AUGUST 2019
R: 19-07-B

REPORT

THE ENERGY IMPACTS OF SMART SPEAKERS AND VIDEO STREAMING DEVICES

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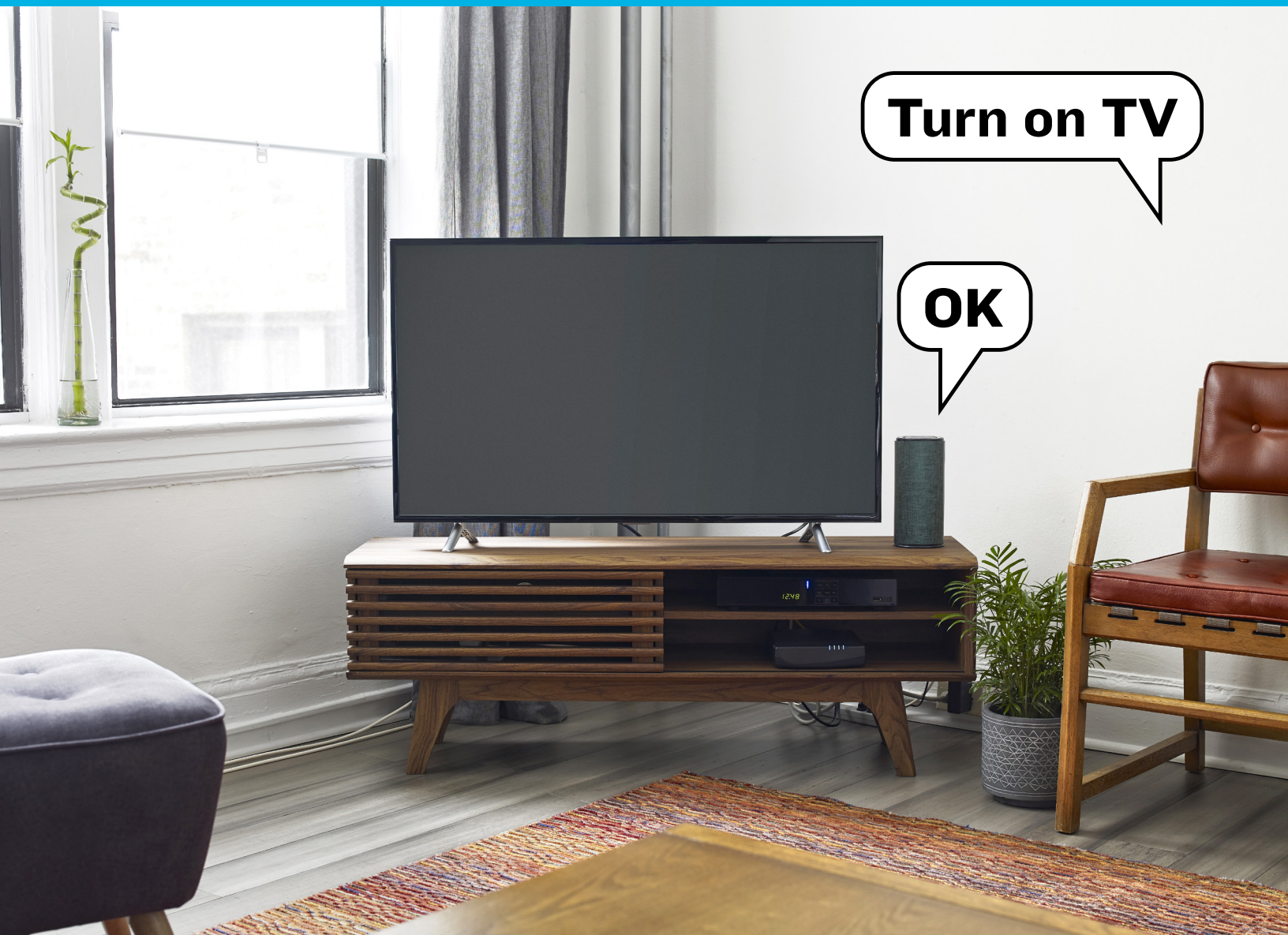

ACKNOWLEDGMENTS

NRDC would like to acknowledge the following individuals for reviewing drafts of the report and providing invaluable feedback:

NRDC: Joe Vukovich, Sheryl Carter, Tina Swanson, Josh Mukhopadhyay, and Pat Remick

Nick Leritz, Northeast Energy Efficiency Alliance

Bijit Kundu, Energy Solutions

About NRDC

The Natural Resources Defense Council is an international nonprofit environmental organization with more than 3 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, Chicago, Montana, and Beijing. Visit us at nrdc.org.

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Table of Contents

Executive Summary

Almost 100 million smart speakers and video streaming devices had been purchased and installed in U.S. households by mid-2018 and millions more will be added by the end of this year in the United States and globally. Smart speakers, also sometimes known as digital and voice assistants, are connected to the internet and respond to voice commands for information, to control smart home devices, or to stream audio content. The most popular model is the Amazon Echo speaker, which features the voice assistant Alexa. Video streaming devices, such as Roku or Apple TV set-top boxes, are connected to the television and allow the user to stream a wide range of video content from the internet via hundreds of applications and services, such as Netflix and Hulu. In addition, newer-model televisions can be linked to a nearby smart speaker, making it possible for the user to wake and control a television by voice without a remote control.

Despite the growing popularity of these devices, there is little information about their energy consumption. In particular, we did not know how much electricity they consume while in standby mode, waiting for the next request from the user. Given the exploding growth in these devices and their ability to control other equipment, including televisions, NRDC undertook a groundbreaking study to determine whether these devices when connected together might significantly affect U.S. energy consumption, consumer utility bills, and the power plant pollution that harms our health and warms the planet.

NRDC retained Pacific Crest Labs to test the power use of a cross-section of these devices both in "on" and "standby" power modes and to perform modeling to assess their overall national energy use. The lab also ran tests to determine if both a television's standby power and its overall annual energy consumption increased when linked to a smart speaker. We did not include the energy used by a modem/router that smart speakers and streaming devices are connected to, because these devices are presumably already operating as part of a home's wireless network when a smart speaker or streaming device is acquired.

