
PECAN STREET

# Smart Cooling: Leveraging Technology and Behavior to Stay Cool and Reduce Energy Demand

July 2023

PECAN STREET

Pecan Street's mission is to accelerate the transition to clean, low-carbon energy, and integrated water management through innovative technology and policy. Our research, data, and technology expertise give researchers, entrepreneurs, policy-makers, and impact investors the insight they need to change the world.

Our real-world testbed of volunteer research participants is the first of its kind on the planet and has become an international model for conducting energy and resource research and product testing. Our commercialization lab is a world-class proving ground for major corporations and startups alike. And our database, the largest source of disaggregated customer energy data, is used by university researchers and industry-leading companies around the world.

Learn more at pecanstreet.org or email info@pecanstreet.org.

Please direct questions about this paper to Cavan Merski, Data Analyst, at cmerski@pecanstreet.org.

# Smart Cooling: Leveraging Technology and Behavior to Stay Cool and Reduce Energy Demand

## Introduction

The COVID-19 pandemic altered daily life around the world, including changes in the way people live, work, and consume energy. As people spent more time at home, Pecan Street found several opportunities to examine home energy trends and conservation opportunities.

Energy used for heating and cooling homes (heating, ventilation and air conditioning, or HVAC) is an excellent example. Homes that may have sat empty during the workday before the pandemic were quickly required to keep residents warm or cool all day, all night, all year. Naturally, energy consumption increased. As the pandemic abated and people returned to work and school, household energy has fallen, but not back to pre-pandemic levels.

Meanwhile, more and more homes are electrifying. Central air conditioning installations are expected to increase as climates warm in historically temperate regions. Improvements in heat pump technology mean electric heat pumps are feasible heating options in colder climates where natural gas or heating oil have been the norm for generations. This is good news for the climate. But it creates electricity challenges: electric heating will increase winter electricity demand in colder climates, and more central air conditioners will increase summer electricity demand in warmer climates.

Hidden in this increased load is a massive conservation opportunity. Analysis of Pecan Street's residential research network demonstrates that HVAC load can be significantly reduced through optimization. We found that air conditioning electricity demand during blazing hot Texas summers was a third lower in homes that used a combination of smart thermostats and manual setpoints when no one is home.

Not only does our analysis show that overall electricity demand can be dramatically shaved, it also demonstrates a significant opportunity to use heating and cooling load as a powerful demand response resource.

## Quick Takes

- "Workday hours" at home doubled during the pandemic, leading to increased electricity demand. They have not returned to pre-pandemic levels, and probably won't.
- Air conditioning is among the largest residential electricity loads, and installations are increasing.
- Real-home electricity data suggest these trends provide massive conservation and demand response potential.

## Methodology at a Glance

- Our analysis explored residential HVAC energy use in Austin, Texas, during summer months of 2019 through 2022 from Pecan Street's network of volunteer participants whose homes are equipped with circuit-level electricity measurement technology.
- The sample included 63 homes and over 700,000 hours of data.
- Measured energy data was paired with participant surveys to gain insight into their thermostat hardware and setpoint behavior and lifestyle changes during the pandemic.
- Energy use data was normalized by home size, and a regression model was built to compare summer HVAC load over time.

## Results At a Glance

- Between summer 2019 and summer 2020, participants reported spending about twice the number of "workday hours" at home. Participants who reported more hours at home use 4% more electricity for air conditioning in summer 2020 than in summer 2019. People who reported fewer hours at home use 5% less.
- Since 2020, workday hours at home have declined, but not to pre-pandemic levels. Likewise, air conditioning electricity demand since summer 2020 has declined, but not to pre-pandemic levels.
- Technology and individual behavior present massive conservation and energy management opportunity. Our analysis predicts that homes with smart thermostats that automatically adjust the temperature setpoint with algorithms or occupancy sensors used 24.5% less energy than homes without them from June - September.
- When smart thermostats are coupled with manual thermostat setpoint interventions, summer air conditioning electricity use in our regression model was 34.5% lower. Both of these effects were present before, during and after COVID, yet the energy savings were largest in years other than the 2020 lockdown.

