Energy Savings from Google Nest Thermostats

This white paper provides an updated assessment of real world energy savings that households may achieve from replacing conventional thermostats with Google Nest smart thermostats. The results reported here are averages across varying populations and are not intended as an estimate of savings for any specific user. Actual savings will vary with a number of factors including occupancy patterns, prior thermostat setting behavior, use of thermostat features, weather, and other factors. Savings estimates are not a guarantee.

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Google Nest

Summary

This white paper summarizes the results from multiple, independently designed and conducted, US-based research studies of the energy savings from Google Nest thermostats based on comparisons of utility bills from before and after installation. The additional energy savings provided by the Seasonal Savings feature are also summarized based on results from dozens of randomized control trials. The overall savings are consistent with the prior white paper from 2015 and indicate average heating savings of about 12% and average cooling savings of 15%.

It's important to note that the savings provided by the thermostat in any given home can be expected to vary significantly from these averages due to differences in how people used their prior thermostat, how they use the features of their Google Nest thermostat, as well as due to occupancy patterns, housing characteristics, heating and cooling equipment, and climate. Savings for any given customer may be much higher or lower than the average values.

Background

Google Nest thermostats can help households save energy in multiple ways[1]:

- by helping create a schedule of heating and cooling setpoints that minimizes energy wasted from heating and cooling homes more than what's needed to stay comfortable;
- by automatically switching to more efficient temperatures when the home is unoccupied;
- by helping to intelligently manage HVAC equipment – minimizing electric auxiliary heat for homes with heat pumps[2] and extending cooling fan runtime when humidity conditions allow[3];
- by offering the Seasonal Savings[4] schedule tune-up feature every winter and summer to help maintain and optimize setpoint schedule efficiency;
- by providing feedback on efficient settings on the display, in the app, and through monthly emails; and
- by monitoring heating and cooling systems for changes that may indicate operational or efficiency problems.

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[1] For more energy savings ideas see https://support.google.com/googlenest/answer/9249254
[2] Heat pump balance https://support.google.com/googlenest/answer/9248719?hl=en
[3] Airwave https://support.google.com/googlenest/answer/9249730?hl=en
[4] Seasonal Savings https://support.google.com/googlenest/answer/9244739?hl=en

The Nest 2015 white paper[5] reported average savings equal to 10%-12% of heating energy and 15% of cooling energy. Those values were based on three early studies using utility meter data before and after installation. This white paper updates the savings to include several more studies and incorporates the additional savings provided by the Seasonal Savings schedule tune-up feature.

Measuring Energy Savings

Measuring the energy savings from installing a smart thermostat may seem fairly simple – just add up the utility meter readings for the year before installing the thermostat and then subtract the total for the year after the upgrade. The problem with that approach is that energy use changes from month to month and year to year for many reasons including:

- weather: hotter or colder heating or cooling seasons;
- changes in household composition: babies are born, children go off to college, etc;
- changes in occupancy patterns: working from home, school schedules, vacations, etc.
- changes in energy using activities: cooking, TV watching, showers and baths, etc;
- changes to the home: additions, finishing off a basement, porch, unfinished attic;
- adding new end uses or appliances: electric vehicle, 2nd refrigerator, video gaming consoles, “smart” home tech, adding central cooling or electric heating or water heating;
- replacing existing appliances and end uses: replacing heating or cooling systems or water heaters

Because of these many shifting factors, the overall change in energy use after installing a thermostat is only equal to the energy savings provided by the thermostat if everything else stayed the same – the same weather, occupancy patterns, appliances, home structure, etc.

To address the potential bias from other factors changing, energy savings studies typically include data for a group of homes that did not get the upgrade to serve as a “control” group. The control group is intended to reflect how energy use would have changed among the upgrade group if they had not installed the upgrade. So if energy use declined by an average of 10% in the upgrade group but declined by 2% in a control group of similar homes, then the savings would be estimated as 10% - 2% = 8%. This approach can work well if a suitable control group can be identified. But if the participants differ from the control group then results will be biased.

