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Small Network Equipment Energy Consumption in U.S. Homes

Using Less Energy to Connect Electronic Devices

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

While much has been learned recently about the energy use of televisions, computers, and cable set-top boxes, little is known about the approximately 145 million small network devices we use to access the Internet and move digital content around our homes. To better understand the per model and national energy use of modems, routers, and other such devices—and how much could be saved by more efficient designs—NRDC and its consultant Ecova measured the power use of 60 models in the field and laboratory using a simplified version of the ENERGY STAR® test method.[1]

From our measurements and modeling, we estimate small network equipment in America's homes consumed more than $1 billion worth of electricity in 2012, equivalent to the output of three large (500 MW) coal-fired power plants. This resulted in 5 million metric tons of carbon dioxide emissions, which represents the annual tailpipe emissions of 1.1 million vehicles.

In fact, we found that the annual national electricity use from all of today's small network equipment is nearly equal to the total annual electricity consumption of all of the households in Silicon Valley, the high-tech capital of the world: a whopping 8.3 billion kilowatt-hours per year. Unfortunately, our analysis shows that most small network devices draw the same amount of power when sitting idle as they do when transmitting large amounts of data at high rates.

While many of the same or similar small network devices are used in commercial settings, this report focuses solely on the small network equipment in U.S. households, the most common of which are:

a) modems, which connect a household to its high-speed (broadband) Internet service provider;

b) wireless routers, which connect computers, printers, tablets, and other devices within a household; and

c) integrated devices called gateways or Internet access devices (IADs), which perform both of these functions and often provide telephone service as well.

Typically these types of small network equipment connect to other in-home devices via wireless antennas or Ethernet ports and cables.

While modems and gateways can be purchased at retail outlets such as Best Buy and Radio Shack, most consumers acquire them from their Internet service provider (usually their phone company or cable TV provider). Customers are likely, however, to purchase their own routers through retail channels rather than lease them from service providers. For our study, we tested devices purchased in stores as well as those distributed by service providers.

INDIVIDUAL HOUSEHOLD USE

Approximately 88 million households subscribe to high-speed Internet service in the United States. Under the most common configuration, a household operates two small network devices: a modem to connect to the Internet, and a router to move the data around the home.

We found that together, these small, innocuous black boxes consume an average of 94 kilowatt-hours (kWh) of electricity every year, nearly the same amount of energy as a new 32-inch flat-screen television that has earned the ENERGY STAR label, or more than twice the annual consumption of a 14-inch ENERGY STAR-certified laptop computer.

Modems, routers, and gateways are the most common in-home network devices and account for most of the energy used by small network equipment in America's homes (see Figures 1 and 2). Few U.S. households use stand-alone switches or wireless access points that can expand a network's access or range. However, a small but growing number of consumers who have high-speed fiber-optic service (Verizon FiOS) connect to service providers through

Optical Network Terminals (ONTs), devices typically attached to the outside of the home that translate optical signals into electronic signals, and vice versa.

We found a broad range in the amount of energy used by devices with similar functionality. Fortunately, the top quartile of small network devices on the market today use one-third less energy than average models. Some of the most efficient devices we tested save energy because they operate at lower power, while other equipment achieved efficiency by effectively scaling power downward when there is little network traffic.

Our analysis also revealed that:

- In most, but not all cases, using a gateway with combined modem and routing functionality is more efficient than using separate modem and router devices.
- There are no significant differences between the average power draw of devices purchased in stores and similar models leased by service providers.
- Differences in power between two Internet service providers that use the same broadband modem are insignificant.

HUGE POSSIBILITIES FOR ENERGY SAVINGS

With NRDC modeling, we estimate that replacing today's inefficient residential small network equipment with efficient models could save 2.8 billion kWh of electricity per year, slashing consumers' energy bills by about $330 million.

Further, there is potential for even greater savings, given that the industry has only begun to develop and deploy products with sophisticated capabilities to scale power without affecting performance.

The two primary standards in play for making home network equipment more energy efficient are IEEE 802.3az Energy Efficient Ethernet (EEE) for Ethernet ports, and IEEE 802.11e automatic power save delivery (APSD). These industry standards and device communication protocols help modems and routers enter a lower-power sleep state when little to no data are moving among computers, printers, the local network, and the Internet. Because the network devices meeting these energy-saving standards remain sufficiently awake to receive/transmit data at any time, consumers will not be adversely affected by the energy efficiency improvements.

Today few of the network devices that make up today's stock of residential network equipment have EEE or other energy efficiency technologies. First-generation EEE devices are expected to produce near-term savings of 5 to 20 percent. Next-generation models may save as much as 80 percent of system power, according to an analysis by Intel and Cisco. Such reductions may more than offset the increase in power draw resulting from the market shift to considerably faster Ethernet devices.

Although our study does not quantify the energy consumption of commercial small network equipment, that sector also consumes a significant amount of power. Therefore, introducing technologies and standards that increase the energy efficiency of small network equipment, whether used in the home or office, will add to the potential national energy savings.

MAKING SMALL NETWORK EQUIPMENT ENERGY SAVINGS A REALITY

Unfortunately, consumers today are not easily able to determine which small network equipment devices are the most energy efficient or, conversely, which are the energy hogs.

However, the Environmental Protection Agency (EPA) is finalizing an ENERGY STAR specification for small network devices that will soon help consumers identify the most efficient devices on retail shelves and choose Internet service providers that offer energy-saving home network equipment as part of their subscription packages. When it becomes effective, consumers shopping for Internet service should request a modem or gateway device with the ENERGY STAR label.

Although the ENERGY STAR specification will not require modems and routers to meet the EEE industry standard, qualifying ENERGY STAR models still will use less energy than other small network devices. However, the EPA should make EEE a future requirement for ENERGY STAR certification of network equipment as well as computers, printers, and other connected devices. It should also ensure that its test procedure and program requirements reward Wi-Fi power scaling technologies.

In addition, state and federal policymakers should consider establishing mandatory energy efficiency standards for small network equipment in order to eliminate the least efficient products from the market. These standards could require EEE on both network equipment and Ethernet "edge devices," such as desktop and laptop computers, printers, game consoles, tablets, and smart TVs.