## A Deeper Dive

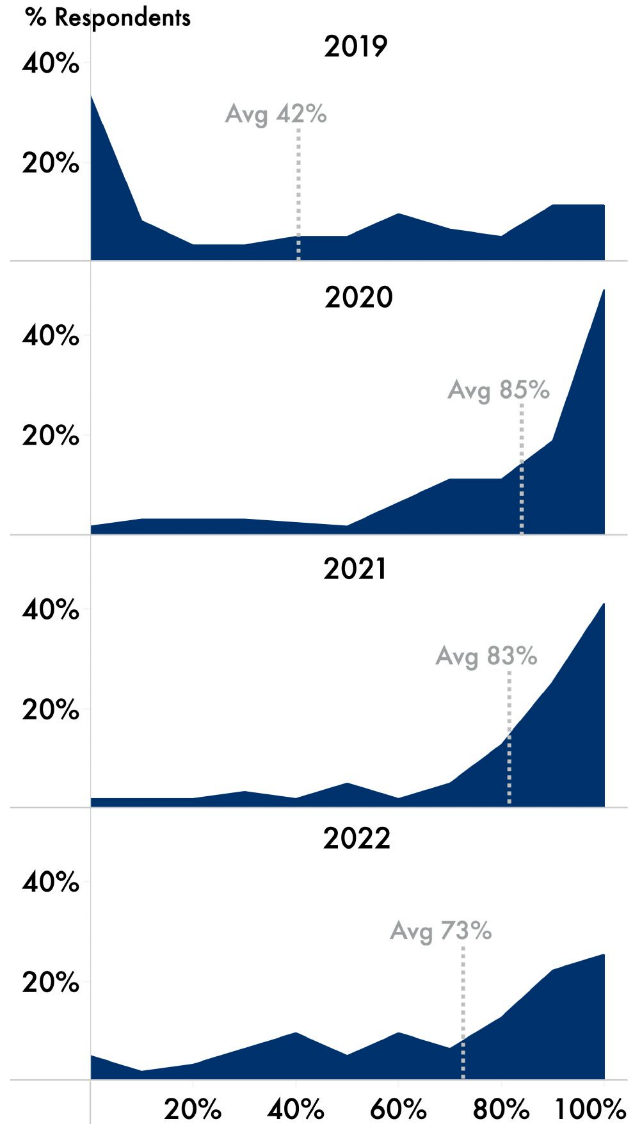
Not surprisingly, workday hours spent at home increased significantly in 2020 due to the pandemic.

Prior to the pandemic, respondents spent an average of 42% of workday hours at home. That doubled to 85% in the summer of 2020.

Workday hours at home declined in the summers of 2021 and 2022 as pandemic restrictions eased. But they have not snapped back to pre-pandemic levels. This could indicate a "new normal" for certain types of jobs and employees.

### Workday Time at Home

**Survey/Percentage of Time 8AM-5PM Spent at Home**




It is worth noting that the pre-pandemic numbers – the summer of 2019 – show what is likely a sample bias for Pecan Street's Austin participants. Most of the homes included in the sample are of middle- to upper-income families who may have had significant workday flexibility before the pandemic or who have at least one adult at home during portions of the day. Research of low- to moderate-income households or those with two or more "outside the home" full-time workers may produce different trends.

## Home More = Use More

The HVAC energy consumption data from our participant network was normalized by the square footage of each home, and a regression model was created to measure the average home load at different temperatures. This technique allows us to compare HVAC load across homes of different sizes and over multiple summers, even as weather conditions like temperature and humidity vary significantly.

