Network Equipment

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1 Executive Summary

The Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas (SCG), San Diego Gas & Electric (SDG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The CASE report submitted by PG&E, SCE, SCG and SDG&E (the California investor-owned utilities, herein referred to collectively as the "California IOUs") in July 2013 provides comprehensive technical, economic, market, and infrastructure information on potential appliance standards for small network equipment (CA IOUs 2013).

Since the submission of its CASE Report, the California IOUs conducted a market and technical review of small network equipment and large network equipment in response to the CEC's invitation to participate webinar on January 15, 2014. The key findings of that research are included in sections organized based on CEC's original invitation to participate questions included in its webinar. This report also includes additional sections for large network equipment that will be useful for this rulemaking.

In addition, the California IOUs are—as of this writing—conducting an engineering tear-down analysis of select residential small network equipment product classes. The overall objective of this work is to help inform the CEC's development of an energy efficiency standard for small network equipment by better understanding the cost-effectiveness implications of improved energy efficiency of small network equipment. This investigation is in direct response to the CEC's request for additional information on cost and cost-effectiveness of a potential standard for small network equipment. We anticipate the research will lead to: i) a better understanding of the component architecture of energy efficient small network equipment, ii) identification of key areas for energy efficiency improvement and iii) development of incremental cost estimates for select product classes investigated (i.e., routers and cable integrated access devices) in meeting the California IOU proposed standard (CA IOUs 2013). The results of this project are expected to be completed in summer 2014, and we look forward to sharing our findings with the CEC and other interested stakeholders.

In conclusion, the California IOUs maintain their recommendation that California adopt an energy efficiency standard for residentially-focused small network equipment. In addition, we support the CEC's efforts to obtain additional information on commercial network equipment and recommend that California adopt an energy efficiency standard for enterprise small network equipment and large network equipment. We also recommend CEC consider an energy efficiency standard for fixed wireless broadband access devices.[1] We recommend that the proposed standards take effect one year after adoption. The adoption of a small network equipment standard is a cost-effective means of helping California meet its long-term energy goals, climate initiatives and air quality guidelines. By adopting standards for commercial network equipment as well, California can achieve additional cost-effective energy savings on the behalf of its ratepayers.

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[1] A fixed wireless access device is defined as a mains power device that enables broadband access via a wireless data connection, such as cellular. An example is Wimax. This is not necessarily describing "hotspots," which may get broadband access with a wired connection.

2 Definitions & Scope

The California IOUs maintain their strong recommendation that California adopt an energy efficiency standard for residentially-focused small network equipment (SNE). In addition, we support the CEC's efforts to obtain additional information on commercial network equipment and recommend that California adopt an energy efficiency standard for enterprise small network equipment and large network equipment. We also recommend CEC consider an energy efficiency standard for fixed wireless broadband access devices.

The California IOUs recommend CEC divide network equipment into four primary categories:

1. Residential Small Network Equipment as define by ENERGY STAR
2. Enterprise Small Network Equipment
3. Large Network Equipment
4. Fixed Wireless Broadband Access Devices (residential small network equipment exempted by ENERGY STAR)

2.1 Residential Small Network Equipment

We recommend aligning with ENERGY STAR's Version 1.0 Small Network Equipment specification (EPA 2013a) on definition and scope for residential SNE: "Network equipment that is intended to serve users in either small networks or a subset of a large network. SNE includes a) all network equipment with integral wireless capability and b) other network equipment meeting all of the following criteria:

i. Designed for stationary operation;[2]
ii. Contains no more than eleven (11) wired Physical Network Ports;
iii. Primary configuration for operation outside of standard equipment racks;
iv. Meets the definition of one or more of the Product Types defined below.

2.1.1 Product types:

1. <u>Broadband Access Equipment</u>
    a. Broadband Modem: A device that transmits and receives digitally-modulated analog signals over a wired or optical network as its primary function. The Broadband Modem category does not include devices with integrated Router, Switch, or Access Point functionality.
    b. Integrated Access Device (IAD): A network device with a modem and one or more of the following functions: wired network routing, multi-port Ethernet switching and/or access point functionality.
    c. Optical Network Termination Device (ONT): A type of device that converts signals between copper (wired) or wireless connections and an optical fiber connection. ONTs are available in either desktop or building-mounted versions with different connectivity options.

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[2] Products that cannot operate while plugged in (i.e., they can only operate under battery power) cannot be tested by the ENERGY STAR SNE test procedure.

2. Local Network Equipment

    a. Access Point: A device that provides wireless network connectivity to multiple clients as its primary function. For the purposes of this specification, Access Points include devices providing only IEEE 802.11 (Wi-Fi) connectivity.

    b. Router: A network device that determines the optimal path along which network traffic should be forwarded as its primary function. Routers forward packets from one network to another based on network layer information. Devices fitting this definition may provide both Router functionality and wireless network capability.

    c. Switch: A network device that filters, forwards, and floods frames based on the destination address of each frame as its primary function. The switch operates at the data link layer of the OSI model.

2.2 Enterprise Small Network Equipment

In addition to the residential small network equipment product classes outlined above, there is also small network equipment with 11 or fewer ports that is designed to primarily serve small commercial markets. This equipment may be broadband access equipment or local network equipment, depending on functionality.

In general, Enterprise SNE, similar in size and port configuration to residential SNE, has highly secure wired and wireless connectivity, and is marketed separately to small offices, home offices, and remote workers. Increased performance and security also accompany a higher price point for enterprise network equipment, generally costing more than twice as much as comparable residential network equipment. Also, enterprise SNE is more likely to be Powered over Ethernet (PoE) and to not utilize an external power supply (EPS).

Technically. this equipment is distinguished from residential SNE based on one or more of the following characteristics:

i. Network equipment capable of accepting interchangeable modules, such as line cards or additional power supplies;
ii. Network equipment with one or more network ports using pluggable or modular media adapters such as Gigabit Interface Convertor (GBIC) or Small Form-factor Pluggable (SFP) modules. This does not include USB ports;
iii. Network equipment whose primary wireless capability is not IEEE 802.11 (Wi-Fi);
iv. Network equipment that receive direct dc power (PoE, USB) or provide power through PoE;
v. Network equipment that is marketed and sold as enterprise network equipment and can be controlled and configured for operation by an external controller.