Our analysis shows that the leading smart speaker and video streaming devices are energy efficient. Each of the devices we tested had annual operating costs of just a few dollars per year (about $1.50 to $4, depending on the model). However, linking smart speakers to a television can, in some cases, cause television standby power and overall annual energy use to skyrocket; in our tests, television standby power use was found to increase dramatically, from less than 0.5 watts to about 20 watts. In a worst-case scenario, this could cost consumers $1.3 billion to $2.5 billion in wasted annual energy.[1] The per household increase would be about an extra $200 over the 10-year lifetime of each TV. Almost all of the extra energy use could be avoided if manufacturers were to design their televisions to sleep in standby mode at less than 1 watt when configured to be awakened via a smart speaker. As part of our research after the initial round of testing, we found two examples of televisions from different manufacturers that can do this, so we assume it is technically feasible for all TV manufacturers in the future.

Here are key findings and recommendations from the research:

- **Tested smart speakers were energy efficient**, in both on and standby mode (still using electricity while waiting to be awakened into full, active on mode). These devices were clearly designed with energy efficiency in mind; all but one model consumed less than 2 watts while in standby mode, despite continuing to "listen" for the activating word, such as Alexa, Google, or Siri, to return to full power mode. Total annual energy use for the tested models ranged from 12 kilowatt-hours per year (kWh/yr) to 33 kWh/yr. Total national annual energy consumption of the roughly 50 million smart speakers in use today is 783 gigawatt-hours (GWh) of electricity, costing U.S. consumers around $100 million per year. Smart speakers use much less annual energy than the bookshelf/mini stereo systems that preceded them for listening to music; the latter typically consumed around 75 kWh/yr.
- **Tested video streaming devices were energy efficient**, using 11 kWh to 24 kWh per year. Total national energy consumption of the roughly 40 million streaming devices in use today is 727 GWh per year and results in $94 million in annual consumer electricity costs. The devices consume less energy than set-top boxes (STBs) from service providers such as Comcast and AT&T, which use 35 kWh/yr to 100 kWh/yr to provide video content to a television, due in large part to the high power usage by STBs when the user is not watching a show.[2] The Google Chromecast Ultra and Roku Ultra streaming devices we tested had standby levels in excess of 2 watts; the Apple and Amazon models we tested each consumed less than 1 watt in standby. If all streaming devices used less than 1 watt in standby, we would save about 204 GWh/yr of electricity, or $26 million, on consumers' annual utility bills and prevent 143,948 metric tons of carbon dioxide pollution every year from the power plants generating the electricity to run the devices.

- **Linking smart speakers to televisions can cause annual television energy use to double.** Controlling televisions by one's voice via a smart speaker is in its early stages of development and deployment. Only a few of the ten 2018 television models we tested offered the ability to both wake and control the TV via a nearby smart speaker. Among those that did, TV standby power increased to approximately 20 watts on average instead of the less than 0.5 watts it would have otherwise used. This increase in consumption can cause a TV's overall annual energy use to more than double. We expect more television manufacturers to add smart speaker connectability in the future and to possibly incorporate the functionality of a smart speaker directly into the television itself, eliminating the need for a separate device.

We hope this report motivates TV manufacturers to seek out designs that require only 1 to 2 watts of standby power to wake and control a television through talking to a nearby smart speaker. This level should be achievable through the addition of a dedicated low-power chip to listen for incoming voice commands or through a new integrated "system on a chip" solution inside the TV that powers down all other circuits while in standby mode.

If one-quarter to one-half of all televisions are eventually connected to smart speakers that can wake and control a television through voice commands, and if the TVs continue to consume an additional 20 watts of standby power, this will cause an increase in annual national energy consumption of 9,709 GWh to 19,418 GWh. That amount of additional electricity use is greater than the annual electricity consumption of all Houston households, or the annual output of three to six large (500-megawatt) coal-burning power plants. With improved television designs that avoid the 20-watt increase in standby power, we can prevent this potential energy penalty and help consumers avoid $1.3 billion to $2.5 billion added to their electric bills every year.

In some additional testing in the spring of 2019, we observed reductions in television standby power for some models that offered connectability to a smart speaker and the ability to wake and control the TV through voice commands and without using the remote control. One model delivered this full functionality for less than 1 watt with sufficiently quick wake times, confirming that our 1- to 2-watt standby power target is indeed achievable.

- **Television On-mode power use when connected to an Apple TV streaming device can increase significantly.** During setup, the Apple TV streaming device gives users the option of improving video quality. When it is selected, the Apple TV will automatically upscale all traditional standard dynamic range (SDR) content to high dynamic range (HDR), a relatively new video format that offers enhanced contrast, brighter highlights, and darker detail. Four of the eight televisions we tested at typical room lighting levels experienced a significant increase in on mode power—an average of 100 percent—when we "opted-in" to upscale all content to HDR via the Apple TV streaming box. This increase happens primarily because these TVs have an energy-saving feature called Automatic Brightness Control (ABC), which is enabled by default for SDR content but automatically disabled for HDR content.

RECOMMENDATIONS

To minimize the energy consumption and associated environmental impacts of these devices while maintaining an excellent user experience, we recommend a number of steps, including these:

- Smart speaker manufacturers should ensure average standby power levels of less than 2 watts.
- Video-streaming devices should attain average standby power levels of less than 1 watt.
- Television manufacturers should achieve 1 to 2 watts average standby power levels when their televisions are configured to wake by smart speaker voice command, not the current 20 watts or so we observed in some models. It is critical to get this right to avoid locking in an extra $1.3 billion to $2.5 billion in annual energy costs in the United States. Television manufacturers should also explore ways to keep the energy-saving ABC feature enabled while preserving a quality viewing experience when playing HDR content.
- Consumers who have streaming devices and subscribe to traditional cable or satellite television should download the app from their service providers and return their set-top boxes to them. The user will have a similar viewing experience and avoid the extra energy use and cost on their utility bill—which could be around $50 per year—associated with household set-top boxes.
- The audio/video specification required to use the ENERGY STAR® label should be revised to include updated test methods and aspirational power targets for smart speakers.
- The U.S. Department of Energy should update its current television energy-use test method so that smart TVs are tested with live internet connections and power use is measured when voice-wake capability is enabled, through either remote smart speaker or television-integrated capability.