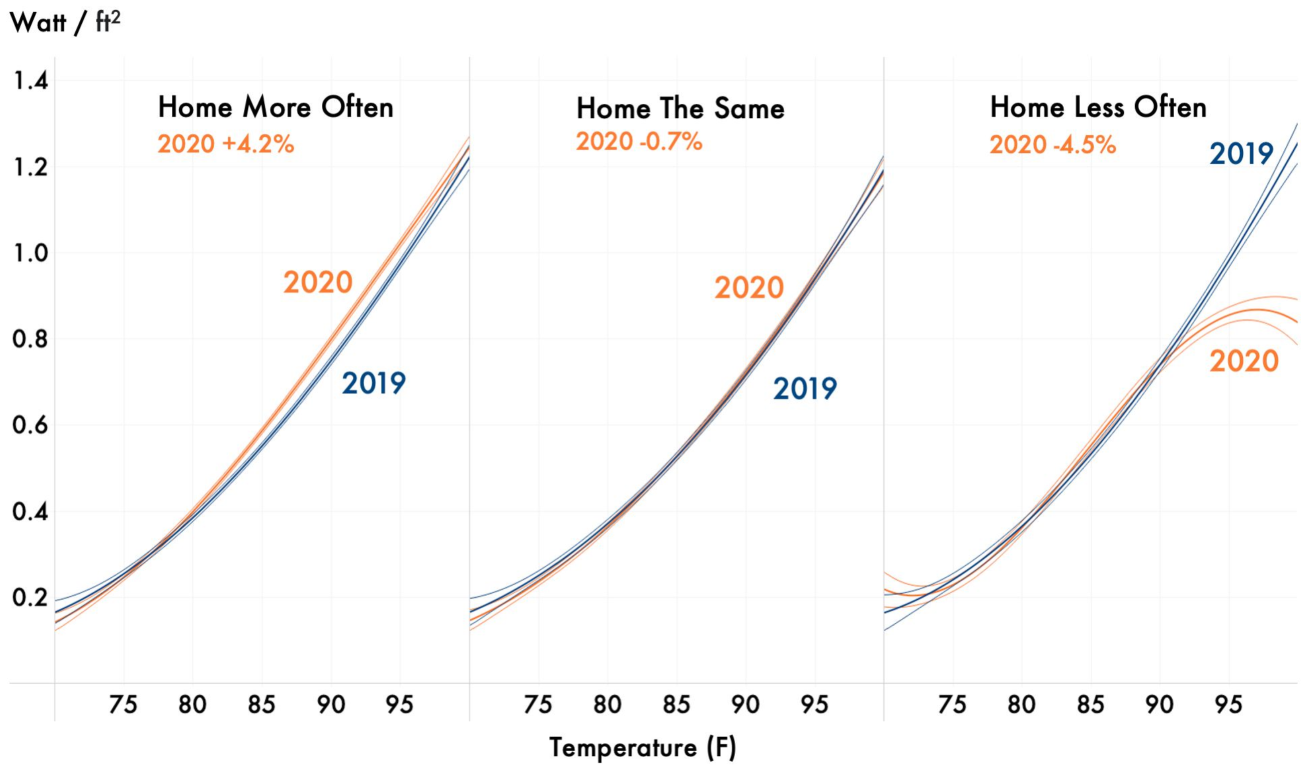
Homeowners who reported spending more time at home during the summer of 2020 than in 2019 used 4% more electricity to cool their homes than they did in 2019.

Those who spent the same amount of time at home used nominally less (1% decrease). Participants who said they were home less during workday hours saw HVAC load reduce by 5%.

Only four respondents said say they were home less in 2020 than in 2019, thus the trend line for 2020 has wide confidence intervals at higher temperatures. It is possible the reduced energy use for these households is the result of the families leaving town to shelter elsewhere.