I. INTRODUCTION

In the United States today, there are approximately 145 million residential small network devices used to access the Internet and move content around our homes.[2,3] While many of the same or similar small network devices are used in commercial settings, this report focuses on devices used in U.S. households, the most common of which are a) modems, which connect a household to its broadband service provider; b) wireless routers, which connect computers, printers, tablets, and other devices within the household; and c) integrated devices called gateways or Internet access devices (IADs), which perform both of these functions and often provide telephone service as well. Since little is known about the energy consumption of these devices, NRDC retained Ecova to build on work done at the Lawrence Berkeley National Laboratory[4] and to conduct a more comprehensive study designed to answer the following questions about small network equipment:

1. How much energy do the major types of products such as modems and routers consume?
2. Is there a significant spread in the power draw of models with similar features? Do some models provide the same function more efficiently than others?
3. What is the national energy use of these devices?
4. What energy-saving opportunities exist, and how can we take advantage of them?
5. Although not typically considered small network equipment, how does the energy consumption of Satellite Outdoor Units (ODUs)—used to send pay-TV signals to a customer's premises—compare with that of broadband modems, which perform a similar function?

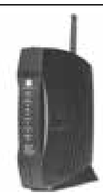
II. SMALL NETWORK EQUIPMENT 101

Residential small network devices enable consumers to access high-speed (broadband) Internet services and to transmit data between devices within the home. ENERGY STAR divides network devices into two main categories: broadband access equipment and local network equipment.[5]

Broadband access equipment allows consumers to access high-speed Internet service from a provider such as their cable, satellite, or phone company.

Figure 1: Examples of Broadband Access Equipment

Modem
Receives a broadband signal from a cable or telephone service provider via a coaxial, telephone, or fiber-optic cable. Typically delivers the broadband signal to a single computer or router via an Ethernet cable.



Gateway
Provides modem functionality plus one or more additional functions, such as Ethernet or Wi-Fi routing. A gateway that receives a broadband signal over a fiber-optic cable is called an optical network terminal (ONT). We exclude gateway devices with set-top box functionality in our discussion of network gateways. If a gateway has set-top box functionality, then we consider it a set-top box gateway.

A gateway or modem connects a household to the service provider via a coaxial, telephone, or fiber-optic cable.[6] Modems and gateways are often configured to work with a specific service provider. Most commonly, broadband access equipment uses a cable line or a digital subscriber line (DSL). Sometimes telephone companies run fiber-optic cable to the home and use an optical network terminal (ONT) to convert light pulses into electronic signals that devices within the home can understand. Most, if not all, residential ONTs have multiple functions, such as providing data, phone, and TV signals to devices in the home network, and therefore are classified as gateways. Although modems and gateways can be purchased directly at retail outlets such as Best Buy and Radio Shack, most consumers acquire them from their Internet service provider.

Local network equipment enables consumers to set up home networks consisting of multiple, connected edge devices such as desktop and laptop computers, printers, game consoles, tablets, and smart TVs. The most common local network devices are routers. There are also switches and wireless access points, though few homes have either. Switches are used in addition to a router to add more Ethernet edge devices than the router can support. Wireless access points are primarily used in commercial settings like airports to provide Wi-Fi access to wired networks. Most consumer access points serve as Wi-Fi range extenders by receiving a Wi-Fi signal and then amplifying and rebroadcasting it. Customers usually purchase local network devices through retail channels, but they sometimes lease equipment from service providers. While categorized as broadband access equipment in this report, gateways also perform functions offered by local network equipment. We use the following definitions for local network equipment:

Figure 2: Examples of Local Network Equipment

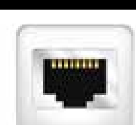
Router
Assigns an Internet Protocol (IP) address—a unique numerical label—to each device within a local network. The router then directs Internet traffic to these devices, such as computers and printers, and may send and receive data over an Ethernet cable or wireless connection.

Switch
Links multiple edge devices in the home and directs Internet traffic to their specific IP addresses. It is generally used to extend a network's range or increase the number of devices that can connect with each other in the network.

Access Point
Provides wireless network connectivity to multiple users as its primary function and does not have routing capability.

Small network equipment typically connects to other in-home devices via wireless antennas or Ethernet ports and cables:

Figure 3: Ethernet Ports and Cables



Ethernet Port
Enables Ethernet cable connection.

Ethernet Cable
Connects networked devices using the Ethernet protocol.

We define small network equipment as network devices with 11 or fewer ports.[7] Typically, modems, ONTs, and access points have one Ethernet port. Gateways, routers, and switches usually have multiple Ethernet ports.

III. POWER MEASUREMENT OF NETWORK DEVICES

TEST METHOD

To understand the power use of small network devices, NRDC worked with Ecova to measure the power draw of 60 network devices using a simplified version of the ENERGY STAR test method.[8] We tested equipment from all product classes, representing a wide range of energy efficiency levels, maximum data transfer rates, and features. We tested devices purchased in stores as well as those distributed by service providers. Where possible, we tested network devices in Ecova's research laboratory. In some cases we conducted field measurements. For example, we could not replicate Verizon's optical signal in our lab, so we tested these devices in a home where Verizon's service was available.

Ecova also tested a limited number of outdoor units (ODUs), the electronics and dish that enable a satellite TV provider to send pay-TV signals to a customer's premises. We did so by using the test method outlined in Appendix A.

RESULTS

Test data are listed in Appendix B and summarized in Figures 5 and 6.

Figure 4: Satellite TV outdoor unit (ODU)

Ecova also tested a limited number of outdoor units (ODUs), the electronics and dish that enable a satellite TV provider to send pay-TV signals to a customer's premises. We did so by using the test method outlined in Appendix A.