2.3 Large Network Equipment

We recommend that a standard align with ENERGY STAR's Large Network Equipment framework document (EPA 2013c) on definition and scope for this product category: efficiency levels for fixed equipment and a reporting requirement for modular equipment.

Large Network Equipment (LNE): Network equipment (a device whose primary function is to pass Internet Protocol traffic among various network interfaces/ports) that is rack-mounted, intended for use in standard equipment racks, or contains more than eleven (11) wired Physical Network Ports.

2.3.1 Product Types:

i. Router: A network device that determines the optimal path along which network traffic should be forwarded. Routers forward packets from one network to another based on network layer information.

ii. Switch: A network device that filters, forwards, and floods frames based on the destination address of each frame. The switch operates at the data link layer of the OSI model.

iii. Security Appliance: A stand-alone network device whose primary function is to protect the network from unwanted traffic.

iv. Access Point Controller: A network device whose primary function is to manage wireless local area network (WLAN) traffic through one or more wireless access point devices.

2.3.2 Product Characteristics:

i. Fixed Network Equipment: A network device that consists of hardware which is mostly a single functional unit.

ii. Modular Network Equipment: A chassis which can accept a variety of functional units to enable networking services.

iii. Managed Network Equipment: A managed network device allows precise control over ports or groups of ports. Managed network equipment must meet the following criteria:

  a. can be configured with redundant power supplies; and

  b. includes a dedicated management controller

iv. Unmanaged Network Equipment: A network device that does not meet the managed network equipment criteria.

2.3.3 Scope:

Only fixed (both managed and unmanaged) routers and switches are under consideration for a specification in the preliminary ENERGY STAR framework (EPA 2013c), although security appliances and access point controllers are included for possible expansion of scope. Given a multi-stage approach that prioritizes easily implemented standards with a large energy savings potential, it is reasonable to prioritize switches and routers, because the two leading testing methodologies (ATIS and ECR) are well suited to these device types (Juniper 2013, ITI 2012) and because they represent the bulk of the savings potential among the LNE device types (Lanzisera 2011).

Security appliances in particular are a clear exemption because they are not amenable to test protocol comparable to that used for switches and routers and the energy savings potential is currently not significant. Security appliances represent 12% of network equipment overall and accounted for 0.4% of 2011 service provider network market revenue in 2011 (Lanzisera 2010, IBM 2013). Furthermore, only 1% of security appliances have the requisite number of ports to qualify as LNE (IBM 2013). On a technical level, security appliances do not have the same potential for dynamically reducing energy consumption with decreased utilization, they are more heterogeneous in the type of function they provide than switches and routers are, and there are not well-established test procedures for gauging the efficiency security appliances (IBM 2013, ITI 2012).

ENERGY STAR has proposed that modular LNE be subject to a *test-and-display* approach rather than a specification. Testing all of the distinct possible configurations of many models of modular LNE, especially large-scale modular equipment with heterogenous customizable hardware, could prove difficult, so a possible solution is to follow the approach that ATIS took with respect to modular LNE with its declared Telecommunications Energy Efficiency Ratio (TEER) and certified TEER metrics. Declared TEER adds together module-level tested power draw to give system efficiency for a configuration, whereas certified TEER is system level testing for a common configuration (Bolla, Bruschi, & Lombardo 2012).

Although ENERGY STAR has not provided definitions of the different functional layers at which LNE may operate within the network topology, this characteristic of LNE is a common method of classifying LNE and several industry stakeholders mentioned in their comments to ENERGY STAR on its preliminary framework that they would like to see LNE further classified into devices that typically operate at the access, aggregation, and core layers (Juniper 2013, IBM 2013, ITI 2012, TIA 2012). Although LNE with certain intrinsic chracteristics are more likely to be found at certain layers-for example, core layer devices tend to be much faster are most often modular routers (IBM 2013)-functional layer describes how a device is situated within the network topology and does not describe any features or characteristics inherent to the device (Lanzisera 2011). That is, any device could theoretically be connected at any functional layer of the network. We recommend that the CEC not complicate its classification system by attempting to define functional layer based on device characteristics. It is likely sufficient to follow ENERGY STAR's lead and test devices with either a full mesh topology or a dual-group partial mesh topology based on whether the device has fully equivalent ports or two classes of ports that support different levels of bandwidth (EPA 2013d, CSCI 2011 p.10). Similarly, we do not recommend that the CEC complicate its classification system by distinguishing between LNE intended for use in datacenters or in enterprise, but rather than standards focus on the observable performance of the LNE device.

2.4 Fixed Wireless Broadband Access Devices

Lastly, we recommend the CEC develop an efficiency standard for a group of products not currently covered by ENERGY STAR's Version 1.0 specification for small network equipment. Wireless broadband technologies like WiMAX enable internet service providers to serve both mobile clients and fixed wireless customers with broadband access speeds on par with ADSL (CA IOUs 2013). We define a fixed wireless broadband access device as a mains-powered device that enables broadband access via a wireless data connection (CA IOUs 2013).[3] Note that service provider satellite dishes are usually related to pay-TV access (e.g., DISH Network, DIRECTV) and not internet access—so they are considered of the scope of network equipment.

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[3] Mains-powered refers to a device that is plugged in, as opposed to exclusively battery powered.

2.5 What are the differences between indoor and outdoor equipment?

We researched the outdoor prevalence of access points and ONTs. Access points can be used in both indoor and outdoor settings. ONTs are usually installed on the exterior of a residence or commercial building; however, most exterior ONTs can be installed inside (DSLReports 2014). Outdoor equipment, such as outdoor rated access points, routers and ONTs, are built to withstand demanding environmental conditions, feature additional self-optimizing protocols to avoid RF interference, and utilize frequency band selection to maintain operation in mixed client environments (Cisco 2014c). In general, outdoor access points are more likely to have the following features in comparison to indoor equipment:

- Support for Power over Ethernet.
- Support for proprietary wireless bridging protocols that use frame aggregation schemes to make more efficient use of long range wireless point-to-point links.
- More access to low-level radio adjustments for the longer round-trip times of long-range links.

