Energy efficiency policy for small network equipment

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Kewords

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Abstract

Energy consumption of small network equipment (SNE) continues to grow as more products are connected to the Internet and use more data-demanding services such as video download and gaming. Previous studies estimate global SNE energy consumption of 179 TWh in 2020, increasing to 215 TWh in 2030. Much of this energy consumption could be avoided; researchers estimate that efficiency improvements – especially power scaling – could decrease energy consumption of SNE by 20 to 50 %. Current energy reduction efforts for SNE, however, are scarce and mostly of a voluntary, industry-led nature, such as the SNE Voluntary Agreements in the US and Canada or the Broadband Code of Conduct in the EU. These approaches are complex and tend to follow business as usual instead of driving innovation.

This paper explores options for mandatory energy efficiency measures, such as minimum efficiency requirements or energy labelling, for SNE based on a functional approach. Our analysis of SNE power data shows that products with similar functions can differ in power consumption, indicating that efficiency improvements exist. In addition, the analysis provides insight into the impact of various components (functions) on product power draw and builds a model to establish a reference value for the power consumption. An energy efficiency index (EEI) is then based on the reference value and can be used to set minimum requirements through ecodesign and an energy label. The minimum requirements assure that the least efficient products are banned from the market, while the energy label, through public procurement and green taxonomy, will stimulate the uptake of the most efficient products.

Introduction

Small network equipment (SNE) is network equipment used in residential and small commercial applications. It comprises a broad range of products whose main purpose is to pass data traffic within a network and in some cases provide that network (Harrington and Nordman 2014). In most use cases, SNE connects a home or small business to the Internet and moves data within the local area network (LAN). As more products are connected to the Internet and use more data-demanding services (e.g., video streaming or online gaming), energy consumption of SNE continues to grow. Previous studies estimate global SNE energy consumption of 179 TWh in 2020, increasing to 215 TWh in 2030 (Ryan et al. 2021).

Product efficiency policies, such as minimum energy performance standards (MEPS) and energy labelling, result in large energy savings, a lower cost of ownership for end-users and drive innovation (Harrington and Waide 2021). Information and communication technology (ICT) products such as SNE, however, have a reputation of being hard to regulate because they are more technically complex and evolve more rapidly compared to other products that have been successfully regulated, like appliances. Current approaches for reducing SNE energy use are scarce and mostly of a voluntary and industry-led, rather than mandatory, nature. These approaches include the EU Broadband Code of Conduct (Bertoldi and Lejeune 2020) and the SNE Voluntary Agreements (VAs) in the U.S. and Canada (Voluntary Agreement 2020). They are technically complex – the EU Broadband Code of Conduct uses over 100 subcategories and allowances for SNE, for example – and appear to fall short on saving energy by following business as usual product offerings rather than driving innovative, energy saving products to the market.

One reason often cited for the lack of progress on reducing SNE energy use is that manufacturers do not have an incentive to design efficient products. Incentives can come in various forms, but government regulation or policy have been be highly effective for other product types (Harrington and Waide 2021). This paper presents a policy approach that can accommodate the technical and market characteristics of SNE devices and achieve the desired policy aims, such as reducing energy consumption. First, we provide an overview and categorization of SNE devices. Next, we analyse SNE power consumption using a functional approach, and review energy savings opportunities. We then use the results of the analysis to define an Energy Efficiency Index (EEI) which can be used to set minimum requirements and energy label classes. We end with conclusions and recommendations.

Overview and categorization of SNE devices

FUNCTIONAL CATEGORIZATION

An SNE device provides one or both of two main functions: (1) receiving and sending data from or to an external wide area network (WAN, e.g., the Internet or the cloud) and (2) receiving and transmitting data within a LAN to end user products such as computers, appliances, or mobile devices. Broadband access equipment provides the first function and has a modem as the defining function: receiving and demodulating analogue signals from, and modulating and sending signals to the broadband service provider network. SNE that performs only this function are modems. SNE that provide additional functions, such as telephone interfaces or LAN-related functions, are referred to as integrated access devices (IADs).