Figure 5: Power draw of small network equipment

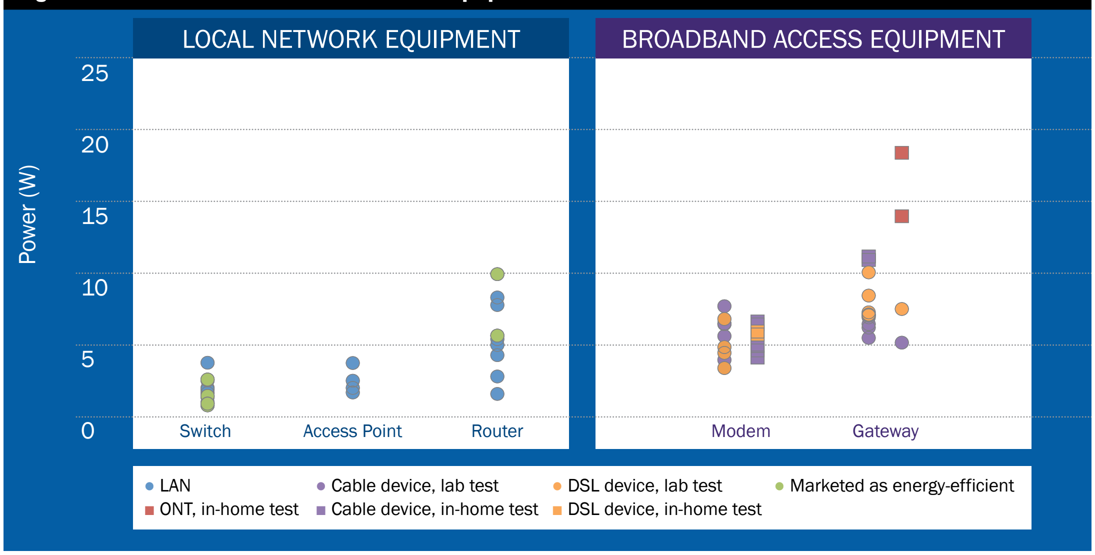


Figure 6: Range of energy use and average (white dot) for each product group

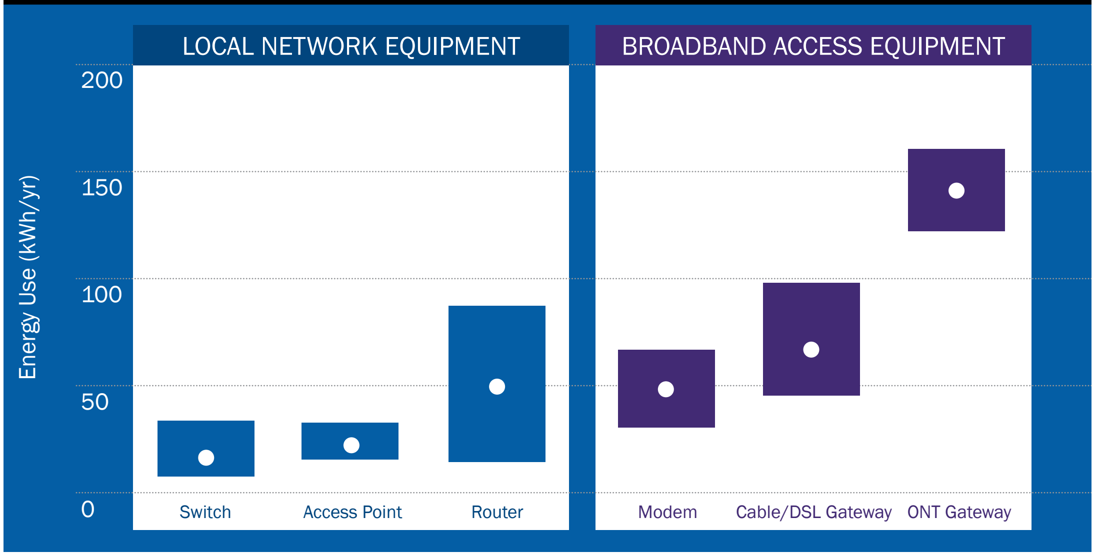
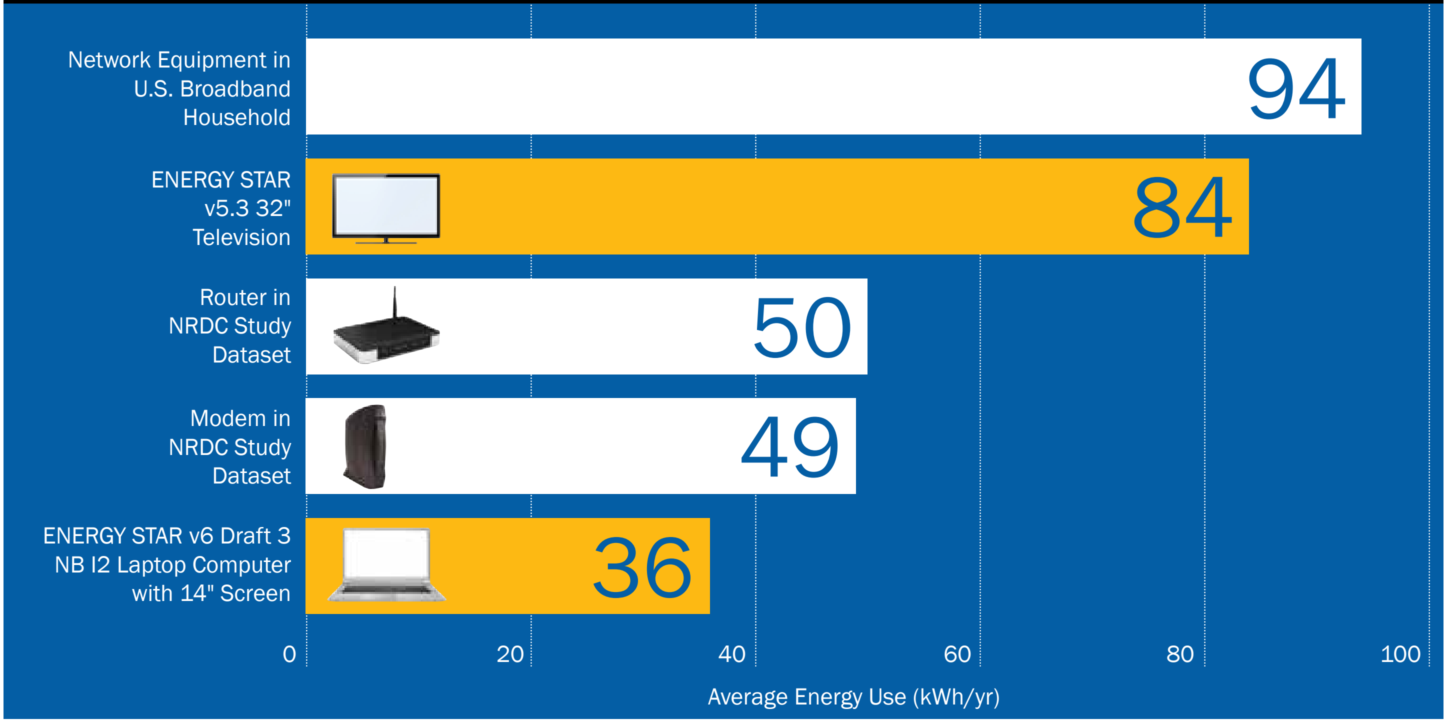