[5] https://storage.googleapis.com/nest-public-downloads/press/documents/energy-savings-white-paper.pdf

The ideal control group is created by randomly assigning a target population into treatment and control groups, like a clinical drug trial. But this approach is challenging for energy upgrades like thermostats because we cannot force those assigned to the treatment group to actually install the upgrade (and cannot prevent the control group from installing the upgrade) and there are no placebo upgrades.

For research projects, a target population can be randomly divided into treatment and control groups where the treatment group can be offered treatment at no cost. Unbiased impacts can be assessed by comparing the entire target treatment group (regardless of whether they actually participated) to the randomized control group. The main drawback of this approach is that low participation rates among the targeted group often result in large uncertainty and the researchers switch to some form of matched comparison group. In addition to being able to design a participant recruitment process, research projects often collect additional data using surveys, submetering, and datalogging temperatures or other quantities of interest. This data can be used to help explain the observed impacts and provide more insights into results.

Findings

Based on the above discussion, we believe that energy savings from smart thermostats are best measured based on analyzing actual energy use of homes over time as part of a well designed research project. But Google Nest does not have access to customer utility data and may not be perceived as an unbiased source of original research findings in any case. Therefore, we rely upon studies performed by independent third parties to estimate average energy savings.

In the 5 years after the Nest Learning Thermostat was first introduced in 2011, several utility companies and energy efficiency program providers sponsored their own research studies to assess the potential energy savings of this new technology. Although research studies are likely to provide the most reliable estimates of smart thermostat energy savings, it is important to note that none of these studies were perfect. Randomized control trials are very hard to implement and every study has issues with either high uncertainty, potential bias, and/or sample representativeness. To guide our review of available studies, we identified three criteria required for inclusion in this analysis:

1. The study reported percent heating and/or cooling savings from installing Nest thermostats;
2. The study employed some sort of experimental / research design; and
3. The study was Independently funded, designed and conducted (i.e. we excluded any studies we conducted ourselves or that we had any control over).

Table 1 lists eight US-based studies, which we found that met all of these criteria.

Table 1. Independent Research Studies on Google Nest thermostats

Research Study	State	# Homes	Description	% Savings Heating	% Savings Cooling
Vectren (Aarish et al., 2015a)	IN	197	replaced manual[6] thermostats, logged temperatures and AC, surveys	13%	14%
Northern Indiana Public Service (Aarish et al., 2015b)	IN	238	replaced manual thermostats, logged temperatures and AC, surveys	13%	16%
Florida Power & Light (Hanna & Elliot 2015)	FL	101	single thermostat home with WiFi		12%
Florida Solar Energy Center (Parker, et al., 2016)	FL	25	intensively monitored multiyear study, within subject design	10%	10%
Southern California Gas (Brannan et al., 2015)	CA	505	designed experiment, very mild weather	5%	
Energy Trust of Oregon (Apex Analytics, 2016)	OR	153	gas heat Do It Yourself (DIY)-install, surveys	6%	
Energy Trust of Oregon (Apex Analytics, 2014)	OR	113	heat pumps, surveys	12%	
Bonneville Power (Kelvsen et al., 2016)	WA	167	heat pumps, surveys, submetering subset	12%	
Average				**10%**	**13%**

The reported energy savings across these US studies averaged 10% for heating and 13% for cooling. The studies represent four quite different regions – the Pacific Northwest (OR/WA), Southern California, Indiana, and Florida – covering a range of heating and cooling climates. Indiana has high heating use and average cooling use; Florida has high cooling but low heating use; Southern California has very low heating use; and the Northwest states have average heating use and very low cooling use (and did not report cooling savings). The diversity of climates and fairly consistent results provide a reasonable basis for estimating average energy savings. We calculated a simple average across the studies rather than using some type of weighting since we view the studies as representing a diverse sample of results across varying populations and the estimates mostly fall in a fairly narrow range.

There are no studies that reported cooling savings in very mild climates where cooling needs are minimal. Very mild climates may experience lower percent savings if heating or cooling is

[6] Note that only 24% of households with programmable thermostats report they are running a program (EIA RECS, 2024).

only used infrequently[7] – the lowest percent heating savings were reported for Southern California, where heating is rarely needed. But the low loads in such mild climates mean that not much energy could be saved even if the percent savings were similar to other climates.