### Average Cooling Load Per Square Foot – 2019 vs 2020 – Survey Response

Regression with 95% Confidence Interval / 63 Homes in Austin, TX / June – September 2019 – 2022



## Smart Thermostats and Setpoints

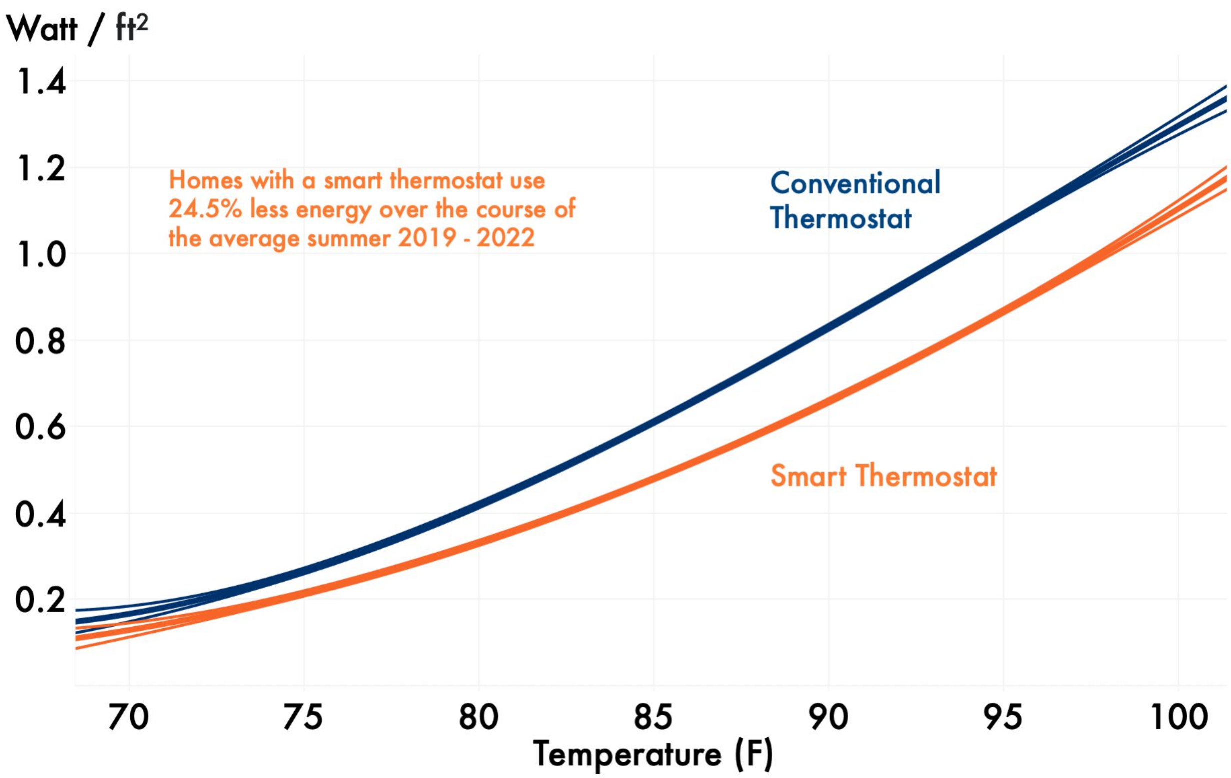
For this analysis, we defined a smart thermostat as one that is internet-connected and has advanced features that can sense occupancy status and modify setpoints automatically. Some models call this a "home/away" mode.

Traditional thermostats may be new, digital and programmable, and may even have internet capabilities. But if they do not have auto-detect home/away status or otherwise try to determine it, we did not consider them "smart." This is an important distinction because our findings suggest that setpoints, schedules AND setpoint adjustments when the home is empty produced the most significant reduction in energy consumption for cooling.

As shown below, homes with a smart thermostat will use 24.5% less cooling power than those without one during an average summer. This phenomenon was less pronounced in the summer of 2020, when time at home was at its highest and time away from home was at its lowest.