Figure 7: Household energy use—network equipment and other consumer electronics



Results and interpretation:

- Local network devices marketed as energy efficient generally draw the least power (Figure 5, green symbols). Some of these products adhere to the EEE standard, while others offer proprietary solutions, such as D-Link Green and TRENDnet GREENnet, as discussed in Section IV.
- In most but not all cases, it is more efficient to use a gateway with combined modem and routing functionality than to use separate modem and router devices (Figure 5).
- There are no significant differences between the average power draw of models purchased at the retail level and similar models leased by service providers.
- Differences in power between two service providers who use the same broadband device are insignificant (~0.2 watt; see Appendix B). However, we are aware that the energy consumption of a given cable set-top box model can differ by service provider because of differences in software. We recommend additional testing to definitively rule out this possibility in broadband equipment. Equipment manufacturers indicate that in the future there could be differences in energy use between service providers who use the same model gateway devices based on how they configure their power management.
- Limited observations suggest that ODUs powered by an external power supply draw a constant 5 to 9 watts throughout the day, resulting in energy consumption of 43 to 79 kWh per year in addition to the energy consumed by the set-top boxes.
- ODUs powered by a household's set-top box via coaxial cable scale power as the number of active load noise blocks (LNBs) within the ODU increases. Each LNB within the ODU serves a distinct group of channels, so increasing the number of channels tuned will increase the number of active LNBs until all are in use. Limited observations of this type of ODU showed that a five-LNB ODU powered by a set-top box drew about 1.25 watts when only one channel was tuned to a maximum of 6.25 watts when all LNBs were active.
- Of the device categories we tested, ONTs draw the most power at 14 to 18 watts, resulting in an annual energy consumption of 123 to 161 kWh per year (Figure 6). In addition to providing Internet and phone service, some of these devices receive video information for watching TV. They do not, however, replace the set-top box at each TV in the home. As with ODUs, subscribers often leave ONT devices connected to the exterior of the house even after they discontinue service. Consequently, the consumer could be paying almost $20 a year for wasted electricity.
- Most small network devices draw the same amount of power when sitting idle as they do when transmitting large amounts of data at a high rate.

Approximately 88 million households subscribe to high-speed Internet service in the United States. On average, each household operates two small network devices that collectively consume 94 kilowatt-hours (kWh) of electricity annually (Figure 7).

IV. NATIONAL ENERGY CONSUMPTION AND SAVINGS OPPORTUNITIES

NATIONAL ENERGY CONSUMPTION

The energy consumption of small network devices adds up. In 2012, small network equipment in U.S. homes consumed approximately 8.3 billion kWh of electricity, equivalent to the annual output of three large (500 MW) coal-fired power plants.[9,10] This resulted in 5 million metric tons of carbon dioxide emissions, or the equivalent annual tailpipe emissions of 1.1 million cars.[11,12] U.S. consumers spend $1 billion per year to power their small network equipment.[13] The annual national electricity use of today's small network equipment is nearly equal to the total use of all of the households in Silicon Valley, the high-tech capital of the world.[14] While this study does not quantify the energy consumption of commercial small network equipment, it also uses a significant amount of energy and adds to the savings potential that would be realized through the introduction of technologies and standards that increase the energy efficiency of network equipment.

We calculated the national energy consumption of residential small network equipment by:

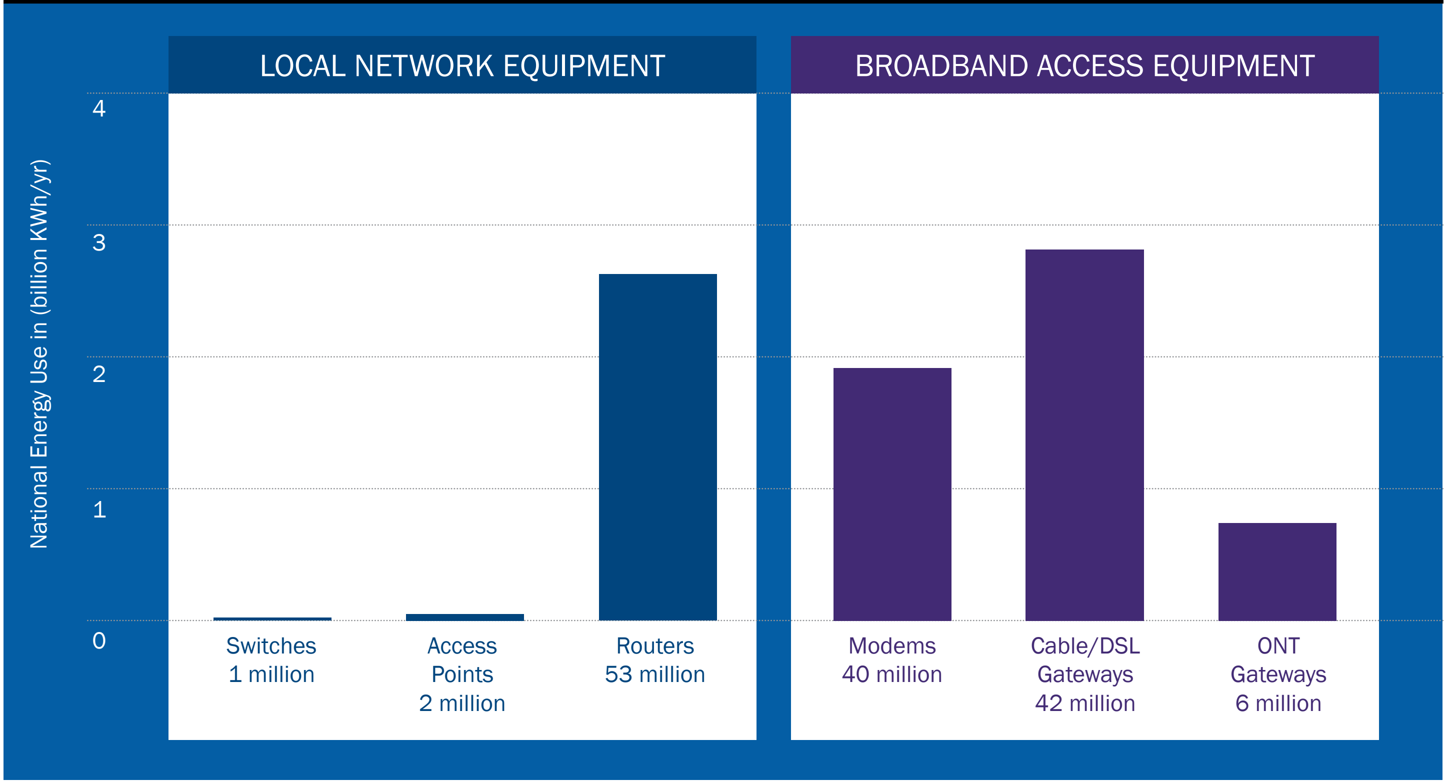
- converting power measurements to annual energy consumption values by assuming these devices spend 100 percent of their time as tested in idle mode;
- multiplying the average unit energy consumption by the estimated number of units for each category of network device, as shown in Table 1 and Figure 8; and
- summing the energy consumption across all six categories, as shown in Table 1.