All of the studies were completed between 2014 and 2016, when smart thermostats were a relatively new product and utility companies and researchers were most interested in assessing their potential savings. The positive results found in these multiple early studies provided sufficient evidence to lead utilities to provide rebates and incentives to encourage customers to install the technology. The launch of utility programs led to a shift from more expensive research studies to on-going program evaluations. We have not included any utility program evaluations because they typically do not meet the criteria for research design, suffer from known biases as described previously, and do not usually provide results for just Nest thermostats.

Assessing Potential Changes in Savings since 2016

The lack of research studies since 2016 raises the question of whether changes have occurred since then that may have affected energy savings. Smart thermostat energy savings may have changed due to:

- changes in how customers use their existing conventional thermostats
- changes in how customers use their Google Nest thermostats
- changes in homes or HVAC systems that could affect thermostat energy savings

Changes in Conventional Thermostat Use

The Residential Energy Consumption Survey is a project of the U.S. Energy Information Administration that surveys thousands of households across the U.S. every five years to characterize residential energy use (EIA RECS, 2024). The survey includes questions about thermostat use. Table 2 compares thermostat behaviors from 2015 and 2020 for households without smart thermostats.

[7] EIA RECS data on thermostat behavior confirms this lower savings potential. Homes with constant thermostat setpoints offer larger savings potential but just 29% of California homes report this behavior compared to 52% in the rest of the country. Californians were nearly 4 times more likely to report just turning the heat on and off as needed (23% vs. 6%), a behavior with low expected savings potential.

Table 2. Thermostat Setting Behaviors: 2020 vs 2015

	Heating			Cooling		
Thermostat Setting Behavior (non-smart thermostats)	2015	2020	Change	2015	2020	Change
Set one temperature and leave it there most of the time	43.1%	49.7%	+6.6%	45.2%	52.0%	+6.8%
Manually adjust the temperature	28.0%	29.4%	+1.4%	26.3%	26.5%	+0.2%
Programmable thermostat automatically adjusts the temperature	18.3%	13.3%	-5.0%	17.5%	13.2%	-4.3%
Turn equipment on or off as needed	10.6%	7.6%	-3.0%	11.0%	8.3%	-2.7%

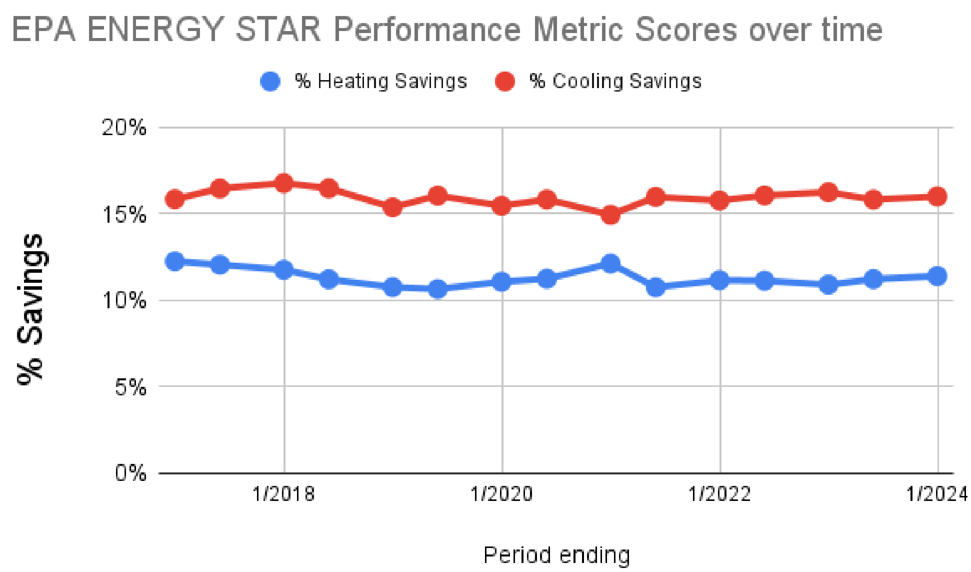
The data show that standard thermostat usage has trended toward less efficient settings. More households in 2020 reported having a constant setpoint (considered the least efficient behavior) and fewer reported having a thermostat that is running a program compared to 2015 (considered a more efficient behavior). These changes indicate that thermostat behaviors of households without smart thermostats have become a little less efficient since 2015, implying greater savings potential from a smart thermostat.