This means that the power draw is likely to be higher than for indoor equipment.

3 Data and Analysis

In the sections below, we include several data submissions and recommendations for the CEC's consideration, including information product functions and modes of operations, energy-saving technologies, market characteristics, and market competition for efficient products.

3.1 What are the relative shipment volumes?

3.1.1 Small Network Equipment

Sales and stock data presented in the California IOU CASE Report (CA IOUs 2013) provides a snapshot of estimated shipment volumes of small network equipment. The California IOU team obtained U.S. sales and sales forecast data for each residential SNE product class from Infonetics.

We look forward to reviewing any new information regarding residential small network equipment shipment volumes, as well as market data on commercial network equipment.

3.1.2 Large Network Equipment

Using U.S. stock estimates from Lansizera & Nordman 2010, a U.S. to California ratio of .13, a design life of 5 years, the CASE Team estimates annual shipments of approximately 11.5 million switches and 83 thousand routers in California. See Appendix B for more on stock estimates for each LNE subcategory(Lansizera & Nordman 2010).

3.2 Optical Network Termination Devices

Optical Network Termination devices (ONTs) are defined as follows: A modem or IAD that converts signals between an optical fiber connection and copper (wired) or wireless connections (EPA 2013a). ONTs are available in either desktop or building-mounted (EPA 2013a). Fiber to the home (FTTH) provides much higher data transfer speeds than DSL or cable service.

3.2.1 What are the shipment trends for these devices in the future?

Market growth of ONTs is expected to remain flat for the next several years, experiencing 0-1% CAGR through 2016. For more detail, see sales and stock data presented in the California IOU CASE Report (CA IOUs 2013).

3.2.2 When do they get installed, and when do they get removed?

When a consumer signs up for an optical network service, service providers install an ONT to serve residential or small business needs. However, deinstallation of ONTs is uncommon; if the consumer were to move or cancel their services, the ONT would stay installed as a piece of grid infrastructure (Verizon 2014). A variety of ONT models are available and are chosen depending on the following factors (DSLReports 2014):

- Residential or business install - 2 vs. 4 plain old telephone service (POTS) lines;
- Interior or exterior installation;
- Multiple dwelling unit (MDU);
- Gigabit passive optical network (GPON) or broadband passive optical network (BPON) equipped central office.

3.2.3 How frequently are backup battery supplies used and at what capacity?

Based on calls with service providers and internet research, residential ONTs typically feature battery backup supplies. There are a number of generic and name-brand batteries available on the market, such as the 12V 8Ah battery designed to replace batteries for Verizon Fios, Century Link and AT&T ONTs (GS Battery 2014). We do not have data whether enterprise ONTs use backup battery supplies.

3.2.1 What are the feature sets of ONTs? Are there differences between residential and commercial units?

Based on the 19 ONTs documented in the ENERGY STAR Draft 3 dataset (EPA 2013b), Tabl 1 shows the prevalence of associated feature sets. Based on online research of available products, we found that there are distinct features offered between residential and commercial units. For example, the Cisco ME 4600 Series ONT family of ONTs are designed for both residential and small business customers. The group of models have similar characteristics and functionality; however, the Cisco ME4624-ONT-RGW and ME4624-ONT-RGW-RF models have additional functionality for small business: dual POTS ports, four Fast Ethernet / Gigabit Ethernet ports, and additional Wi-Fi functionality (802.11 b/g/n 2.4GHz 2x2 MIMO) (Cisco 2014b).

Table 1. Feature Sets of ONTs in ENERGY STAR Draft 3 Dataset (EPA 2013b)

Feature	Percentage of products in dataset
4 Fast Ethernet Ports	11%
1 Gigabit Port	21%
4 Gigabit Ports	63%
Wi-Fi	21%
POTS	53%
EEE	0%
MIMO	0%

Note: 5% of devices had 2 gigabit ports.

3.3 Newly released performance data for ENERGY STAR qualified small network equipment indicate a trend towards energy efficiency

In the ENERGY STAR Small Network Equipment (SNE) certified product list, there are seven products certified as of this writing, including 6 routers and one integrated access device (IAD) classified as a very-high-bit-rate digital subscriber line (VDSL) product (EPA 2014). The calculated average power adjusted for functionality for the routers is 0.77 W (EPA 2014). In 2013, the Natural Resources Defense Council (NRDC) measured the power draw of 60 SNE models in the field and laboratory (NRDC 2013). The data from NRDC (2013) were submitted to EPA to inform their ENERGY STAR data set. The calculated average power adjusted for functionality for the routers in the ENERGY STAR data set (EPA 2013b) from May 2013 is 2.32 W—based on 62 routers. The routers in the certified product list tend to be newer, and also have lower adjusted power, indicating a natural trend towards energy efficiency.

3.4 Provide information and data regarding technology trends

3.4.1 Wi-Fi power scaling technologies

The California IOU CASE report provides preliminary information on Wi-Fi power scaling technologies: "IEEE 802.11ac, a recently ratified Wi-Fi standard targeted at providing a high quality media sharing experience within the home, delivers data rates measured in gigabits per second at lower power for equivalent data rates to 802.11n … Interviews with manufacturers indicate that silicon to support energy efficient Ethernet and Wi-Fi power scaling is expected to have significant market share in 2014, even in the absence of any mandatory efficiency standards" (CA IOUs 2013, pg. 18, 37).

In order to better understand Wi-Fi power scaling, we tested a battery-powered wireless router with expected power scaling capabilities. Though this battery-powered product has lower Wi-Fi data rate than the non-battery power products we are investigating in our on-going engineering tear-down project, the technology of Wi-Fi power scaling can be applied to non-battery power products. At a wireless data transfer rate of 0 kb per second, the power draw is 1.28 W. However, at the maximum data rate, the power draw is 1.35 W. While we were not able to isolate the power draw attributed to the Wi-Fi system, this shows significant energy savings potential associated with Wi-Fi power scaling.