LAN equipment provides the second function and includes SNE devices that do not have a direct interface to a service provider. Rather, the defining function of these products is to move traffic between products within a LAN. Common LAN equipment includes routers, access points, and switches, and newer-to-market equipment such as Wi-Fi mesh systems (multi-component products that improve Wi-Fi coverage by establishing and maintaining a mesh network), and smart home or IoT gateways (a type of proprietary LAN equipment that connects consumer end products like light bulbs or home security systems to the LAN). LAN equipment is segmented by how it moves data on the LAN and the associated sophistication of the device. These categories are related to the functional layers on which products operate within OSI model network topology. Processing requirements (and therefore, in theory, power requirements) increase with layer (Stobbe and Berwald 2019). Table 1 summarizes the function-based SNE categorization (Dayem and Mercier 2021).

This approach is similar to other classification schemes for SNE. The SNE VA in the U.S., for example, splits LAN equipment into two categories based on a similar criterion: "basic" products with low data processing needs that operate on OSI model layer 1, and "advanced" products that include routers, access points, and VoIP-capable devices associated with OSI model layers 2 and up (Voluntary Agreement 2020).

SNE products can provide additional functions that are not directly related to moving data on a WAN or LAN. For example, a recent addition to the market are products that incorporate SNE functionality into other product form factors, such as an LED bulb with an integrated access point. These products possess components that provide network functions, as well as additional components to provide the non-network functions. The LED bulb with access point example would contain a wireless network interface to provide its network functions and an LED and LED driver to provide the lighting function. In these types of products, components may be dedicated to a certain function, such as a dedicated network processor, or shared by functions, such as power supply. These multi-function products are not the focus of the discussion in this paper, but the analysis and policy approach below applies to their network functions and related components.

CATEGORIZATION BASED ON POWER CONSUMPTION

To develop energy efficiency measures for SNE devices, the relation between the product functions and the power or energy consumption needs to be assessed. Any variation in a function that does not (significantly) impact power consumption can be ignored when setting efficiency targets or energy class limits. In general, three types of characteristics can be distinguished that likely influence the power consumption of SNE devices (Figure 1).

Table 1. Function-based SNE categorization.

Type	Category	Function	Product Examples
Broadband Access Equipment	Modem	Receiving/sending and demodulating/modulating analog signals from/to the broadband service provider network	Modem
	IAD	Modem plus additional function(s)	Home gateway Modem-router
LAN Equipment	Level 1	Transmit bits	Hub Range extender
	Level 2	Transport frames containing physical addressing	Some switches Access point Bridge
	Level 3	Transport packets containing IP addresses	Router Some switches
	Level 4+	Security or other advanced functions	Firewall

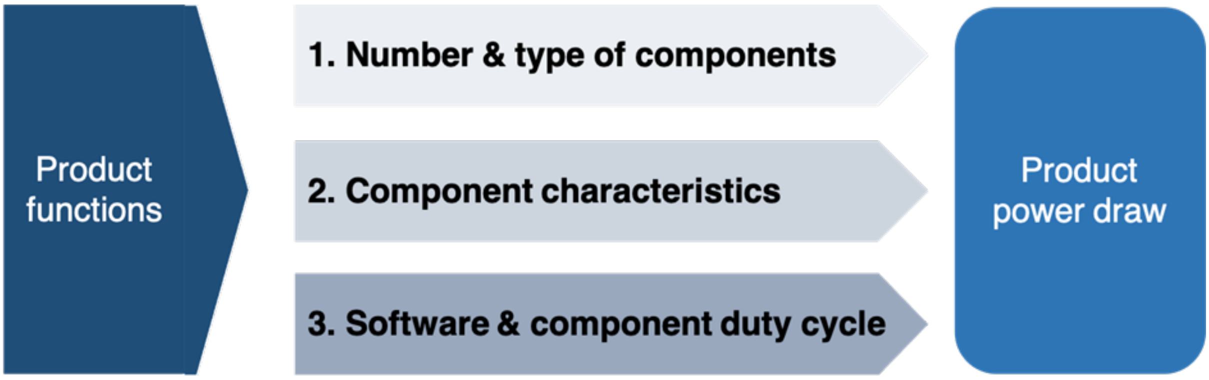


Figure 1. Component characteristics that impact SNE device power consumption. Source: Dayem and Mercier (2021).