### Average Cooling Load of Smart vs. Conventional Thermostats

Regression with 95% Confidence Interval / 63 Homes in Austin, TX / June – September 2019 – 2022

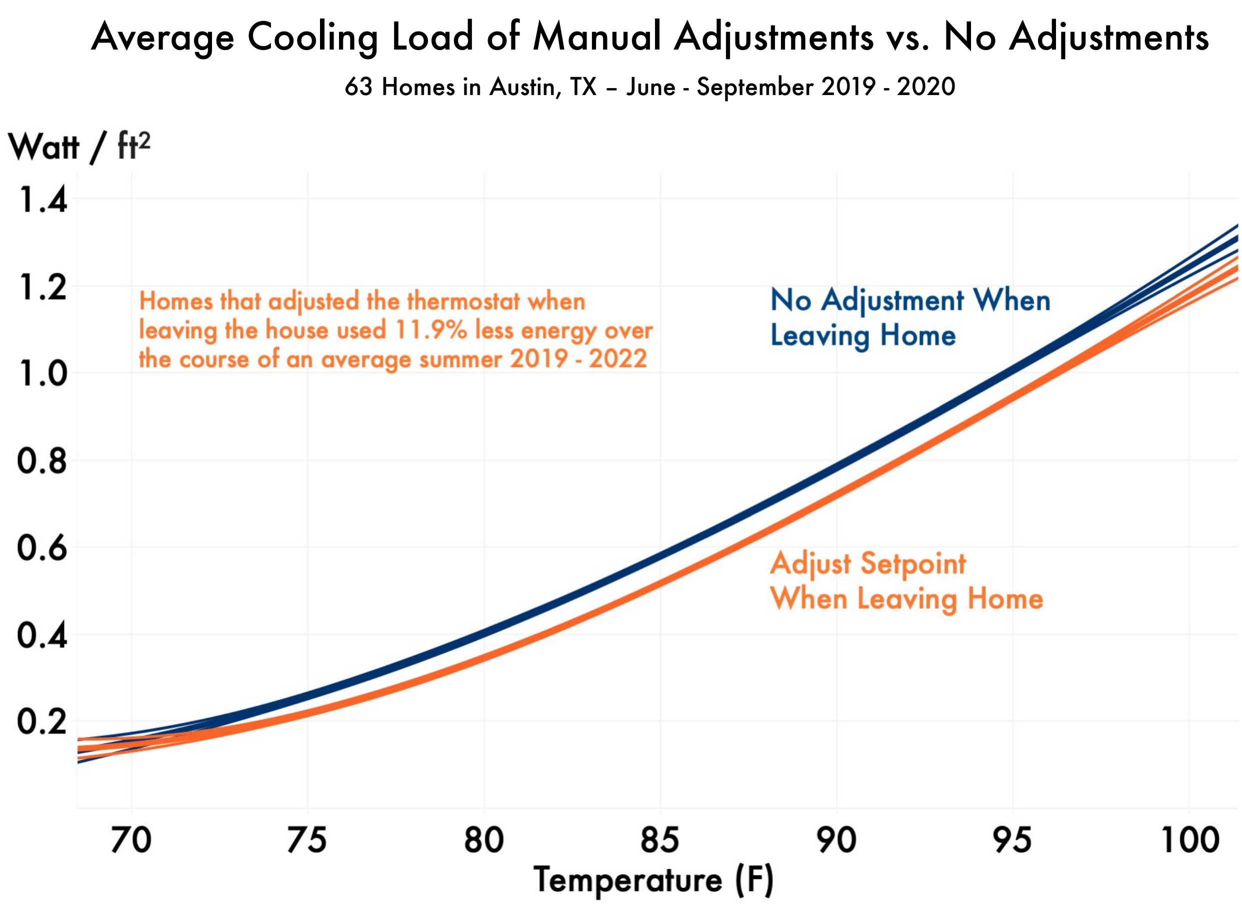


## Manual Away Settings

Overall, respondents who said they adjust their thermostat setpoint manually when leaving the house use 11.9% less cooling energy than homes who said they do not. Again, this phenomenon was less pronounced in 2020.

There is a common misunderstanding regarding thermostats that assumes an HVAC system exerts extra effort to restore a comfortable temperature after the thermostat has been adjusted higher. This can be true for long and dramatic changes when it is very hot – for example, turning a setpoint from 74 degrees to 90 degrees for hours when the outside temperature is 110 degrees. Less significant changes – for example, from 74 degrees to 79 degrees for short durations – do not put excessive pressure on efficient air conditioner systems.