3.4.2 Market penetration of Energy Efficient Ethernet

First ratified in 2010, IEEE 802.3az Energy Efficient Ethernet (EEE), is the primary means for achieving power scaling in devices with wired LAN functionality by allowing components to enter a sleep mode called low power idle (LPI) between packet transmission cycles. The near term savings from first generation EEE devices is estimated to be 5 to 20 percent of system power at low data rate and next generation network devices could possibly save up to 80 percent of system power (CA IOUs 2013). Table 2 shows data on the 200 products in the ENERGY STAR data set from May 2013 (EPA 2013b). 12% of these products have EEE. These products tend to have slightly more ports than the average. Because savings from EEE is per port, the total savings is greater if the device has more ports. In the current ENERGY STAR certified product list (EPA 2014), six out of seven certified devices have EEE as of this writing.

Table 2. Port and Energy Efficient Ethernet prevalence in ENERGY STAR Draft 3 Dataset (EPA 2013b)

Product type as disclosed	Number of products	Number of products with EEE	Percent of total devices with EEE	Average number of port(s) for all devices	Average number of port(s) of EEE devices
Access Point	20	7	35%	1	1
Cable Modem	8	-	0%	1	-
DSL Modem	6	-	0%	1	-
IAD ADSL	9	-	0%	4	-
IAD Cable	8	-	0%	4	-
IAD VDSL	8	1	13%	4	4
IAD/Gateway	1	-	0%	4	-
ONT	27	-	0%	4	-
Router	69	6	9%	4	5
Switch	44	9	21%	8	7
Total	**200**	**23**	**-**	**-**	**-**
Average	**-**	**-**	**12%**	**5**	**6**

3.4.3 Market trends towards the use of gateway devices

IADs—also known as gateway devices—are growing in popularity. Instead of standalone modems, service providers are more frequently supplying customers with a single IAD device that also incorporates Wi-Fi, Ethernet, and VoIP phone services (CA IOUs 2013). According to sales data in CA IOUs (2013), IADs experienced cumulative sales growth (CAGR) of 4% from 2009-2012, whereas non-IAD broadband product classes (modems, Optical Network Termination (ONT) devices) experienced declining cumulative sales growth of -7% during the same time period.

Figure 1 shows an example of marketing for a single IAD device designed for multiservice (i.e., multifunction) needs.

Figure 1 Example of IAD Device (Cisco 2014a)

Cisco IAD (Integrated Access Device)

The Cisco Integrated Access Device (IAD) has been designed for current and emerging multiservice needs of competitive local exchange carriers and other service providers. This series offers integration of data, toll-quality analog or digital voice, security and wireless services for customer premises equipment (CPE) solution.

3.5 Provide power supply Information

3.5.1 Percentage of products using external power supplies

Out of 31 small network equipment products tested in-lab for NRDC (2013), three utilize an internal power supply (IPS): one cable modem, one access point, and one IAD ADSL device (Table 3). Approximately 90% of corresponding products in the dataset tested in-lab operate using external power supplies (EPS).

Table 3 Products tested in lab from NRDC (2013) with Internal Power Supplies

Product type as disclosed	Number of products	Number of products with IPS	Percent of total devices with IPS
Access Point	5	1	20%
Cable Modem	4	1	25%
DSL Modem	4	-	-
IAD ADSL	3	1	33%
IAD Cable	6	-	-
Router	4	-	-
Switch	9	-	-
Total	**35**	**3**	-
Average	**-**	**-**	**12%**

3.5.2 Power supply sizing, max output relative to typical operation

Our testing indicates that many SNE EPSs are significantly oversized. In these cases, using a smaller EPS would typically be lower cost, smaller, and greater efficiency because the EPS would be operating at a more optimal loading point. There are concerns about durability if an EPS is run near its maximum capacity many hours per year. However, this can be addressed by designing the EPSs to operate at a lower temperature. Similar logic can be applied to internal power supplies if they are currently oversized.

3.5.3 Current efficiencies

Out of the 25 products we have tested that have EPSs, eight have level V and 17 have level IV EPSs. Depending on the device power requirement, the increase in efficiency moving from level IV to level V is about 5 to 10%. Furthermore, moving from level V to level VI is another 5 to 10% efficiency improvement. This indicates there is significant energy savings potential by switching the EPSs to level VI, the new U.S. Department of Energy (DOE) standard (best in class EPSs available in ~2012). Based on products available for purchase online, we found that a majority of enterprise SNE use EPSs—with some products using Power over Ethernet. Therefore, we expect significant EPS energy savings opportunities for enterprise SNE as well.

In addition, EPSs have long been regulated for energy efficiency, but IPSs have not. Therefore, we expect an even greater energy efficiency opportunity for the products with IPSs.

3.6 Energy Usage: Large Network Equipment

3.6.1 Test Methods

For Large Network Equipment (LNE), efficiency is widely accepted as the ratio of energy consumption to effective throughput, most commonly measured in W/Gbps (Kharitonov 2009, CSCI 2011). This ratio is measured in different circumstance for different purposes. For example, one might measure efficiency with half the ports active because this is a common real world occurance (Lanzisera 2010), in low throughput state because switches most often operate at low throughput (Lanzisera 2011), or at the maximum throughput because it is important that LNE be able to efficiently operate at peak utilization without overheating (Kharnitonov 2009).

