Residential Appliance Saturation Surveys.

and providing more robust values than its predecessor. New methodologies include a transition to a grid-based calculation and additional stations from before the 1930s (NOAA, 2021b).

There are important limitations to keep in mind when relating degree days to energy use. First, the thermal comfort of building occupants depends on more than just indoor temperatures (Kwok and Rajkovich, 2010). Heating and cooling energy use for a given set of degree days also depends on a variety of factors beyond the technical characteristics of structures and equipment, such as social practices, occupant preferences, and thermal comfort management regimes (Deumling et al., 2019; McGilligan et al. 2011). Second, degree days cannot fully express the complexity of weather, how and where it changes, or how these changes affect indoor conditions (Azevedo et al., 2015). For example, nighttime low temperatures have increased more than daytime high temperatures in much of California, especially since 2000 (Lindsey, 2018; see the *Annual air temperature indicators*). This can reduce the contribution of nighttime temperatures to natural cooling but is scarcely captured in degree days indicators. Also, though 65˚F is the standard base temperature used for computing degree days in U.S. energy applications, different base temperatures—such as a higher base temperature for CDD (EIA,1983) — could give different results for energy predictions. Overall, since climate patterns, land use, construction, building technologies, social patterns, and modeling methods are changing, legacy computational practices using CDD and HDD might be usefully revamped as well.

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References:

Azevedo JA, Chapman L and Muller CL (2015). Critique and suggested modifications of the degree days methodology to enable long-term electricity consumption assessments: A case study in Birmingham, UK. *Meterological Applications* **22**(4): 789-796.

CalEPA (2010). *Indicators of Climate Change in California: Environmental Justice Impacts*.

CEC (2009). California Energy Commission. *Potential Impacts of Climate Change on California's Energy Infrastructure and Identification of Adaptation Measures* (CEC-150-2009-001).

CEC (2012). California Energy Commission. *Our Changing Climate 2012: Vulnerability & Adaptation to the Increasing Risks from Climate Change in California* (CEC-500-2012-007).

CEC (2015). California Energy Commission. *2015 Integrated Energy Policy Report* (CEC-100-2015-001-CMF).

CEC (2018). California Energy Commission. *Tracking Progress. Energy Equity Indicators*.

CEC (2020). California Energy Commission. *Final 2019 Integrated Energy Policy Report* (CEC-100-2019-001-CMF).

Chen, M, Ban-Weiss GA and Sanders KT (2020). Utilizing smart-meter data to project impacts of urban warming on residential electricity use for vulnerable populations in southern California. *Environmental Research Letters* **15** (6): 064001.

Cooper G (1998). *Air-Conditioning America: Engineers and the Controlled Environment 1900-1960*. Baltimore, MD: The Johns Hopkins University Press.

Deumling, R, Poskanzer D, and Meier AK (2018). 'Everyone has a peer in the low user tier': The diversity of low residential energy users. *Energy Efficiency* **12**(1): 244-259.

DNV (2021). Det Norske Veritas. California Statewide Residential Appliance Saturation Study Data Server.

Fernandez-Bou SA, Ortiz-Partida JP, Dobbin KB, Flores-Landeros H, et al. (2021). Underrepresented, understudied, underserved: Gaps and opportunities for advancing justice in disadvantaged communities. *Environmental Science & Policy.* **122**: 92–100.

Kwok AG and Rajkovich NB. (2010). Addressing climate change in comfort standards. *Building and Environment* **45**(1): 18-22.

Lindsey R (2018). NOAA News & Features: Extreme Overnight Heat in California and the Great Basin in July 2018.

Marston AD (1935). Degree days for cooling. *Bulletin of the American Meteorological Society* **16**(10): 242-244.

McGilligan C, Natarajan S, and Nikolopoulou M (2011). Adaptive comfort degree-days: A metric to compare adaptive comfort standards and estimate changes in energy consumption for future UK climates. *Energy and Buildings* **43**(10): 2767-2778.

Meng Q and Mourshed M (2017). Degree-day based non-domestic building energy analytics and modelling should use building and type specific base temperatures. *Energy and Buildings* **155**: 260–268.

NOAA (2005). National Oceanic and Atmospheric Administration. NOAA National Weather Service Climate Prediction Center Degree Day Monitoring and Data: Explanation. Retrieved October 2016.

NOAA (2021a). National Oceanic and Atmospheric Administration. NOAA Climate at a Glance: U.S. Time Series. Retrieved March 2021.

NOAA (2021b). National Oceanic and Atmospheric Administration. NOAA Monitoring References: U.S. Climate Divisions. Retrieved March 2021.

NOAA (2021c). National Oceanic and Atmospheric Administration. Degree Day Monitoring & Data, National Weather Service Climate Prediction Center. Retrieved April 7, 2021.

Patrick DR and Fardo SW (2009). Ch 7: Power Distribution Equipment. *In: Electrical Distribution Systems* (2nd ed). Lilburn, Georgia: The Fairmont Press, Inc.

US EIA (1983). US Energy Information Administration. *Regression Analysis of Energy Consumption by End Use*.

US EIA (2009). US Energy Information Administration. *Household Energy Use in California*.

US EIA (2013). US Energy Information Administration. *Residential Energy Consumption Survey*.

US EPA (2016). US Environmental Protection Agency. Climate Change Indicators in the United States. Retrieved December 15, 2017.

USGCRP (2020). US Global Change Research Program. National Climate Assessment. Retrieved August 16, 2020.