Sizing is another important aspect of heat pump performance. If a heat pump is not sized correctly to a home or is installed in a leaky thermal envelope, the efficiency of the heat pump decreases as it relies more heavily on backup heating sources. Electric resistance heating, the most common backup heat source, is much less efficient than heat pumps and natural gas furnaces. It's important to hire a reputable installer and understand a home's energy performance and utility rates before deciding on which heat pump system to install.



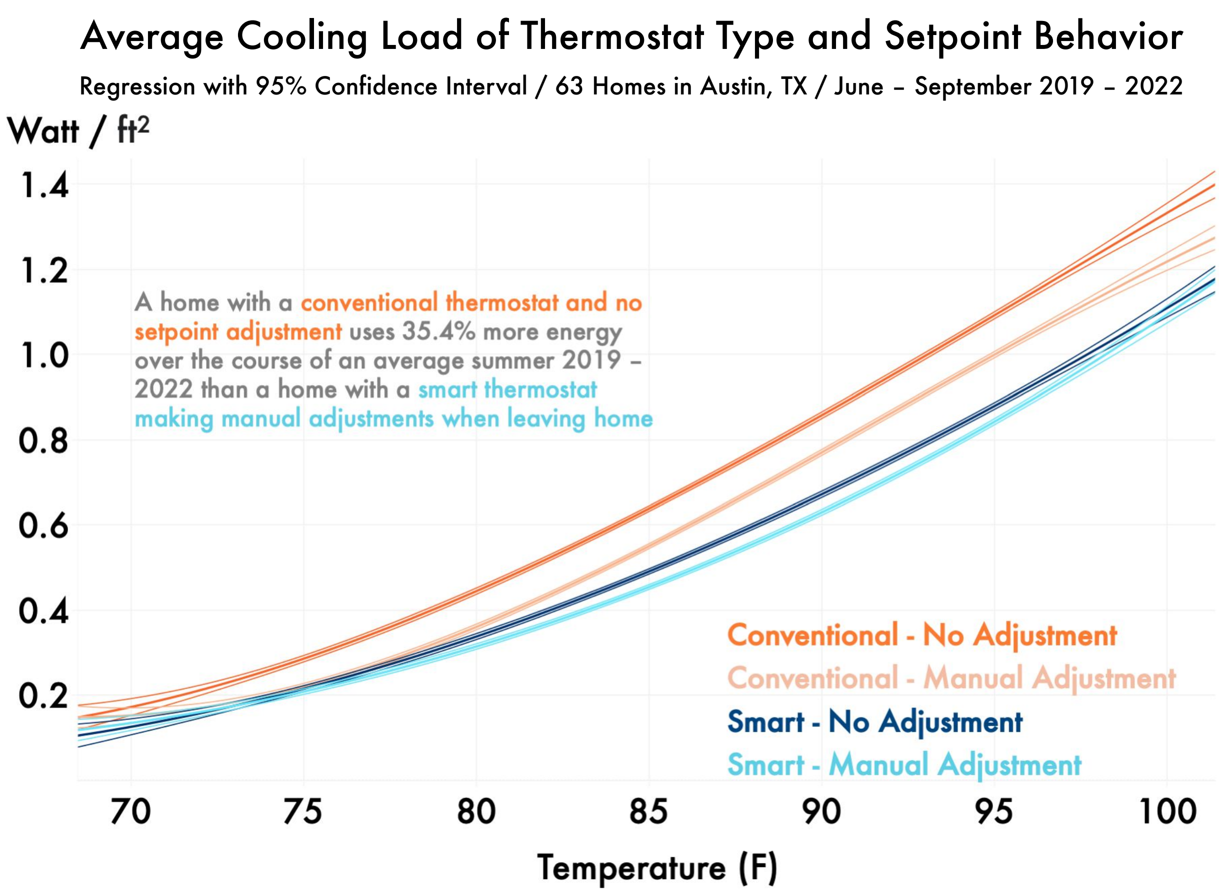
## Compounding Benefits: Smart Thermostats and Smart Consumers

Manually adjusting thermostat setpoints reduces energy use, whether or not the home has a smart thermostat. In fact, manual "away" adjustments for traditional thermostat homes was 2.7 times as effective than in smart thermostat homes. But manual adjustments helped reduce energy use in smart thermostat homes, too.