Overall, the test methods outlined by ENERGY STAR in the Draft 1 Test Method (EPA 2013d) are a practical approach to assessing the energy consumption of the products in the LNE scope. The main focus of the ENERGY STAR test method is variable load testing that closely mimics the current industry standard for voluntary testing, (ATIS)-0600015.03.2013. For all LNE products in the scope, ENERGY STAR test procedures measure the power draw with all ports active in the Unit Under Test (UUT) at the following throughput levels:

- Maximum throughput
- 30% of maximum throughput
- 10% of maximum throughput
- 0.01% of maximum throughput

Maximum throughput is defined as in ATIS as the highest rate of traffic flow that can be directed successfully. The 10% and 30% levels are also derived from ATIS and ENERGY STAR has elected to test both levels for all LNE rather than choosing one or the other based on product class. The 0.01% level, or Very Low Utilization level (VLU), is a departure from the traditional full idle, but this approach recognizes the need for LNE to be continuously active and incentivizes power saving strategies at the realistic VLU level.

UUTs are also tested with half their ports active at the four throughput levels described above. Half-port testing is a vital aspect of the ENERGY STAR test method that deserves emulation, because this level of port utilization reflects how LNE are commonly connected in the real world (Lanzisera 2010) and because port utilization generally affects power draw of LNE more than data throughput (Lanzisera 2011).

ENERGY STAR has not defined a specific variable load efficiency metric for distilling the measured power data and throughput levels into a single number (EPA 2013d). Traditionaly, ATIS test methods are used to compute a Telecommunications Energy Efficiency Ratio (TEER) metric, which is the weighted average of the power draw at different levels of throughput divided by the weighted average of the tested throughput levels [W/Gbps] (Bolla, Bruschi, & Lombardo 2012). A variable load efficiency metric similar to TEER is the measure of efficiency most endorsed by industry (See ENERGY STAR Large Network Equipment 1.0 comment letters. If the CEC wishes to set a TEER-like standard, we recommend that ENERGY STAR's test methodology is used as a starting point and that the average ratio of power draw to throughput employs weightings that are representative of the average duty cycle for the product class in question. In line with ENERGY STAR's testing methodology, half-port testing should be included in a variable load efficiency metric, presumably in a separate metric designed to capture the UUT's efficiency when port utilization is more representative of real world conditions.

Other noteworthy aspects of the ENERGY STAR test method that deserve replication include:

- Devices are tested as-shipped instead of having energy-saving featues all turned on or off
- Devices with ports that support EEE are tested in connection with other EEE-enabled devices, which allows the EEE to demonstrate its energy-saving potential
- If devices have PoE, a separate test is run in which the power draw of the UUT is measured with PoE active at variable PoE loads (Maximum, 90%, 50%, and 20% PoE)

ENERGY STAR is also considering addressing specific features or capabilities, such as:

- Ability to power down unused ports
- Remote administration of ports individually
- Presence of variable speed fans
- Ability to scale power dynamically with the level of utilization
- Implementation of EEE (IEEE 802.3az)
- Ability to perform well at higher operating temperatures
- Ability of devices to provide nearly real-time system performance data to network for use by management systems.

Several industry stakeholders have expressed a preference for a whole-system measurement of efficiency (such as a variable load efficiency metric) over more reductionistic, component-level standards (Juniper 2013, ITI 2012, AT&T 2012). Focusing on the performance of components may complicate an LNE specification without ensuring the performance of the whole system (Juniper 2013, CSCI 2011). We recommend, where possible, to favor a whole system approach that incentivizes energy efficiency directly rather than incentivizing features or components that aim to promote efficiency. For example, it is important to incentivize LNE that can better to scale power draw dynamically to variable throughput. Theoretically LNE should be able to linearly scale power draw to throughput (Barroso 2007), but right now it falls far short of that potential (Lanzisera 2011). We recommend that this goal not be included as a separate requirement, but rather incentivized with a whole system variable load efficiency metric.

Although the preliminary ENERGY STAR test method is a strong foundation, there are issues that require further consideration. Devices that perform functions of both a switch and a router may require allowances for the extra energy that these additional features will use. Moroever, devices with features that promote energy savings beyond the scope of the device may deserve credits to fairly recognize their broader savings potential. For example, LNE with ports that support EEE save energy in any EEE-enabled devices to which they are connected (Lanzisera 2010); LNE with network presence proxying allow connected devices to go into sleep mode without losing connectivity (LBNL 2013); and devices with Power over Ethernet may be able to reduce whole system power by transferring power through Ethernet cable to where it is most needed (EPA 2013c, IBM 2013 comments, Cisco 2013).

3.6.2 Energy Use Per Unit

The CASE Team collected power draw and W/Gbps data via publicly available Miercom testing reports published for switches and routers between 2008 and 2013 (Miercom 2014). The data typically includes both lab results from the product tested and industry averages. See Appendix A for these data.[4]

3.6.3 Efficiency Measures

The most promising opportunities for increasing energy efficiency in LNE involve increasing the ability of LNE to dynamically adjust power draw to variable utilization. While it is theoretically possible for LNE to consume minimal power when throughput is low, LNE are not at all close to the theoretically linear relationship between utilization and power draw (Kharnitonov 2009, CSCI 2011). In fact, the vast majority of LNE energy consumption occurs without any throughput or port utilization (Lanzisera 2011). Technically feasible innovations that decrease power draw in response to decreased port utilization and/or decreased throughput can yield significant savings (Lanzisera 2010). For example, redesigning the switch fabric to scale capacity to port utilization, could reasonably achieve energy savings by 25% given commonly observed port utilization patterns (Lanzisera 2010).

EEE is an important efficiency measure specified by IEEE 802.3az that allows a LNE device to briefly enter a very low power state when not actively managing network traffic (Lanzisera 2010). Although EEE cannot save energy in LNE that are not connected to EEE-enabled devices, if both the LNE and the connected devices support EEE then both the LNE and the networked devices save energy, nearly doubling the savings on average (Lanzisera 2010). In 2010, it was estimated that the average LNE product capable of supporting gigabit Ethernet could save 12% of its energy use through EEE (Lanzisera 2010). Figure 2 below shows an example of the savings opportunity for one product —7% savings in idle mode — accordinging to Miercom laboratory testing.