Changes in Use of Google Nest Thermostats

We explored trends in how efficiently Google Nest thermostats are being used by assessing changes in our EPA ENERGY STAR smart thermostat performance metric scores (EPA, 2016). EPA describes the metric as: "smart thermostat service providers use EPA-provided software to analyze and combine a year of data from hundreds of their customers' homes, reflecting how the thermostats were actually used, to calculate national savings metrics for heating and for cooling"[8]. Heating savings must be at least 8% and cooling savings at least 10% to comply with ENERGY STAR.

EPA's calculation is expected to overestimate actual savings in some ways and underestimate in other ways, but it provides a consistent approach for exploring trends in how efficiently customers are controlling their temperatures. The plot below shows the Google Nest heating and cooling scores from all submissions since the start of the standard (covering 2016) through the end of 2023.

[8] See https://www.energystar.gov/products/smart_thermostats/key_product_criteria



The scores stayed fairly steady over time with no real trend that would indicate a decline in performance. The heating score was 0.9% lower in 2023 and the cooling score was 0.2% higher. The scores vary from year to year so these changes may reflect normal variability.

Changes in Homes and HVAC systems

Thermostat energy savings could be affected by characteristics of the homes. Better insulated and tighter homes should respond more slowly to changes in thermostat setpoints due to slower heat transfer rates which may reduce the savings from thermostat setbacks. But such changes are unlikely to have a material impact because the housing stock changes slowly. EIA RECS data for 2020 shows no improvements over 2015 in terms of reported insulation levels or draftiness and just a 1% decline in average gas heating energy use (EIA RECS, 2024).

Smart thermostat savings may also be affected by HVAC system characteristics. Some types of systems may operate at lower efficiency when recovering from temperature setbacks. This issue is well known for conventional heat pumps with electric resistance backup heating[9] but Google Nest thermostats have been shown to provide significant savings for such systems in two of the studies cited here (Apex Analytics, 2014; Kelvsen et al., 2016). This issue can also arise for other systems including modulating condensing boilers and variable speed heat pumps. However, these system types are not common and many variable speed heat pumps are not even compatible with standard 24V thermostats such as Google Nest.

[9] See https://www.energy.gov/energysaver/programmable-thermostats

Based on the above assessments of factors affecting savings that may have changed over time, it appears that smart thermostats should save about as much energy today as when the research was conducted.

Seasonal Savings

Seasonal Savings is a free, opt-in thermostat feature that "tunes up" customer schedules by making a series of very small adjustments toward more efficient temperatures over a few weeks at the start of each heating and cooling season. The feature can stop or reverse changes if it detects signs of discomfort from user dial turns.

Seasonal Savings was originally launched in 2013 as an offering to utility companies to help boost energy savings among their customers with Nest thermostats. Google Nest launched dozens of deployments targeted to specific utility territories across the US and in Europe from 2013 through early 2020. Most deployments were designed as large randomized control trials to provide for accurate evaluation of savings based on heating/cooling runtime data, Several utilities conducted independent evaluations (Apex Analytics, 2017; Guidehouse, 2019; Guidehouse, 2020a; Guidehouse, 2020b; Navigant, 2018; Navigant, 2020; Perussi & Hicks, 2019; Sierzchula et al, 2019) More details about the feature and evaluation methods and results were summarized in a peer-reviewed paper (Blasnik, 2018).

In the summer of 2020, Google Nest started to offer Seasonal Savings to all customers as a free feature and millions of customers have opted to participate each season. Because enrollment is open to all, full season randomized control trials are no longer an option. But results from the many large scale randomized control trials prior to 2020 can provide an estimate of savings. Overall, savings results from randomized control trials were available for 33 cooling season deployments and 24 heating season deployments conducted between 2017 and 2020. These deployments targeted 1.9 million thermostats in 24 utility service territories in 11 states with an overall 50% opt in rate. Seasonal Savings provided an average 3.3% cooling savings and 4.1% heating savings[10] across these studies.