Smart thermostats (blue lines) have the largest normalized HVAC energy reduction effect. Participants with a smart thermostat who manually adjust the setpoint when leaving (light blue) use 35.4% less energy than those with conventional thermostats who did not adjust when leaving (light orange).

This suggests:

1. Smart thermostats are powerful conservation tools, and
2. Better, smarter and more "conservation-minded" setpoint adjustments when the home is empty could conserve more energy than today's models.



## HVAC Conservation as Resource

HVAC energy use can not only be reduced, it can be shifted. That's the premise behind utility programs like Austin Energy's Energy Rush Hour: thermostat setpoints in thousands of homes can be adjusted slightly during peak demand periods. Such demand response strategies not only help during unusually high demand periods, they can also make better use of available resources all day and all year. This can reduce market-wide utility costs, like new generation facilities, transmission lines and other infrastructure whose cost eventually trickles down to customers. Since summer peak loads on the grid are highly correlated with cooling loads, this presents a monumental opportunity for demand response.

Here, utilities have two powerful levers.

**Direct Load Control Programs**, like Austin Energy's Power Partner Purchase Program and Florida Power & Light's On Call, grant the utility the ability to adjust certain appliances in a customer's home, such as air conditioners or water heaters, to benefit the broader grid. These programs can be highly effective at reducing peak demand, particularly the phenomenon observed in our analysis where thermostats are adjusted higher when homes are vacant during peak demand hours.

**Time-of-use (TOU) Rates** are another tool that can leverage the flexibility of cooling load. TOU rates charge more for electricity during peak demand times and less during off-peak times. This provides customers a direct financial incentive to shift usage to off-peak times and reduce strain on the grid during peak periods.

Both demand response programs and time-of-use rates can be effective, but their effectiveness can vary depending on factors such as the specific design of the program, the local climate, and customer behavior. For example, TOU rates may be more effective in areas where there is a clear distinction (and therefore, customer awareness) between peak and off-peak times.

Direct load control programs may be more effective in areas where consistent loads like cooling drive peak demand, as in Texas. Also, some customers may find TOU rates easier to understand and respond to than direct load control programs.

# Pushing for More

Capturing the full conservation benefit of smart thermostats comes down to two factors: install more of them and use them to their full potential.

Smart thermostats are getting smarter. That trend will continue, and, given recent advancements in machine learning and artificial intelligence, we expect their ability to assess variables like outside weather, HVAC model, occupancy status and user preferences to improve dramatically in coming years. In short, thermostat capability does not appear to be a limiting factor in capturing these potential energy savings.

More likely, cost and clear user benefits will create stronger headwinds for broader adoption. Many utilities offer generous rebates to significantly reduce the purchase price of smart thermostats, and some connect the rebates to ongoing demand-response programs that allow the utility to adjust cooling setpoints during peak demand. Our message to utilities and technology companies is simple: go further.

- In addition to one-time rebates, customers could be rewarded monthly for maximizing their thermostat's conservation features like day-to-day setpoint schedules, seasonal reviews and adjustments, and using the home/away detection feature.
- Utilities should test various marketing messages for their rebate programs and thermostat-based conservation programs. Some customers, for example, will be immediately suspicious giving a utility access to their thermostats. But these customers should not be written

off. They may simply need reassurance that any temporary setpoint adjustments can be easily overridden manually.

- To increase customer enthusiasm for peak conservation, utilities may consider testing TOU rate structures that provide significant financial incentives for shifting cooling load to pre- and post-peak hours.
- Thermostat companies could make scheduling and occupancy detection features more prominent or "on by default."
- Technology companies that offer in-home tech platforms, like Apple and Google, could improve compatibility and cross-functionality and more creatively market the conservation power of using a customer's location.