Although this report focuses exclusively on models sold in the United States and the energy and environmental impacts caused by their use in this country, almost all of these devices are also sold internationally. We can expect several hundred million more of these devices to be installed globally over the next few years. We urge manufacturers to develop energy efficient versions of their products regardless of where they are meant to be sold, and to ensure that software and user interfaces are updated as needed for non-U.S. markets as well.

Chapter 1: Introduction

Sales have exploded during the past few years for new internet-connected smart speakers such as the Amazon Echo, generically referred to as Alexa, and video streaming devices that allow users to view an almost unlimited range of content on their new televisions.[3] However, there have been little, if any, readily available data on the power consumption of these devices when in active or standby modes. With about 100 million of these devices installed as of mid-2018 in the United States alone, NRDC retained Pacific Crest Labs to conduct a study of their energy consumption.[4]

The study attempted to answer the following questions:

- How much power do some of the most popular models of smart speakers consume, both when they are playing music and when they are only in standby mode, awaiting a voice command? Are some models more efficient than others in standby mode? What are the national impacts in terms of total annual energy use and operating costs?
- How much power do some of the most popular models of video streaming devices consume, both when streaming video content accessed from the internet via a wireless connection and when in standby mode? Are some models more efficient than others in standby mode? What are the national impacts in terms of total annual energy use and operating costs?
- What impact does linking smart speakers to new televisions have on energy use? For example, how does linking an Amazon Echo or Google Home smart speaker to a 2018 model-year television affect the television's standby power and overall annual energy consumption? If this feature is deployed widely with new televisions, what are the national environmental and economic impacts? And are there design options that could deliver this functionality with minimal incremental standby power use?

All of the models tested were purchased directly from retail outlets to ensure testing was done on the same models that consumers buy. We thank the Northwest Energy Efficiency Alliance (NEEA) for allowing NRDC to use the televisions that NEEA had purchased for its own research on the test method used for measuring television power levels and for identifying potential concerns about the impact of television voice wake capability on TV standby power.

Chapter 2: Smart Speaker Testing

Smart speakers, also known as digital assistants, are devices that connect to a home wireless network through an internet connection, which allows the user to get answers to questions such as "Will it rain today?" and "Who led the NBA in scoring in 2017?" and to stream music, podcasts, and so on.

For this study we tested these models:

- Amazon Echo—2nd Generation
- Apple HomePod
- Google Home
- Google Home Mini
- Harman Kardon Invoke

The first four are some of the biggest sellers and represent the vast majority of sales, whereas the Harman Kardon Invoke was selected because it represents Microsoft's entry into the market with its Cortana voice assistant. At the time of testing, it was the only smart speaker that could wake the Xbox gaming console by voice command.[5] We did not include any of the popular Sonos speakers because they did not have voice recognition when we began the study, although the manufacturer has since added this capability to its products.

Figure 1 shows the smart speaker and video streaming models we tested, along with the meter used to perform the power measurements.

SMART SPEAKER TEST METHODS

Each of these devices was purchased new and set up in its default configuration. If there were forced menu choices (e.g., options to select crash reporting or location services), we chose to opt in. That resulted in selecting the options most likely to consume the most power. Once the unit was set up and connected to a local wide area network (e.g., a live internet signal via a wireless router), Pacific Crest Labs conducted the following measurements.

FIGURE I: SMART SPEAKER AND VIDEO STREAMING DEVICE SAMPLES AND POWER ANALYZER

On mode testing—With a voice command, we asked each smart speaker to play news, classical music, and popular music. We selected a volume level representative of the level that one would be likely to use while listening to music in the background (typically 3 on a scale of 10). News and music were played in equal proportions for several minutes, and the average power value for each of the three content types was calculated in watts. We used a simple average of these three power values to approximate the typical power used by each smart speaker in the on mode. Note: The power values reported were meant to estimate on mode power use. We recognize that measured power may vary depending on the specific content being played and the volume level selected.[6]

Standby power testing—While music or news was playing, we told the device to stop playing and then measured the device's standby power over an 18-hour period. We monitored the variations in standby power use during this time and measured average standby power use after power use stabilized and remained essentially unchanged over time.

Most, but not all, devices stabilized within a few minutes. Our intention was to understand how these products behave in typical real-world conditions rather than to strictly follow existing industry test methods that might deliver slightly greater precision during on mode testing but would require much more sophisticated procedures. For example, the test method for measuring on mode power for products such as smart speakers requires the content to be played at a specific decibel level that would require a more elaborate setup. Also, the official Department of Energy test method for measuring television standby power does not involve connecting a television to a live internet connection and does not provide any guidance on whether or how to connect a smart speaker to a television prior to testing.

Wake-time testing—We measured the time it took each speaker to respond to a voice command when the device was in standby mode. For this test, we asked the sleeping device, "What time is it?" and then started a timer, stopping when the speaker began to provide an audio response. This wake time is an indication of how quickly a device is able to power up from its low-power state.

All testing was performed using a Tektronix PA1000 power meter calibrated in accordance with the International Electrotechnical Commission (IEC) standard IEC 17025.[7]

To calculate each model's annual smart speaker energy use (kWh/yr), we applied a daily duty cycle of 1,241 hours per year in on mode and 7,519 hours per year in standby.[8] These values represent roughly 3.5 hours per day of active usage and 20.5 hours in standby. For video streaming devices we applied a duty cycle of 7 hours per day in on mode and 17 hours per day in standby, the same duty cycle used by the U.S. Environmental Protection Agency (EPA) in its ENERGY STAR program for set top boxes (STBs—the boxes provided by cable, satellite, and telephone companies to their customers to access Pay TV services), to determine each model's annual energy use.

SMART SPEAKER POWER TESTING RESULTS

The on and standby mode power levels observed during audio testing for each smart speaker are provided in Table 1.

All of the devices used little power to stream audio content. These values are quite impressive given that the devices are both maintaining an internet connection and delivering sound. While the Apple HomePod and Harman Kardon Invoke had slightly higher on-mode power levels, these devices may deliver louder bass or greater fidelity, which typically requires some additional power.