The net impact of Seasonal Savings on overall average thermostat energy savings can be estimated by multiplying the average savings by the participation rate (which averaged 45.8% for cooling and 43.0% for heating over the past two years), resulting in a net increase in overall average savings of 1.8% for heating and 1.5% for cooling.

[10] One heating study from mild Southern California with savings of 11.7% was excluded as an outlier

Overall Energy Savings

The overall average savings for Google Nest thermostats can be estimated as the sum of the savings from installing the thermostat (Table 1), plus the average savings per thermostat from Seasonal Savings (adjusted for enrollment rate). Table 3 summarizes these results.

Table 3. Overall Energy Savings

	Heating	Cooling
Average Savings from Nest thermostat installation	10%	13%
Average added from Seasonal Savings	1.8%	1.5%
Total savings	**12%**	**15%**

Other Energy Savings Studies and Methods

Smart thermostat energy savings have also been estimated outside of field research projects. Many utility energy efficiency program evaluations have estimated savings by analyzing changes in energy use for customers who received a rebate. Savings have also been characterized using methods that don't involve analyzing utility meter data, usually by making assumptions about the thermostat setting behavior without the smart thermostat and then using a building energy simulation or a statistical analysis of smart thermostat data to estimate energy savings compared to the assumed baseline. These alternatives each have drawbacks that make them generally less reliable for estimating energy savings

Energy Efficiency Program Evaluations

Most energy savings studies are not designed research projects but are instead evaluations of on-going utility programs. Utility energy efficiency program evaluations are primarily "observational" studies because, instead of employing a research design, they compare changes in energy use for households who decided to participate (e.g., received a rebate) vs. a sample of those who did not participate. This approach provides biased results if the non-participant sample does not accurately reflect how participant energy use would have changed during the study period without the thermostat. This bias appears to be particularly large for smart thermostat evaluations.

Data from program evaluation surveys and the U.S. Energy Information Administration have found that smart thermostat buyers are generally younger, wealthier, and more tech-oriented than non-participants. These differences have resulted in multiple studies finding that smart thermostat buyers are more likely to buy an electric vehicle, have a baby, build an addition onto their home, and add other end uses compared to the households in the comparison group – even when that group was carefully constructed from nearby homes with similar prior energy use[11]. The latest EIA Residential Energy Consumption Survey (EIA RECS, 2024) confirms these differences – showing that smart thermostat households are younger and wealthier and much more likely to have an electric vehicle, have more children and own more tech products such as video gaming consoles, home theaters, computers, and smart speakers.

The net result is that overall smart thermostat household energy use is on a generally increasing path (relative to the comparison group) unrelated to the thermostat. This bias can be large compared to the energy savings expected from the thermostat. Several evaluations have reported significant increases in baseload (i.e. loads unrelated to heating or cooling) electricity use in smart thermostat homes. This increased usage would be expected from the self-selection bias – having babies, building additions, and buying electric vehicles increase all types of energy use. Program evaluation practice has been to assume this increased usage is caused by the thermostat, resulting in low or even negative savings (e.g., Guidehouse, 2018).

More recent studies have started to recognize this bias in smart thermostat program evaluations and some have attempted adjustments to mitigate it. But these adjustments rely on questionable and subjective assumptions (e.g., that the percent increase found in baseload energy use is equal to the bias and that bias is the same for heating and cooling) . For these reasons, it's hard to consider smart thermostat utility program evaluations as a reliable source for energy savings.

Savings vs. 72°F Constant Setpoint

Some thermostat manufacturers claim large energy savings by calculating the savings compared to an assumed constant set point of 72°F for heating and cooling all year. When we perform a similar calculation for Google Nest thermostats, we find "savings" that are about twice as large as those found in the real world research studies from which our savings claims are derived. This difference is not unexpected since many people use more efficient setpoints than the arbitrary 72°F and many practice some amount of setbacks. For households that actually keep their thermostat at 72°F year round, this approach provides a reasonable estimate of energy savings. But for other customers it can be quite misleading if they do not consider the assumed baseline behavior.