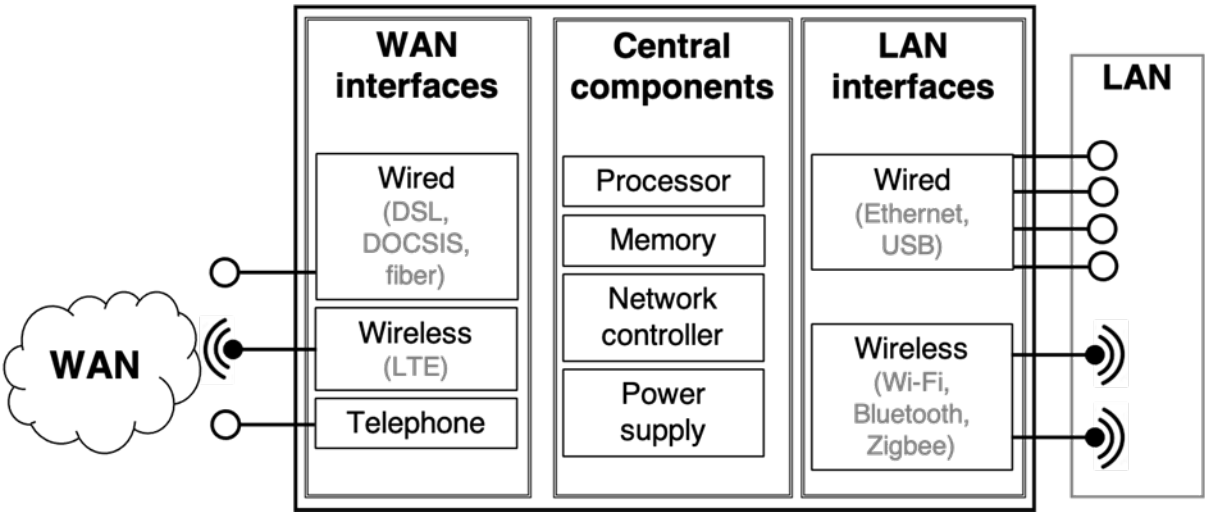


Figure 2. Main components in SNE products; adapted from Stobbe and Berwald (2019).

Number and type of components

A product's functions determine the number and type of components needed. Below follows a short discussion on the main components, based on Stobbe and Berwald (2019) and illustrated in Figure 2. All broadband access equipment (modems and IADs) contain at least one WAN interface, which is a physical connection point that provides access to the Internet service provider's wired, wireless, or optical broadband network using an appropriate communication protocol. The type of WAN interface used in a product depends on the data transmission medium. DSL and DOCSIS interfaces transmit data over phone lines and coaxial cables respectively; optical network interfaces transmit data over fibre optic cables; cellular interfaces (LTE) enable wireless broadband access.

All LAN and broadband access equipment contain one or more LAN interfaces, which are physical connection points that allow end user devices such as computers, printers or televisions within a building to connect to one another and share data. LAN equipment and IADs may have multiple wired (e.g., Ethernet or USB) and wireless LAN interfaces (e.g., Wi-Fi, Bluetooth, Zigbee). A product with more LAN interfaces in use will draw more power.