Other than the Harman Kardon model, all of the units we tested achieved less than 2 watts of power in standby mode. The wake times that we observed were all within 1 to 2 seconds. These standby levels are quite acceptable given the devices' ability to always be listening for the wake command, such as Alexa, Google, or Siri; to maintain a connection to the home wireless network; and to have very fast resume times. We are unaware of a technical reason why the Harman Kardon Invoke and other smart speakers shouldn't be able to achieve a standby level of less than 2 watts. It should be noted that the Harman Kardon Invoke speaker was the only device we tested that ran on Microsoft's Cortana voice assistant software, which might be the source of the slightly elevated standby power level.

Table 2 provides each model's annual energy use, as well as the estimated number of units installed in the United States as of fall 2018. The installation numbers were obtained from Consumer Intelligence Research Partners (CIRP), and we assumed that the energy of the product we tested represents roughly the average of the product family reported by CIRP.[9] The annual energy use for these models ranged from 12 kWh to 33 kWh per year, which is lower than the typical bookshelf/mini-speaker systems (i.e., the systems from several years ago that had a tuner, cassette and/or DVD player, and two detached small speakers) that were previously used and consumed around 75 kWh/yr.[10] (Note: We did not include the energy used by the home's modem/router that the smart speakers are connected to because those devices are already in the user's home and operating.)

Per our modeling, we estimate that the smart speakers currently installed in America's homes consume a total of 783 gigawatt hours per year (GWh/yr), meaning U.S. households are consuming $102 million worth of electricity per year to power these devices.

TABLE 1: AVERAGE POWER USE BY SMART SPEAKERS DURING ON AND STANDBY MODES

	ON-MODE POWER (WATTS)	STANDBY POWER (WATTS)
Google Home Mini	1.7	1.4
Amazon Echo (2nd Gen.)	2.4	1.6
Google Home	2.2	1.9
Apple HomePod	5.9	1.9
Harman Kardon Invoke	4.2	3.8

TABLE 2: ANNUAL ENERGY USE, U.S. STOCK, AND NATIONAL ENERGY USE OF SMART SPEAKERS

	ANNUAL ENERGY USE (KWH/YR) PER MODEL	U.S. STOCK (MILLIONS)	NATIONAL ENERGY USE (GWH)
Google Home Mini	12.3	4	49
Amazon Echo (2nd Gen.)	15.2	35	532
Google Home	17.1	8	137
Apple HomePod	21.6	3	65
Harman Kardon Invoke	33.4	Insig.	Insig.
Total		50	783

Chapter 3: Video Streaming Device Testing

Consumers purchase video streaming devices in order to expand the range of content they can view on their televisions. These devices, sometimes referred to as over-the-top (OTT) boxes or dongles, allow the user to stream content from services such as Netflix, Hulu, Amazon Prime, Google's YouTube television, and up to hundreds of other choices via a wireless internet connection. The devices we purchased ranged in price from $35 to $200.

We tested these devices:

- Amazon Fire TV 4K Ultra HD HDMI Dongle
- Apple TV 4K set-top box
- Google Chromecast 4K Ultra HDMI Dongle
- Roku Ultra 4K/HDR set-top box

All of these devices except Google Chromecast are controlled by a separate remote control that comes with the streaming device. Google Chromecast enables users to stream (or "cast") video and music from laptops, tablets, and smartphones to a television without the use of a separate remote control. Casting involves starting a video on a mobile device and then clicking on a casting button that asks you which device you would like to cast to. Once the user selects the display device, the video appears there but can still be controlled from the mobile device. Given the rich user interface of mobile devices, this enables a user to more quickly and easily select and control content to play on his or her television. Audio casting offers similar capability. Chromecast dongles (roughly the size of a thumb drive) host no apps; they only support media casting.

VIDEO STREAMING DEVICE TEST METHOD

Each device was purchased new, and we set them up as a typical user would. We first connected the streaming device to the television in its default configuration and then linked the television to the local wide area network to wirelessly access the internet.

For the on-mode power measurement, we recorded for two minutes the power levels while an SDR show from Netflix was playing.[11] We then stopped the show via the remote control, turned off the television via its remote control, and continued to measure the streaming device's power for approximately eight hours. We analyzed the data, determined when stabilization occurred, and reported the average standby power level after stabilization.

We also measured the wake time from an OTT device remote control command to the appearance of its home screen on a connected TV.

VIDEO STREAMING DEVICE TESTING RESULTS

Table 3 reflects the results of the testing, including the on and standby power levels, and time it took to display the home screen.

The on-mode power levels ranged from 2.3 watts to 3.3 watts. The standby power levels ranged from 0.7 watts to 2.7 watts. The Google and Roku products had higher standby levels (more than 2 watts) than the other devices, which were less than 1 watt. Although not a huge difference, the extra watt of power that is consumed whenever the user is not streaming content adds up at the national level, given that about 40 million streaming devices are in use.

Using the duty cycle of 7 hours on, 17 hours standby, the annual energy use for these devices ranged between 11 kWh/yr and 25 kWh/yr, which is quite similar to the values we saw for the smart speakers we tested.

To determine national impacts, we gathered data on the number of these devices installed in the United States as of the first quarter of 2018.[12] The total amount of electricity consumed by these devices nationally is approximately 727 gigawatt hours per year (GWh/yr). That translates to around $94 million in annual consumer electricity costs. If all of these devices were able to achieve 1 watt in standby,

TABLE 3: AVERAGE POWER USE BY VIDEO STREAMING DEVICES DURING ON AND STANDBY MODES, START-UP LATENCY, AND ANNUAL ENERGY USE

	ON-MODE POWER (WATTS)	STANDBY POWER (WATTS)	TIME TO HOME SCREEN (SEC.)	ANNUAL ENERGY USE (KWH/YR)
Amazon Fire TV	2.3	0.9	1.8	11
Apple TV	2.9	0.7	6.7	12
Google Chromecast Ultra	2.6	2.2	1.0	20
Roku Ultra	3.3	2.7	6.2	25