Modems, routers, and gateways are the most common in-home network devices and account for most of the energy used by small network equipment in U.S. homes (Figure 7). U.S. households use few stand-alone switches, which enable consumers to add additional wired devices to their network, or wireless access points that add wireless access to a wired network or extend the range of a wireless network. Therefore, their contribution to total national energy consumption is low. A small but growing number of consumers connect to their service provider through ONTs, devices typically attached to the outside of the home which translate optical signals to electronic signals and vice versa for subscribers who have high speed fiber optic service (Verizon FiOS).

Table 1: Estimated energy consumption of U.S. residential small network equipment

Product Type	Average Power (W)	Average Unit Energy Consumption (kWh)	Units (millions)	National Energy Use (TWh)	Power Plants
Modems	5.7	50	40	2.0	0.7
Gateways	7.9	69	42	2.9	1.0
Routers	5.7	50	53	2.6	0.9
Switches	1.9	17	1	less than 0.1	0.0
Access Points	2.6	23	2	less than 0.1	0.0
ONTs	16.2	142	6	0.8	0.3
Total			**144**	**8.3**	**2.9**

Figure 8: U.S. energy use: residential small network equipment (U.S. residential stock is noted below each product category)



Note: Estimated number of small network devices in U.S. homes in 2012 based on an analysis of market data presented in: B. Urban, V. Tiefenbeck, and K. Roth, Energy Consumption of Consumer Electronics in U.S. Homes in 2010, Fraunhofer Center for Sustainable Energy Systems, final report to the Consumer Electronics Association, 2011.

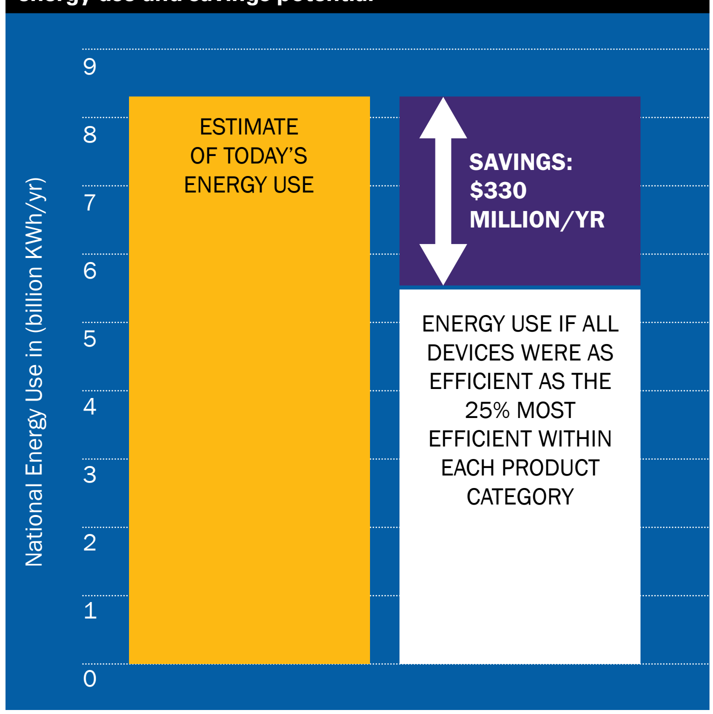
ENERGY SAVINGS POTENTIAL

It is evident from our test measurements that much of the variation in measured power levels within each of the six product categories we tested is due to variation in capabilities, as opposed to efficiency. For example, 1-gigabit-per-second network devices generally use more energy than their 100-megabit-per-second counterparts, and cable modems require more power than their Asymmetric Digital Subscriber Line (ADSL) counterparts.

To compensate for feature differences in our analysis, we use ENERGY STAR functional adders and base allowances to feature-normalize power levels. We find that the top quartile of small network devices on the market today use one-third less energy than average models. Some of the most efficient devices we tested save energy because they operate at lower power, while other devices achieve efficiency because they effectively scale power downward to adjust for little network traffic.

Replacing today's stock of inefficient residential small network equipment with efficient models could save 2.8 billion kWh of electricity per year, slashing consumers' energy bills by about $330 million (Figure 9).