EPA ENERGY STAR Savings Metric

Another savings calculation approach that relies upon an assumed baseline behavior is the EPA ENERGY STAR smart thermostat performance metric described previously (EPA, 2016). Rather

[11] see Stewart et al., 2023; DNV-GL, 2020; DNV-GL, 2021; DNV-GL, 2022; Apex Analytics & Empower Dataworks, 2021

than calculate energy savings using an assumed fixed baseline temperature, the EPA metric uses thermostat data to identify a comfort temperature preference for each home based on the 90th (10th) percentile of indoor temperatures on heating (cooling) days. Percent savings are then calculated compared to maintaining a constant comfort temperature based on a statistical analysis of a year of thermostat data.

The EPA metric is expected to overestimate energy savings because some households use temperature setbacks. But it may underestimate savings in other ways. The metric assumes that the comfort temperature is a household comfort preference and is not affected by the thermostat. But Seasonal Savings is known to result in more efficient comfort temperatures, which reduces the energy savings from the metric even though increasing actual energy savings. Internal research has also found that comfort temperatures are affected by default set points used in some Google Nest thermostats. There are also other more esoteric reasons that can cause the metric to over or under estimate savings. The net result is that the EPA metric likely has some bias but the extent and direction are unknown.

Table 3 showed Google Nest thermostat EPA metric scores averaged 11.4% heating savings and 16.0% cooling savings in 2023. These values are nearly identical to results from our analysis of research studies and Seasonal Savings. It is tempting to think the similarity of these values suggests that the EPA scores support the values from the research studies, but the similarity may be somewhat coincidental given the unknown extent of bias in the EPA metric.

Savings in Other Countries

All of the research studies on Nest thermostat energy savings were conducted in the U.S. However, savings in Canada are likely to be similar to savings in the northern regions of the U.S since the climates, homes,and HVAC system are generally similar and the same thermostat models are sold in both countries.

Google Nest also sells thermostats in seven countries in Europe[12] which are specifically designed to control boilers. The majority of these Google Nest thermostats are located in the United Kingdom. To gain a better understanding of thermostat energy savings in the U.K., Google sponsored a research study conducted by the well respected Behavioural Insights Team (Parker, 2017). The research project actually involved multiple studies with the primary impact analysis coming from a randomized control trial. They also separately analyzed the impacts of Seasonal Savings. They reported average heating savings of 6%-7% from thermostat installation and an additional 4.5% savings from seasonal savings for each thermostat that opted in to that feature.

[12] Countries include the U.K., Ireland, Netherlands, France, Belgium, Spain, and Italy

Lower savings were expected for the U.K. because of the common use of timers to shut off boilers at night in many homes, which limits the potential savings of a smart thermostat. The use of boiler timers is not common in most other countries in Europe, so the U.K. savings are considered a conservative estimate of the savings in those other countries. Google uses these U.K. results to estimate overall global energy savings from Nest thermostats outside of the U.S. and Canada.

Factors Affecting Savings

Although this white paper presents estimates for average heating and cooling energy savings from Google Nest thermostats, it is important to recognize that energy savings can vary dramatically from home to home due to differences in how people used their prior thermostats, how they use their Google Nest thermostat, occupancy and behavior patterns, comfort preferences, climate, and characteristics of their homes and HVAC systems. Larger savings can be expected for households that:

- have a manual or programmable thermostat that is not running a program[13] (or carefully managing their setpoints manually), especially if they use their Google Nest thermostat to help create an efficient schedule;
- do not maintain very efficient setpoints when away on vacation and set an efficient Eco temperature on their Google Nest thermostat;
- enroll in Seasonal Savings every winter and summer to help keep their schedules efficient; and
- have a heat pump with electric resistance auxiliary heat in a colder climate and an existing thermostat that does not have smart auxillary heat controls, especially if they set their Heat Pump Balance feature to “Max Savings.”

Savings tend to be lower for households that were already paying close attention to their thermostat settings either running a program with efficient setbacks or carefully managing it manually. Lower savings are also expected for homes that are always occupied and for customers who choose not to use key thermostat features such as Seasonal Savings.

[13] Only 24% of programmable thermostat users report actually running a program according to EIA data,

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