TABLE 4: ANNUAL ENERGY USE, PERCENT OF AND TOTAL U.S. STOCK, AND NATIONAL ENERGY USE OF LEADING VIDEO STREAMING DEVICES			
	PER UNIT ANNUAL ENERGY USE (KWH/YR)	U.S. STOCK (MILLIONS)	NATIONAL ENERGY USE (GWH/YR)
Amazon Fire TV	11	11	122
Apple TV	12	9	101
Google Chromecast Ultra	20	6	128
Roku Ultra	25	15	376
Total		41	727

we would save 204 GWh per year (worth $26 million annually) on consumers' utility bills and prevent 143,948 metric tons of carbon dioxide equivalent (CO_2e) emissions per year.[13]

A useful point of comparison for the streaming devices' annual energy use are the set-top boxes (STBs) distributed by the cable, satellite, and telephone company service providers. These devices use 35 kWh/yr to 100 kWh/yr to provide video content to a television, due in large part to the fact that they continue to draw near full power when not in use.[14] If unplugged, the STB have unacceptably long reboot times of a few minutes.[15]

It should also be noted that pay television service providers, such as Comcast and DirecTV, are increasingly developing and offering solutions whereby customers can receive content on their television directly from an app (that is, by clicking on an icon on the screen) and can get rid of their set-top box.[16] The switch away from STBs to the use of apps would result in significant national energy savings, lower electric bills for consumers, and reduce emissions of harmful pollutants from power plants.

Chapter 4: Linking a Television to a Smart Speaker and Operating It Through Voice Commands

As we began our study we became aware of a new and exciting feature that enables the user to link a smart speaker to a television. Once the initial setup is completed, the user can, with certain new televisions from the 2018 model year and later, control the television via voice rather than a remote control. In a few limited cases, the user can also wake the television from standby mode simply with a voice command.

As part of our research we decided to also study what impact, if any, this new capability might have on a television's standby power use and resulting annual energy use. Although today's televisions typically have low standby power levels (typically less than 0.5 watt), it was possible the numbers could go up considerably if a television had to keep additional circuits "awake" in order to listen for a voice command.

To perform this testing, we accessed eight different 2017 and 2018 television models previously purchased by the NEEA for its own energy testing. The models are listed in Table 5. They represent a range of brands and corresponding operating systems, which are potential determinants of the television's standby power level when linked to a smart speaker.

TEST METHODS FOR MEASURING STANDBY POWER USE OF TVS LINKED TO SMART SPEAKERS

We attempted to link the Amazon Echo 2nd Generation Speaker and the Google Home Speaker to each of the above televisions. (Neither the Apple HomePod nor the Harman Kardon Invoke supported this capability.) It took time to navigate the user menus and in some cases required calling customer support to link the television and smart speakers

TABLE 5: TELEVISION MODELS TESTED				
YEAR AND BRAND	MODEL	SIZE	TECHNOLOGY	OPERATING SYSTEM
2018 LG	OLED55C8PUA	55″	OLED	WebOS
2018 LG	SK8000PUA	49″	Edge-lit with local dimming	WebOS
2018 Samsung	QN55Q8FN	55″	QLED Full Array with local dimming	Tizen OS
2018 Samsung	55NU8000	55″	Edge-lit with local dimming	Tizen OS
2018 Sony	XBR55X900F	55″	Full Array with local dimming	Android TV
2018 Vizio	P55-F1	55"	Full Array with local dimming	SmartCast
2017 TCL	55S405	55"	Full array, no local dimming	Roku TV
2017 Westinghouse	WA50UFAI001	50"	Edge-lit, no local dimming	Amazon Fire

together. We made sure the televisions and speakers were connected to a wide area network and a live internet signal before conducting testing. Otherwise the televisions were in default configuration per the DOE test method.

When setting up each television for the first time, we accepted any software updates if prompted. We then elected to disable future software updates so we could repeat our testing without the variability that new updates could cause. All testing was done in the fall of 2018.

For each television, we performed a standby power test before we linked it to a smart speaker. We then turned off the television by pressing the power button on the TV's remote control. We measured the television's standby power overnight in the same way that we tested smart speakers and OTT boxes.

We then linked each television to a smart speaker and measured its standby power over a period of two hours. We chose this shorter testing interval after preliminary tests suggested that television power levels were fairly stable in this network-standby mode.

RESULTS AND POTENTIAL NATIONAL IMPACTS

Table 6 summarizes the results for standby power tests conducted on the Amazon Echo smart speaker where in some cases the user can both wake and control (e.g., change channel, adjust volume, etc.) the TV via voice commands, while in other instances the user could control the TV but not wake it by voice command.

We also tested televisions with the Google Home speaker. Table 7 summarizes results for models we were able to successfully connect to and control with this smart speaker.

The key findings from this testing:

- The televisions that could be controlled, but not wakened, by voice command were able to maintain low standby levels of less than 0.5 watts while preserving their normal wake times (less than 10 seconds).

TABLE 6: RESULTS FROM INTERACTION TESTS WITH TVS AND AMAZON ECHO SMART SPEAKER (SS)							
	SAMSUNG 8000	SAMSUNG Q8	LG OLED	TCL	SONY	WESTINGHOUSE	VIZIO
Echo 2nd Generation	Control only TV: 0.4 W SS: 1.6 W	Control only TV: 0.3 W SS: 1.6 W	Control only TV: 0.2 W SS: 1.6 W	Control only TV: 0.3 W SS: 1.6 W	Wake & control TV: 21.2 W SS: 1.6 W	Wake & control TV: 22.9 W SS: 1.6 W	Wake & control TV: 19.8 W SS: 1.6 W

TABLE 7: RESULTS FROM INTERACTION TESTS WITH TVS AND GOOGLE HOME SMART SPEAKER (SS)				
	LG OLED	LG SK	SONY	VIZIO
Google Home	Control only TV: 0.3 W SS: 1.9 W	Control only TV: 0.3 W SS: 1.9 W	Wake & control TV: 21.1 W SS: 1.9 W	Wake & control TV: 18.8 W SS: 1.9 W

- Each of the televisions that supported both wake and control capabilities resulted in standby power levels between 18.8 watts and 22.9 watts on average. This represents a roughly 20-watt increase in standby power from its less than 1 watt level and more than doubles the annual energy consumption of many TVs.