Figure 9: U.S. residential small network equipment energy use and savings potential



Further, there is potential for even greater savings, given that industry is in the early phases of development and deployment of power-scaling devices. The two primary standards that enable network equipment power scaling are IEEE 802.3az Energy Efficient Ethernet (EEE) and IEEE 802.11e Automatic Power Save Delivery (APDS) for Wi-Fi devices. Few of the network devices that make up today's stock of residential network equipment have EEE or other energy efficiency technologies. None of the modems or ONTs we tested supported EEE. Of the 23 routers and gateways we tested, all of which were introduced between 2009 and 2012, only two supported EEE and only one supported TRENDnet's Wi-Fi power scaling technology, so the opportunity to capture additional savings by increasing market penetration of these capabilities appears to be large. Manufacturers report that EEE will be pervasive in the next few years. Furthermore, next-generation products with EEE should save even more than today's efficient models by scaling power in the whole device instead of only in individual ports.

ENERGY SAVING TECHNIQUES

Some of the most efficient devices we tested save energy because they operate at lower power than other products with similar features regardless of the throughput rate. Other devices made the most-efficient list because they scale power downward effectively when there is little network traffic. As mentioned above, power scaling methods include IEEE 802.3az Energy Efficient Ethernet (EEE) for Ethernet ports and IEEE 802.11e automatic power save delivery (APSD). Ratified in 2010, EEE enables Ethernet ports and system components to enter a sleep mode called Low Power Idle (LPI) in between data packets when transmitting at less than maximum data rate and when both ends of the network link have EEE enabled. EEE does this without impacting the performance of consumer computing applications. The industry expects near-term savings from first-generation EEE devices to be 5 to 20 percent of system power at low data rate. Next-generation network silicon—designed with power islands, voltage scaling, and other power-saving approaches—is expected to save up to 80 percent of system power.[15] These savings may more than offset the increase in power draw resulting from the shift to the faster data transfer rates coming to the market, which will require 1-gigabit-per-second Ethernet devices.

Wi-Fi power scaling technologies are emerging as well. One manufacturer, TRENDnet, has introduced a suite of energy-saving features, labeled Green Wi-Fi, that can reportedly save energy by enabling Wi-Fi routers to a) operate at reduced power when no Wi-Fi clients are connected, b) reduce their signal strength when connected clients are in close range, and c) enter a low-power state between data packets without affecting performance. TRENDnet reports its Green Wi-Fi products use 66 percent less power when unassociated with a Wi-Fi user and 53 percent less when connected but not transferring data.[16]

To benefit from EEE, the devices on both ends of an Ethernet connection, such as a router and a computer, must have EEE enabled. If an EEE-capable router is connected to one EEE-capable computer and another computer without EEE enabled, the router port connected to the EEE computer will scale power to use, and the port connected to the other PC will not scale power to use. Manufacturers enable EEE by default on most compliant network devices. However, EEE was not default-enabled on half of the EEE-capable computers we tested.[17] Moreover, it is difficult to find the software setting to enable it. We confirmed in our lab that network devices with EEE drew less power when transferring data with EEE enabled than it did with EEE disabled.

V. POLICY AND CONSUMER OPTIONS RECOMMENDATIONS

VOLUNTARY LABELING PROGRAMS AND MANDATORY STANDARDS

Unfortunately consumers are not easily able to tell when they are shopping for small network equipment which devices are the most efficient ones. This will soon change as the EPA finalizes an ENERGY STAR specification for small network devices that will help consumers identify those that use the least energy. The specification will also help them choose an Internet service provider that offers efficient home network equipment as part of its subscription packages.

ENERGY STAR does not currently require that devices meet the EEE standard. We encourage ENERGY STAR to make EEE a future requirement for both network equipment and connected devices, such as computers and printers. It should also ensure that its test procedures and program requirements reward Wi-Fi power scaling technologies.

State and federal policymakers should consider setting mandatory energy efficiency standards for small network equipment in order to eliminate the least efficient products from the market. These standards could require EEE compliance both for network equipment and for Ethernet edge devices.

International policymakers already recognize small network equipment as an important energy-saving opportunity. The European Union's Code of Conduct encourages broadband equipment with Ethernet interfaces to implement EEE and enable the technology by default.[18]

CONSUMER OPTIONS

Until EEE becomes an ENERGY STAR requirement, consumers should look for devices that are both ENERGY STAR qualified and EEE enabled to ensure that their devices are efficient and support edge device energy savings. Unfortunately, it will take the most conscientious of consumers to find these devices, as EEE equipment is typically identified only by an obscure "802.3az" marking on the package or in online specifications. Manufacturers such as TRENDnet and D-Link have EEE products on the market today (Figure 10).

Consumers can also reduce Wi-Fi transmit power on some wireless devices, can schedule times of day when Wi-Fi turns off, and can use timers to power down network devices overnight or during other periods of regular inactivity. However, network devices that support phone service tend to include battery backup to preserve phone service during power outages—most important, the ability to dial 911—so they should not be powered down without careful consideration.

Figure 10: Examples of low power, EEE-enabled devices on the market

TRENDnet REW-711BR router

D-Link DGS-108 switch

APPENDIX A: SAMPLING PLAN AND TEST METHOD

MODELS TESTED

Before selecting devices to test, we conducted a market survey of small network products offered in retail stores and distributed by service providers in the United States. Our goal was to select products commonly purchased by consumers or distributed by service providers. Within this group of products, we made our best effort to select devices that represented a wide range of energy efficiency and features such as maximum data transfer speed. Table 2 shows the number of products we tested in each category by test location: in situ in a subscriber's household, or in Ecova's lab.

Table 2: Small network equipment tested by Ecova

Product Category	Number tested in-home	Number tested in-lab	Total tested
Modem	7	9	16
Gateway	2	12	14
Optical Network Terminal	2	-	2
Router	-	9	9
Switch	-	11	11
Access Point	-	4	4
Outdoor Unit	4	-	4
Total	**15**	**45**	**60**

TESTING METHODOLOGY

We tested network devices in the lab where possible in order to ensure accuracy levels consistent with those required by the ENERGY STAR test method. For lab tests, we measured average power (P_{avg}) using a modified version of the ENERGY STAR Test Method for Small Network Equipment. The key difference between our test procedure and ENERGY STAR's is that we did not use a shielded box for wireless testing. We simply ensured that a nearby wireless client was connected over Wi-Fi.