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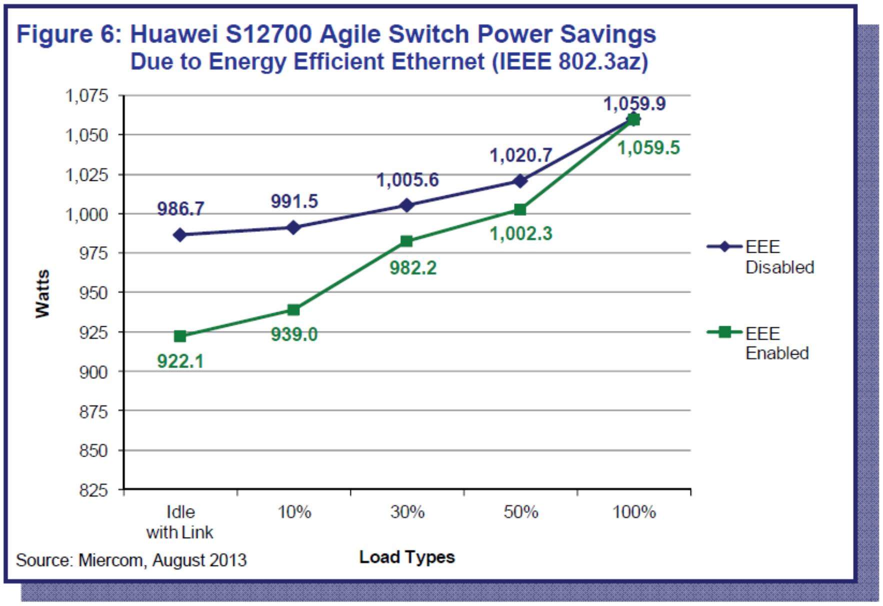
[4] Tolly Reports are also a potential source for these data, and can be found at http://www.tolly.com.

Figure 2 Example of EEE Savings Opportunity (Miercom 2014)



Source: Miercom, August 2013

The Huawei S12700 agile switch exhibits very low power consumption during fully loaded 384 x 1GE port tests. Additional energy savings was achieved when 802.3az Energy Efficient Ethernet setting was enabled on the switch. The switch exhibits lower power consumption than most switches in this class, even before the EEE savings feature was enabled.

If the CEC does decide to set standards on the component level, then internal power supply efficiency is a promising metric. In 2010, internal power supply efficiency was estimated at 70-80% based on manufacturer data (Lanzisera 2010). In an comment letter to ENERGY STAR, Cisco suggested that adherence to the 80 Plus Gold standard is becoming increasingly common in LNE (Cisco 2013). This standard requires approximately 90% efficiency, saving about 10% to 20% overall.

Other savings measures include port shutdown, machine hibernation and LED power saver mode, as demonstrated in a few units tested by Miercom (2014).

3.7 Energy Consumption and Efficiency Measures: Small Network Equipment

The California IOUs are—as of this writing—conducting an engineering tear-down analysis of select residential small network equipment product classes. The overall objective of this work is to help inform the CEC's development of an energy efficiency standard for small network equipment by better understanding the cost-effectiveness implications of improved energy efficiency of small network equipment. This investigation is in direct response to the CEC's request for additional information on cost and cost-effectiveness of a potential standard for small network equipment. We anticipate the research will lead to: i) a better understanding of the component architecture of energy efficient small network equipment, ii) identification of key areas for energy efficiency improvement and iii) development of incremental cost estimates for select product classes investigated (i.e., routers and cable IADs) in meeting the California IOU proposed standard (CA IOUs 2013). The results of this project are expected to be completed in summer 2014, and we look forward to sharing our findings with the CEC and other interested stakeholders.

After completing the engineering tear-down analysis, we plan to provide CEC with information on the following questions:

3.7.1 What causes one network device to consume less than the other?

3.7.2 Are there costs associated with those differences?

3.7.3 What are the pros/cons to product performance of efficient devices?

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Appendix A: Power Draw and W/Gbps Data

Product & Industry Avg. Power Draw

Product Type	Brand	Model #	Product Idle Power (W)	Product Power at 70% Load - Layer 2 Traffic (W)	Product Power at 100% Load - Layer 2 Traffic (W)	Industry Avg. Idle Power (W)	Industry Avg. Power at 70% Load - Layer 2 Traffic (W)	Industry Avg. Power at 100% Load - Layer 2 Traffic (W)
Aggregation Services Router	Cisco	ASR 1006	380	400	410			
Integrated Services Router	Cisco	1941 W	31					
Integrated Services Router	Cisco	2911	49	68	68			
Integrated Services Router	Cisco	2951	58	77	77			
Integrated Services Router	Cisco	3945	91					
Switch	Cisco	Catalyst - C2960S-48TS-L	46	48	48			
Switch	Cisco	Catalyst - C3560X-48T-S	119	124	125			
Switch	Cisco	Catalyst - C3750X-48T-S	125	127	128			
Switch	Cisco	WS-C2960X-48TD-L	27	45	45			
Switch	CIsco	WS-C2960XR-48TD-I	29	44	44			
Switch	HP	Procurve Switch 8212zl	447	515	517	569	880	1203
Switch	HP	Procurve Switch 5406zl	283	313	314	401	616	847
Switch	HP	Procurve Switch 2610-48	35	38	38	45	66	90
Switch	HP	Procurve Switch 2510-48	103	107	108	104	143	194
Switch	HP	Procurve Switch 6600-24G-4XG	181	191	194	185	192	254
Switch	HP	Procurve Switch 6600-24XG	302	340	345	238	347	461
Switch	HP	Procurve Switch 3500yl-48G	179	243	248	208	324	391
Switch (LED Power Saver Mode On)	HP	Procurve Switch 1810G-8	7	7	7	12	12	12
Switch (LED Power Saver Mode Off)	HP	Procurve Switch 1810G-8	8	8	8			
Switch (LED Power Saver Mode On)	HP	Procurve Switch 1810G-24	20	21	21	33	35	35
Switch (LED Power Saver Mode Off)	HP	Procurve Switch 1810G-24	21	22	22			
Switch	HP	Procurve Switch 2520G-8-PoE	15	15	15	18	19	19
Switch	HP	Procurve Switch 2520G-24-PoE	33	33	34	47	48	48
Switch	HP	Procurve Switch 2520-8-PoE	13	14	14	15	16	16
Switch	HP	Procurve Switch 2520-24-PoE	30	30	30	42	43	43
Switch	HP	A5820-24XG	158	160	161			288
Switch	HP	A5800-24G-PoE	99	100	100			118
Switch	HP	A5800-24XG	117	118	119			148
Switch	HP	A5800-48G-PoE	147	149	150			160
Switch	HP	A7506	846	884	890	931	973	1141
Switch	HP	A12508	2546	2779	2842			
Switch	HP	E4800-24G	104	107	109	110	136	176
Switch	HP	E4800-48G	59	60	61	67	75	84
Switch	HP	V1910-48G	59	61	62	70	79	80
Switch	HP	A5120-48G SI	59	61	62			
Switch	HP	E2620-24	13	21	21			
Switch	HP	E2620-24 PPoE+	22	30	30			
Switch	HP	E2620-24 PoE+	24	32	32			
Switch	HP	E2620-48	20	33	33			
Switch	HP	E2620-48 PoE+	30	39	39			
Switch	HP	2920-48G	44	70	72			
Switch	HP	2530-48G	23	50	51			
Switch	Huawei	S5700-LI Series-52P-LI	25	35	40			
Switch	Huawei	S12700			987			1060