Given that a typical television spends around 19 hours per day in standby mode and only 5 hours per day in on mode, a significant jump in standby power mode can dramatically affect a television's overall annual energy use.[17] In Figure 2 we show how linking a television that can be wakened by voice control to a smart speaker can produce high television standby power levels. Here the television's annual energy use jumps from 106 kWh/yr all the way to 248 kWh/yr, more than doubling. To put that into perspective, two of these TVs would consume as much energy per year as a new mid-sized household refrigerator.

Although the combined feature of waking and controlling a television by voice is just beginning to come on the market, we understand that it will become much more common in the 2019 models that will be widely available in the second half of the year. If this trend continues and manufacturers fail to optimize their televisions for low standby power levels when linked to smart speakers, we could see large increases in national energy consumption. If one-fourth to one-half of all televisions in the United States have this feature and a 20-watt increase of standby power, we would see an increase in national annual energy consumption of 9,709 GWh to 19,418 GWh, which is equivalent to the annual electricity generation of three to six large (500-megawatt) coal burning power plants and more than the annual electricity consumption of all the households in Houston.[18] This extra electricity use would add $1.3 billion to $2.5 billion to national household electric bills.

We have presented this information in informal individual discussions with some of the leading television manufacturers and hope it serves as a wake-up call, drawing proper attention to this issue as the industry increasingly incorporates the wake-and-control feature and designs future televisions. We believe television manufacturers should be able to deliver this great new feature for only 1 to 2 watts of television standby power. This could be accomplished in a number of ways, including the addition of a low-power network proxy chip or similar capability in a system-on-chip block with power islanding, whereby all other components/features such as the television tuners are turned off.

We are confident that a low-standby power engineering solution exists because the Amazon Fire TV dongle can act as a network proxy that wakes the television from low-power sleep via HDMI Consumer Electronics Control (CEC). If one uses the Fire TV dongle with, for instance, the Sony television, the two products use a total of 1.4 watts in standby—0.5 watts for the television and 0.9 watts for the Fire TV dongle.

We understand that adding components increases cost. Our hope is that manufacturers add this capability on a chip for little cost in the system as smart speaker use gains market penetration.

Another innovation we might see are Internet-connected televisions that come with full smart speaker–type capabilities built into them, eliminating the need to purchase and install a smart speaker near the television to achieve hands-free operation. We believe that these implementations can achieve low-power standby as well. Amazon provides many low-power reference designs that manufacturers can leverage to develop Alexa-enabled products with low standby power. Other voice assistant developers may provide low-power reference designs as well. The ball is in the court of the TV manufacturers.

FIGURE 2: POTENTIAL IMPACT OF POOR WAKE BY VOICE IMPLEMENTATION IN TVS[19]

LEARNINGS FROM FOLLOW-UP DISCUSSIONS WITH MANUFACTURERS AND ADDITIONAL TESTING

In March and April 2019, NRDC reached out to several television manufacturers to share our testing results and preliminary analysis. During these calls we also sought to gain feedback from the manufacturers, as well as any information they could share about the future of wake and control features in new televisions and any potential reductions in standby power. Afterward we conducted targeted additional testing on a few models using each one's most up-to-date software.

During these conversations we learned:

Sony has developed and pushed a software update to its 2018 model year televisions. After our discussions with Sony, we accepted the software update and retested the Sony model XBR55X900F. The standby power level for this television, when connected to the Amazon Echo and with the wake and control command feature enabled, was 8.2 watts, down from the 21.2 watts observed during our initial testing prior to the software update. We were unable to connect this television to our Google Home smart speaker.

Vizio informed us that the model we had tested, the P Series P55-F1, is one of the company's high-end models, and the high standby power level of 18 to 19 watts when connected to Amazon Echo or Google Home was due to the high power chip set used in the P Series televisions. The company indicated that we should see much lower standby power levels for its more mainstream, higher volume-selling units. To confirm this, we purchased an entry-level model (Vizio V505-G9 SmartCast) and performed testing after connecting it to the Amazon Echo and Google Home Mini. The results of our testing are shown in Table 8.

Vizio advertises that its SmartCast televisions, which include the new model we purchased, can be turned on and off and controlled with both Amazon Echo and Google Home smart speakers. However, we were unable to achieve full functionality with the Echo speaker. We could wake the television with the Echo but could not control it or turn it off. To determine if we could control the TV, we attempted to change the volume and to start YouTube and Netflix. We were surprised to find that we could wake the television by voice from a 1-watt sleep with the Quick Start feature turned off, even though the setup instructions stated that we would have to turn on Quick Start to achieve wake-by-voice functionality. This is evidence that a television can be turned on by voice command for less than 1 watt from sleep. The sleep power level should have nothing to do with whether television control works when it's on. We believe that with software bug fixes to its on-mode control, Vizio could fully enable Echo wake and control with a standby power level of less than 1 watt.

Voice control with the Google Home Mini smart speaker behaved as expected. With Quick Start enabled we could wake, control, and turn off the television by voice. With Quick Start disabled we could still control and turn off the television by voice command, but we could not wake it by voice. We are optimistic that a software upgrade could enable wake and control of this television with both Amazon Echo and Google Home smart speakers.

LG 2018 models that we tested in the fall of 2018 with June 2018 software provided only voice control to operate the television once it was turned on manually. But with April 2019 software installed, the LG SK8000PUA was able to wake by voice command after being in a 0.5-watt sleep state overnight, as shown in Table 9.

These results were extremely encouraging, as the Vizio and LG televisions were able to achieve less than the 1-watt standby level we are recommending to the industry while providing user-acceptable wake times. In addition, in each case this was achievable through a software update alone.

Since we performed this testing, LG removed the wake-by-voice capability for its models introduced in 2018. We were unable to learn from LG why this decision was made. We could not perform additional follow-up testing on the 2019 models from LG or other manufacturers as they were not available prior to the initial writing of this report.