For devices that we could not test in the lab, we conducted in-home tests without a calibrated power source or meter; therefore, it is likely that the accuracy of these test results is somewhat lower.

Our ODU test method depended on how the ODU was powered. There are two ways that ODUs typically are powered:

- An external power supply (EPS) provides power to the ODU, inserting it on the signal coaxial cable at some point between the set-top box (STB) and the ODU. In this arrangement, all of the electronics in the ODU are powered at all times.
- An STB provides power to the ODU via the coaxial cable. In this arrangement, the connected STB powers only the portions of the ODU electronics that are required for the channels that are being received.
- We tested these two types of ODUs using separate methods. For EPS-powered ODUs, a Kill A Watt® meter was installed between the outlet and the EPS, and power was observed in the following modes: with no STBs connected; with STBs connected but turned off; and with one, two, three, four, or more STBs connected and turned on, tuned first to ESPN High Definition and then Discovery High Definition, recording the power consumed in each configuration.

For STB-powered ODUs, Ecova made a DC power measurement in each of the coaxial cables supplying a five-LNB ODU powered via four coaxial cables. The total power delivered to the ODU via coaxial was measured with a channel selection such that one, two, three, and then five LNBs were active.

APPENDIX B: NRDC SMALL NETWORK EQUIPMENT TEST RESULTS

Notes:

1. The products sampled for this study represent a subset of popular models available on the market in mid-2011. We used simple average power values by product category to estimate the national energy consumption of small network equipment stock.
2. Products highlighted in blue represent products marketed with energy efficient features.

Product Class	Manufacturer	Model Number	Location of Test	Service Type	Service Provider	Power (W)			
						WAN Test	LAN Test	Wireless Test	ENERGY STAR average power
Router	Cisco	Linksys WRT54GL	Lab	-	-	-	4.6	4.2	4.4
Router	Mediabridge	Medialink MWN-WAPR150N	Lab	-	-	-	2.9	2.9	2.9
Router	TRENDnet	TEW-711BR	Lab	-	-	-	1.8	1.6	1.7
Router	D-Link	DIR-655	Lab	-	-	-	5.7	4.4	5.1
Router	Apple	Airport Extreme (5th Gen)	Lab	-	-	-	9.0	7.7	8.4
Router	Apple	Airport Extreme A1354	Lab	-	-	-	8.4	7.3	7.8
Router	Netgear	R6300-100NAS	Lab	-	-	-	10.4	9.6	10.0
Router	D-Link	DIR-665	Lab	-	-	-	6.4	5.0	5.7
Router	Netgear	WNDR3400	Lab	-	-	-	5.7	5.3	5.5
Switch	LevelOne	GSW-0807	Lab	-	-	-	0.9	-	0.9
Switch	TRENDnet	TE100-S50g	Lab	-	-	-	1.7	-	1.7
Switch	D-Link	DGS-108	Lab	-	-	-	1.0	-	1.0
Switch	TRENDnet	TPE-S44	Lab	-	-	-	3.8	-	3.8
Switch	TRENDnet	TE100-S5	Lab	-	-	-	2.1	-	2.1
Switch	NetGear	FS605	Lab	-	-	-	2.0	-	2.0
Switch	Cisco	Linksys SE1500	Lab	-	-	-	1.1	-	1.1
Switch	Cisco	Linksys SE2500	Lab	-	-	-	2.6	-	2.6
Switch	D-Link	DSS-8+	Lab	-	-	-	2.7	-	2.7
Switch	TRENDnet	TEG-S80G	Lab	-	-	-	1.5	-	1.5
Switch	D-Link	DGS-1008G	Lab	-	-	-	1.5	-	1.5
Access Point	NetGear	WN3000RP	Lab	-	-	-	-	2.6	2.6
Access Point	Apple Airport Express	MB321LL/A	Lab	-	-	-	-	3.8	3.8
Access Point	Diamond	WR300N	Lab	-	-	-	-	2.1	2.1
Access Point	Uspeed	AK-66UPWNWR-WU	Lab	-	-	-	-	1.8	1.8
Modem	Motorola	SB6121	Lab	Cable	-	6.5	-	-	6.5
Modem	Arris	WBM760A	Lab	Cable	-	5.7	-	-	5.7

Product Class	Manufacturer	Model Number	Location of Test	Service Type	Service Provider	Power (W)			
						WAN Test	LAN Test	Wireless Test	ENERGY STAR average power
Modem	Zoom	5241	Lab	Cable	-	7.8	-	-	7.8
Modem	Motorola	SB5100	Lab	Cable	-	6.6	-	-	6.6
Modem	Cisco	DPC3000	Lab	Cable	-	6.9	-	-	6.9
Modem	Zoom	ADSL 5715	Lab	DSL	-	4.0	-	-	4.0
Modem	ZyXEL	Prestiqe 660M	Lab	DSL	-	3.5	-	-	3.5
Modem	NETGEAR	DM111P	Lab	DSL	-	4.5	-	-	4.5
Modem	D-Link	DSL-2320B	Lab	DSL	-	4.9	-	-	4.9
Modem	Cisco	DPC3008	In-home	Cable	Comcast	6.7	-	-	6.7
Modem	uBee	U10C018.80	In-home	Cable	Charter Communica-tions	5.0	-	-	5.0
Modem	uBee	DOM3513	In-home	Cable	Comcast	6.5	-	-	6.5
Modem	RCA Digital Broadband	DCM425	In-home	Cable	Time Warner	4.2	-	-	4.2
Modem	uBee	U10C035	In-home	Cable	Comcast	6.0	-	-	6.0
Modem	Westell	6100	In-home	DSL	Verizon	4.7	-	-	4.7
Modem	Netopia	Cayman 3300 Series	In-home	DSL	CenturyTel	5.8	-	-	5.8
Gateway	NetGear	CG3000D	Lab	Cable	-	10.1	10.6	9.6	10.1
Gateway	Motorola	SBG6580	Lab	Cable	-	11.0	11.4	10.5	11.0
Gateway	ARRIS	TG862G/GT	Lab	Cable	-	7.0	7.3	6.6	7.0
Gateway	NetGear	CG814WG	Lab	Cable	-	7.4	7.4	7.2	7.3
Gateway	Cisco	DPR2320	Lab	Cable	-	5.5	-	5.7	5.6
Gateway	uBee	DDW2600	Lab	Cable	-	7.1	7.5	6.8	7.1
Gateway	Actiontec	Q2000	Lab	DSL	-	11.4	11.5	10.8	11.2
Gateway	Westell	VersaLink 7500	Lab	DSL	-	7.1	7.4	6.8	7.1
Gateway	CenturyLink	C1000A	Lab	DSL	-	8.4	8.9	8.1	8.5
Gateway	Actiontec	M1000, W1000	Lab	DSL	-	5.6	-	6.9	6.3
Gateway	2Wire	2Wire 2700HG-B	Lab	DSL	-	7.2	7.4	7.0	7.2
Gateway	Motorola	3347	Lab	DSL	-	6.4	6.7	6.4	6.5
Gateway	Arris	TM302G	In-home	Cable	RCN	5.3	5.4	5.0	5.2
Gateway	Netgear	CG814WG V2	In-home	Cable	Time Warner	7.6	7.8	7.3	7.6
ONT	Tellabs	ONT611	In-home	Fiber	Verizon/Frontier FiOS	14.0	-	-	14.0
ONT	Motorola	ONT1000GJ2	In-home	Fiber	Verizon	18.4	-	-	18.4