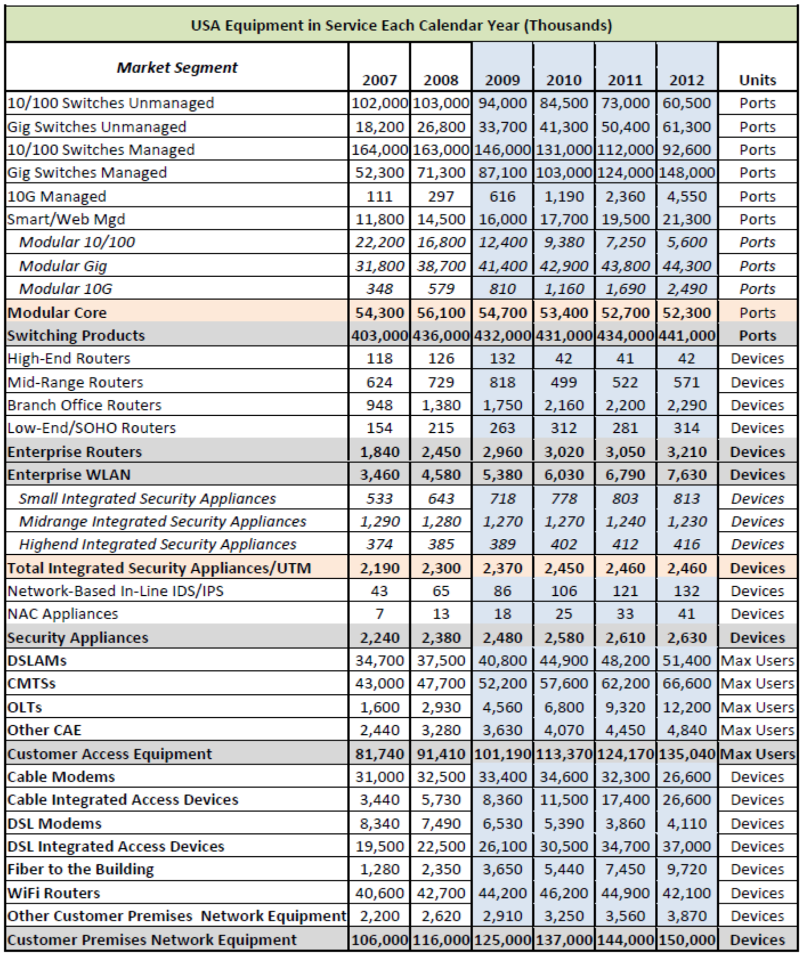
Source: Miercom 2014

Product & Industry Avg. Watts/GB

			Product				Industry Avg.			
Product Type	**Brand**	**Model #**	**Watts/GB (Jumbo Frames - 9208 bytes)**	**Watts/GB (Large Size Frames - 1508 bytes)**	**Watts/GB (Medium Size Frames - 512 bytes)**	**Watts/GB (Small Size Frames - 64 bytes)**	**Watts/GB (Jumbo Frames - 9208 bytes)**	**Watts/GB (Large Size Frames - 1508 bytes)**	**Watts/GB (Medium Size Frames - 512 bytes)**	**Watts/GB (Small Size Frames - 64 bytes)**
Aggregation Services Router	Cisco	ASR 1006								
Integrated Services Router	Cisco	1941 W		37.9						
Integrated Services Router	Cisco	2911		49.0						
Integrated Services Router	Cisco	2951		45.0						
Integrated Services Router	Cisco	3945		84.9						
Switch	Cisco	Catalyst - C2960S-48TS-L		0.9				3.0		
Switch	Cisco	Catalyst - C3560X-48T-S		2.4				3.0		
Switch	Cisco	Catalyst - C3750X-48T-S		1.9				3.0		
Switch	Cisco	WS-C2960X-48TD-L		0.7				1.5		
Switch	CIsco	WS-C2960XR-48TD-I		0.7				1.5		
Switch	HP	Procurve Switch 8212zl		1.6	1.6	2.2		3.5	3.6	4.7
Switch	HP	Procurve Switch 5406zl		1.9	1.9	2.6		4.6	4.7	6.1
Switch	HP	Procurve Switch 2610-48		9.6	9.9	12.6		14.4	14.8	18.6
Switch	HP	Procurve Switch 2510-48		2.3	2.3	2.9		4.1	4.2	5.3
Switch	HP	Procurve Switch 6600-24G-4XG		3.7	3.8	5.0		4.3	4.4	5.7
Switch	HP	Procurve Switch 6600-24XG		2.0	2.0	2.8		2.3	2.3	3.0
Switch	HP	Procurve Switch 3500yl-48G		3.9	4.1	5.3		6.4	7.1	9.1
Switch (LED Power Saver Mode On)	HP	Procurve Switch 1810G-8		0.5				0.8		
Switch (LED Power Saver Mode Off)	HP	Procurve Switch 1810G-8								
Switch (LED Power Saver Mode On)	HP	Procurve Switch 1810G-24		0.4				0.7		
Switch (LED Power Saver Mode Off)	HP	Procurve Switch 1810G-24								
Switch	HP	Procurve Switch 2520G-8-PoE		0.8				1.0		
Switch	HP	Procurve Switch 2520G-24-PoE		0.7				1.0		
Switch	HP	Procurve Switch 2520-8-PoE		2.5				2.9		
Switch	HP	Procurve Switch 2520-24-PoE		2.3				3.4		
Switch	HP	A5820-24XG	0.7					1.2		
Switch	HP	A5800-24G-PoE	1.6					1.9		
Switch	HP	A5800-24XG	1.3					1.7		
Switch	HP	A5800-48G-PoE	1.7					1.8		
Switch	HP	A7506		3.0	3.5	4.1		4.0	4.3	5.2
Switch	HP	A12508	4.3	4.4	4.5	5.7				
Switch	HP	E4800-24G		2.5	2.6	3.3		3.5	3.6	4.5
Switch	HP	E4800-48G		2.2	2.5	2.9		3.7	3.8	4.8
Switch	HP	V1910-48G	1.2				1.5			
Switch	HP	A5120-48G SI	1.2				1.5			
Switch	HP	E2620-24		3.4				5.1		
Switch	HP	E2620-24 PPoE+		5.1				9.0		
Switch	HP	E2620-24 PoE+		4.7				7.3		
Switch	HP	E2620-48		3.7				5.8		
Switch	HP	E2620-48 PoE+		4.5				8.1		
Switch	HP	2920-48G								
Switch	HP	2530-48G		1.0				3.4		
Switch	Huawei	S5700-LI Series-52P-LI		0.8				5.7		
Switch	Huawei	S12700								

Source: Miercom 2014

Appendix B: Stock Estimates



USA Equipment in Service Each Calendar Year (Thousands)