TABLE 8: WAKE-BY-VOICE CHARACTERISTICS OF VIZIO P55-F1 TV WITH ECHO AND GOOGLE SMART SPEAKERS

	TELEVISION QUICK START	TELEVISION STANDBY POWER (W)	WAKE BY VOICE TIME (SEC.)	WAKE TELEVISION BY VOICE?	CHANGE VOLUME BY VOICE?	TURN OFF TELEVISION BY VOICE?
Echo 2nd Generation	QS On	8.3	7	Yes	No	No
	QS Off	0.9	10	Yes	No	No
Google Home Mini	QS On	8.3	4	Yes	Yes	Yes
	QS Off	1.0	N/A	No	Yes	Yes

TABLE 9: WAKE-BY-VOICE CHARACTERISTICS OF LG SK8000PUA TV WITH AMAZON ECHO SMART SPEAKER

	TELEVISION QUICK START (QS)	TELEVISION STANDBY POWER (W)	WAKE BY VOICE TIME (SEC.)	WAKE TELEVISION BY VOICE?	CHANGE VOLUME BY VOICE?	TURN OFF TELEVISION BY VOICE?
Echo 2nd Generation	QS On	0.5	7	Yes	Yes	Yes

Chapter 5: Impact of Apple TV Upscaling on Television On-Mode Power Use

During the Apple TV streaming device setup process, the device prompts the user to select an option that improves video quality, as shown in Figure 3. When this is selected, the Apple TV device automatically upscales all traditional standard dynamic range (SDR) content to high dynamic range (HDR), a relatively new video format that offers enhanced contrast, brighter highlights, and darker detail.

Four of the eight televisions tested at typical room lighting levels have an energy-saving feature called Automatic Brightness Control (ABC) that is enabled by default for SDR content and automatically disabled for HDR content. These televisions experienced an average on mode power increase of 100 percent when we accepted Apple's offer to get the best picture and tried HDR. Table 10 reflects the results.

FIGURE 3: APPLE TV PROMPT WHEN CONNECTED TO A NEW TELEVISION

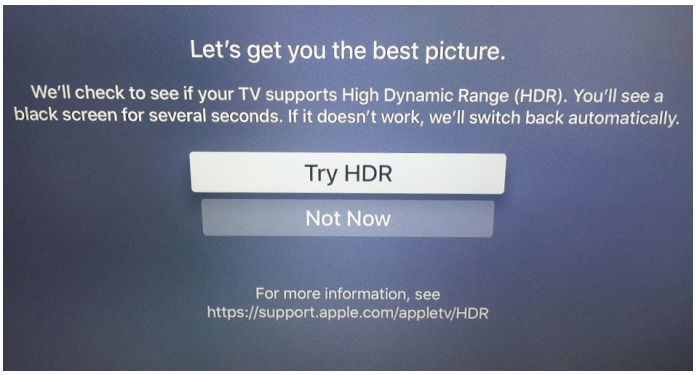

TABLE 10: DEFAULT SETTINGS AND ASSOCIATED POWER LEVELS FOR TVS PLAYING 4K SDR AND HDR CONTENT

BRAND	MODEL	ABC ON BY DEFAULT FOR SDR CONTENT	ABC ON BY DEFAULT FOR HDR CONTENT	POWER USE WHILE VIEWING 4K SDR CONTENT (W)	POWER USE WHILE VIEWING 4K HDR CONTENT (W)	OVERALL % POWER INCREASE
Sony	XBR55X900F	Yes	Not Selectable	72.7	148.3	104%
Hisense	H8E	Yes	Not Selectable	47.4	100.8	113%
LG	OLED55C8PUA	Yes	No	70.5	112.1	59%
LG	SK8000PUA	Yes	No	49.5	113.5	129%
Samsung	QN55Q8FN	Yes	Yes	54.4	48.6	-11%
Samsung	55NU8000	Yes	Yes	57.6	59.6	3%
Vizio	P55-F1	No	Not Selectable	183.1	201.2	10%
TCL	55S405	N/A	N/A	82.0	106.5	30%

To conduct this Apple TV test, we played a 10-minute real-world test clip developed by NRDC, first in SDR mode and then upscaled to HDR10 by our Apple TV 4K. In the latter case, the television acts as if it is receiving native HDR content. We chose HDR10 because it is the most common HDR format offered today, and recent testing shows that the most common HDR formats yield similar power levels. We configured the televisions in their default settings per the DOE test method, such as default home mode and the selection of the more energy-consumptive options when prompted by the television (e.g., crash reporting, sharing marketing data). For those televisions that defaulted to ABC-enabled, we tested at 15 lux, determined via empirical research by both Lawrence Berkeley National Labs and the Collaborative Labeling and Standards Program to be the typical ambient light level of televisions in U.S. households during home viewing.

We chose to test at this typical light level—as opposed to testing at each of the four light levels: 3, 12, 35, and 100 lux as stipulated in the DOE test method—to simplify our testing. As a result, one cannot directly compare our measurements to official representations of television energy consumption such as the EnergyGuide label that is required to be displayed per the rules of the Federal Trade Commission. Because the DOE test method measures power by playing SDR content, it is clear that ABC-enabled televisions fed HDR content by an Apple TV streaming device use more energy than the EnergyGuide label indicates, but perhaps not twice the power.

Chapter 6: Recommendations

Below are our recommendations to help minimize energy use and environmental impacts caused by these products while preserving an excellent user experience.

- **Television manufacturers** should strive to have their models achieve less than 1 watt in standby when configured to wake by smart speaker voice command, rather than the current 20 watts or so we observed in some models. It's critical to get this right and avoid locking-in an extra $1.3 billion to $2.5 billion worth of annual energy use in the United States. The mid-level LG television we tested, when connected to a smart speaker, demonstrated wake-by-voice capability with less than 1 watt in standby during April 2019 follow-up testing. This suggests that others should be able to do the same.

  Television manufacturers should also explore ways to keep the energy-saving ABC feature enabled while preserving a quality viewing experience when playing HDR content and when upscaling SDR content to HDR. This will avoid the doubling of power use associated with playing HDR content that we have observed for some TVs.

- **Smart speaker manufacturers** should strive to achieve standby levels of less than 2 watts, like the vast majority of today's smart speakers already achieve.