Endnotes

1 Environmental Protection Agency (EPA), *ENERGY STAR® Test Method for Small Network Equipment*, Final Draft, Rev. November 2012, energystar.gov/products/specs/sites/products/files/ES_SNE_Final_Draft_Test_Method_Nov2012.pdf.

2 Estimated number of small network devices in U.S. homes in 2012 based on an analysis of market data presented in: B. Urban, V. Tiefenbeck, and K. Roth, *Energy Consumption of Consumer Electronics in U.S. Homes in 2010*, Fraunhofer Center for Sustainable Energy Systems, final report to the Consumer Electronics Association, 2011.

3 We use the terms *small network devices* and *small network equipment* interchangeably to refer to equipment used to perform the networking function, as opposed to the edge devices—like tablets and notebooks—that enable user interaction with the network.

4 Lawrence Berkeley National Laboratory conducted a study of network equipment energy use, including case field studies of networks in a campus, a medium-size commercial building, and a typical home: S. Lanzisera, B. Nordman, and R.E. Brown, 2010. "Data Network Equipment Energy Use and Savings Potential in Buildings," *2010 ACEEE Summer Study on Energy Efficiency in Buildings*.

5 *EPA, ENERGY STAR® Program Requirements for Small Network Equipment*, draft 2, version 1.0, 2012, energystar.gov/products/specs/sites/products/files/ES_SNE_Draft_2%20_V1_Specification_Nov2012.pdf.

6 We did not test any set-top box gateways, which are capable of outputting audio and video signals as well as providing set-top box functionality.

7 EPA, *ENERGY STAR® Program Requirements for Small Network Equipment*, draft 2, version 1.0, 2012, energystar.gov/products/specs/sites/products/files/ES_SNE_Draft_2%20_V1_Specification_Nov2012.pdf.

8 EPA, *ENERGY STAR® Test Method for Small Network Equipment, final draft*, rev. November 2012, energystar.gov/products/specs/sites/products/files/ES_SNE_Final_Draft_Test_Method_Nov2012.pdf.

9 ODU energy consumption is not included in our estimates of national energy consumption or savings potential.

10 Coal-fired power plant figure is based on a unit of measurement called a Rosenfeld: the equivalent of displacing a 500 MW existing coal plant operating at a 70% capacity factor with 7% T&D losses. Displacing such a plant for one year would save 3 billion kWh/year at the meter and reduce emissions by 3 million metric tons of carbon dioxide per year as described in: J. Koomey et al., "Defining a Standard Metric for Electricity Savings," *Environmental Research Letters* 5, no. 1 (2010):014017, iopscience.iop.org/1748-9326/5/1/014017/.

11 Estimated carbon dioxide emissions from electricity consumption based on 0.6 metric ton of CO2 per MWh. Energy Information Administration, *2010 Summary Statistics*, Table 1, www.eia.doe.gov/cneaf/electricity/st_profiles/us.html. Note we use this emissions factor for electricity consumption, taking into account both baseload and non-baseload generation. We use a different emissions factor to estimate potential emissions reductions resulting from savings strategies.

12 Estimated number of equivalent cars based on 135,207 passenger vehicles per 1 billion kWh of electricity use. EPA, *Greenhouse Gas Equivalencies Calculator*, rev. April 2013, www.epa.gov/cleanenergy/energy-resources/calculator.html#results.

13 Assumes national residential electricity rate of 11.72 cents per kWh. U.S. Energy Information Administration, *Residential Average Monthly Bill by Census Division, and State 2011*, Table 5A, www.eia.gov/electricity/data.cfm#sales.

14 Total residential electricity use for San Mateo, Santa Clara, Santa Cruz, and Alameda counties was 9.3 billion kWh in 2011. California Energy Commission, *Energy Consumption Data Management System (ECDMS), Electricity Consumption by County*. 2012, ecdms.energy.ca.gov/elecbycounty.aspx.

15 Cisco/Intel, *IEEE 802.3az Energy Efficient Ethernet: Build Greener Networks*, 2011, www.cisco.com/en/US/prod/collateral/switches/ps5718/ps4324/white_paper_c11-676336.pdf.

16 TRENDnet, *TRENDnet Green Initiatives*, 2011, www.trendnet.com/downloads/GREENnet_Initiatives.pdf.

17 None of these computers were ENERGY STAR qualified.

18 EC, European Commission. 2013. *Code of Conduct on Energy Consumption of Broadband Equipment, Version 4.1*. Institute for Energy and Transport, Renewable Energy Unit. http://www.telecom.pt/NR/rdonlyres/523BB1DB-55C9-4929-BA8C-839648106B2D/1463116/CodeofConductBroadbandEquipmentV4_1final.pdf.

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