Market Segment	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Units**
10/100 Switches Unmanaged	102,000	103,000	94,000	84,500	73,000	60,500	Ports
Gig Switches Unmanaged	18,200	26,800	33,700	41,300	50,400	61,300	Ports
10/100 Switches Managed	164,000	163,000	146,000	131,000	112,000	92,600	Ports
Gig Switches Managed	52,300	71,300	87,100	103,000	124,000	148,000	Ports
10G Managed	111	297	616	1,190	2,360	4,550	Ports
Smart/Web Mgd	11,800	14,500	16,000	17,700	19,500	21,300	Ports
Modular 10/100	*22,200*	*16,800*	*12,400*	*9,380*	*7,250*	*5,600*	*Ports*
Modular Gig	*31,800*	*38,700*	*41,400*	*42,900*	*43,800*	*44,300*	*Ports*
Modular 10G	*348*	*579*	*810*	*1,160*	*1,690*	*2,490*	*Ports*
Modular Core	**54,300**	**56,100**	**54,700**	**53,400**	**52,700**	**52,300**	Ports
Switching Products	**403,000**	**436,000**	**432,000**	**431,000**	**434,000**	**441,000**	**Ports**
High-End Routers	118	126	132	42	41	42	Devices
Mid-Range Routers	624	729	818	499	522	571	Devices
Branch Office Routers	948	1,380	1,750	2,160	2,200	2,290	Devices
Low-End/SOHO Routers	154	215	263	312	281	314	Devices
Enterprise Routers	**1,840**	**2,450**	**2,960**	**3,020**	**3,050**	**3,210**	**Devices**
Enterprise WLAN	**3,460**	**4,580**	**5,380**	**6,030**	**6,790**	**7,630**	**Devices**
Small Integrated Security Appliances	*533*	*643*	*718*	*778*	*803*	*813*	*Devices*
Midrange Integrated Security Appliances	*1,290*	*1,280*	*1,270*	*1,270*	*1,240*	*1,230*	*Devices*
Highend Integrated Security Appliances	*374*	*385*	*389*	*402*	*412*	*416*	*Devices*
Total Integrated Security Appliances/UTM	**2,190**	**2,300**	**2,370**	**2,450**	**2,460**	**2,460**	**Devices**
Network-Based In-Line IDS/IPS	43	65	86	106	121	132	Devices
NAC Appliances	7	13	18	25	33	41	Devices
Security Appliances	**2,240**	**2,380**	**2,480**	**2,580**	**2,610**	**2,630**	**Devices**
DSLAMs	34,700	37,500	40,800	44,900	48,200	51,400	Max Users
CMTSs	43,000	47,700	52,200	57,600	62,200	66,600	Max Users
OLTs	1,600	2,930	4,560	6,800	9,320	12,200	Max Users
Other CAE	2,440	3,280	3,630	4,070	4,450	4,840	Max Users
Customer Access Equipment	**81,740**	**91,410**	**101,190**	**113,370**	**124,170**	**135,040**	**Max Users**
Cable Modems	31,000	32,500	33,400	34,600	32,300	26,600	Devices
Cable Integrated Access Devices	3,440	5,730	8,360	11,500	17,400	26,600	Devices
DSL Modems	8,340	7,490	6,530	5,390	3,860	4,110	Devices
DSL Integrated Access Devices	19,500	22,500	26,100	30,500	34,700	37,000	Devices
Fiber to the Building	1,280	2,350	3,650	5,440	7,450	9,720	Devices
WiFi Routers	40,600	42,700	44,200	46,200	44,900	42,100	Devices
Other Customer Premises Network Equipment	2,200	2,620	2,910	3,250	3,560	3,870	Devices
Customer Premises Network Equipment	**106,000**	**116,000**	**125,000**	**137,000**	**144,000**	**150,000**	**Devices**

Source: Lanzisera and Nordman 2010a