- **Video-streaming device manufacturers** should achieve the standby power levels of less than 1 watt attained by both Apple and Amazon. This could result in annual national savings of 500 GWh, or $70 million.

- **Consumers** who have streaming devices such as Apple TV, Roku, Chromecast, or Amazon Fire TV and subscribe to traditional cable or satellite television service should look to download the app from their service providers and return their set-top boxes. The user will receive the same experience and avoid the extra energy use and associated cost, which could be around $50 per year per household.

- **The EPA** should complete the ENERGY STAR Audio/Video Specification Version 4.0 to provide updated test methods and aspirational targets for smart speakers. This will help ensure manufacturers continue to pay sufficient attention to the energy efficiency of their products, which is important because many consumers preferentially purchase products with the ENERGY STAR label.

- **The DOE** should update its current television energy use test method to add representative HDR content, add language to address concerns about the persistence of energy-saving features such as ABC, require smart televisions to be tested with live internet connections, and measure power use when voice wake capability is enabled either through remote smart speaker or TV-integrated capability.

CONCLUSION

Since new smart speaker and entertainment-related devices studied in this report will only continue to grow in popularity both in the United States and internationally, it's essential for manufacturers to ensure their products use as little electricity as possible, especially when they are waiting to be used and in standby mode. The greatest priority should be placed on new television designs to ensure that television standby power levels remain low even when linked to a smart speaker and when capable of being awakened and controlled through voice commands. Doing so will avoid unnecessary increases in consumer energy bills and electricity generation, which will decrease the likelihood of more power plant pollution that leads to health problems and warms our climate.

ENDNOTES

1 Calculated on the basis of $0.13/kWh. See U.S. Energy Information Administration, "Electric Power Monthly," June 25, 2019, https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.

2 D+R International, *2017 Annual Report: Voluntary Agreement for Ongoing Improvement to the Energy Efficiency of Set-Top Boxes*, August 9, 2018, https://www.energy-efficiency.us/library/pdf/STB2017AnnualReport.pdf.

3 Sarah Perez, "Report: Smart Speaker Adoption in U.S. Reaches 66M Units, With Amazon Leading," TechCrunch, https://techcrunch.com/2019/02/05/report-smart-speaker-adoption-in-u-s-reaches-66m-units-with-amazon-leading/ (accessed Feb. 5, 2019).

4 John Koetsier, "Amazon Echo, Google Home Installed Base Hits 50 Million; Apple Has 6% Market Share, Report Says," Forbes, August 2, 2018, https://www.forbes.com/sites/johnkoetsier/2018/08/02/amazon-echo-google-home-installed-base-hits-50-million-apple-has-6-market-share-report-says/#4fb91bc5769c.

5 Ibid.

6 In making these measurements, we followed the spirit but not the letter of the ENERGY STAR A/V equipment test method. The ENERGY STAR test method would have required us to feed a sine wave to the speaker and monitor total harmonic distortion (Annex A). That is a more expensive and replicable type of testing than was warranted for this type of study, which focuses on typical use versus exact repeatability.

7 ANSI Webstore, "ISO/IEC 17025:2017," https://webstore.ansi.org/standards/iso/isoiec170252017?gclid=Cj0KCQjw6cHoBRDdARIsADiTTzZO5w7Ms-V1eVGwQMkQXqhVBnybU2JcJA0pxMnbwnQx_-I3m0Xa3JwaAjsGEALw_wcB.

8 Duty cycle figures are derived from assumptions for shelf speakers in Bryan Urban, "Consumer Electronics in U.S. Homes: Energy Use in 2017," Fraunhofer USA presentation at Energy Efficiency in Domestic Appliances and Lighting (EEDAL) 2017 annual meeting, Irvine California, September 13–15, 2017, https://www.cse.fraunhofer.org/hubfs/2017%20-%20Urban%20-%20EEDAL%20-%20CTA%20Energy%20in%20Homes.pdf.

9 John Koetsier, "Amazon Echo, Google Home Installed Base Hits 50 Million."

10 Bryan Urban et al., *Energy Consumption of Consumer Electronics in U.S. Homes in 2017*, Fraunhofer USA, December 2017, http://www.cta.tech/cta/media/policyImages/policyPDFs/Energy-Consumption-of-Consumer-Electronics-in-U-S-Homes-in-2017.pdf.

11 Most of today's content is formatted as SDR. High Dynamic Range (HDR) formats, such as Dolby Vision, offer new, enhanced contrast.

12 "Parks Associates: Nearly 40% of U.S. Broadband Households Own a Streaming Media Player," Cision PR Newswire, May 31, 2018, https://www.prnewswire.com/news-releases/parks-associates-nearly-40-of-us-broadband-households-own-a-streaming-media-player-300657338.html.

13 U.S. Environmental Protection Agency, "Greenhouse Gas Equivalencies Calculator," last updated December 2018, https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

14 For information on set-top box annual energy use, see D+R International, *2017 Annual Report: Voluntary Agreement for Ongoing Improvement*.

15 Ibid.

16 Ibid., p. 6, 20–23.

17 Per the duty cycle assumptions in the DOE test method. See "Energy Conservation Program: Test Procedures for Television Sets," *Federal Register*, October 25, 2013, https://www.federalregister.gov/documents/2013/10/25/2013-24346/energy-conservation-program-test-procedures-for-television-sets.

18 Houston has 840k households. Per data from the Energy Information Administration, the average household consumed 10,399 kilowatt-hours per year. At that rate, Houston's residential electricity consumption is: 840,000 x 10,400 = 8,736,000,000 kWh, or 8.736 TWh. Our upper-end impact figure of 19 TWh is more than twice Houston's annual residential electricity consumption. U.S. Census Bureau, "Quick Facts: Houston City, Texas," last updated July 1, 2018, https://www.census.gov/quickfacts/houstoncitytexas. U.S. Energy Information Administration, "Frequently Asked Questions: How Much Electricity Does an American Home Use?" last updated October 26, 2018, https://www.eia.gov/tools/faqs/faq.php?id=97&t=3.

19 57 W represents the sales-weighted average power level of new units sold in 2018 per ENERGY STAR Retail Products Platform (ESRPP) data.