WAN and LAN interfaces – collectively referred to as network interfaces – are designed to transmit data using a network protocol: a set of rules that determines the format, speed, and other properties of the data transferred. These factors can impact SNE power requirements; faster and more complex data transfer may require more power. Wireless data transfer generally requires more power than wired transfer. New versions of a network protocol are progressively added to enable improvements such as faster data rates or improved security.

SNE devices also require central components such as processors, network controllers, memory, and power supplies, to provide supporting functions. The capability or capacity of the central components is determined in part by the network functionality. A more function-rich product will include more processing and memory capacity than a simple product, for example, and, all other things being equal, draw more power.

Component characteristics

Key characteristics of components influence functionality and, likely, the power draw of products. Focusing on network interfaces, such characteristics include bandwidth (the maximum data transfer rate of an interface) and network protocol. For wireless interfaces, transmit power and the number of antennas are also important characteristics. Products with higher bandwidth, greater transmit power, and more antennas will, in theory, draw more power. Wired types of interfaces, which move data along a cable, should draw less power than most wireless interfaces, which require power to broadcast signals over an acceptable distance like within a house. Other characteristics are inherent to the component itself, such as its efficiency in delivering its function.

Software and component duty cycle

The average power consumption of a component with any given set of characteristics depends on its duty cycle – the time spent in its various operating states – which is controlled by software. A component that constantly utilizes its higher power states will draw more power than a comparable component that utilizes lower power states when its function is not needed. Software can enable such power scaling, which is an important energy savings strategy that scales power to the work being done and powers down unused components. On the product level, the duty cycle links the power consumption in various modes (e.g., idle, on) to the energy consumption of the product: $E = \sum P_i \times t_i$, where i (1 to n) denotes the mode, P_i the power consumption in mode i and t_i the time spent in mode i. Since the usage time of products is generally not subject to policy, efficiency measures focus on power consumption only, or use a standard duty cycle to calculate the energy consumption from the power consumption in various modes.

In reality, software and component duty cycles are difficult, if not impossible, to discern from product inspection or specifications, and therefore are not useful for categorization. Factors that are easily identified and therefore useful for categorizing SNE include the types of components, particularly network interfaces, the number of components of a particular type, and bandwidth (Mercier et. al 2018). Network protocols apply to a specific type of network interface and determines bandwidth. Therefore, network protocol can be used in the categorization as a proxy for interface type and bandwidth. For products with wireless network interfaces, the transmit power is a significant power impact.

Analysis of SNE power consumption

INTRODUCTION AND METHODOLOGY

The aim of the analysis of SNE power consumption is to assess relationships between characteristics identified in the foregoing section and power consumption, based on power measurements of products on the market. All power measurements are conducted on products in an idle state, in which no or little data traffic occurs[1]. Nevertheless, idle power is relevant for energy efficiency policy because most of the time SNE devices are in idle mode or in a mode with little data traffic. Furthermore, most SNE products do not scale power to data rate, thus idle power is generally representative of power draw at non-zero data rates.

We used four datasets in the analysis, each containing idle power measurements for a range of SNE products:

c't: c't Magazin is a German magazine and website geared towards tech-savvy consumers. It offers a range of content on electronic products, including reviews and tests, some of which contain idle power measurements. We collected about 120 reviews that included idle power measurements from 2016 to 2020 and recorded product characteristics such as WAN interface type and number, and LAN interface bandwidth.

Dangl: This dataset was collected by Georg Dangl with support from the International Energy Agency's Electronic Devices and Networks Annex (EDNA) (Dangl 2019). It includes idle power measurements of three IADs and six IoT gateways. The year of first release of the products ranges from 2013 to 2018. Each product was tested up to five times, each test with a different combination of connected network interfaces.

NRCan: Similar to the Dangl dataset, this data collected by Natural Resources Canada (NRCan) includes multiple tests per product, with different network interface connections. It contains test results for six modems, four IADs, ten routers, and four smart home gateways.

U.S. VA: Internet service providers and manufacturers that participate in the VA are required to report idle power and the characteristics of the product that determine its power allowance, including product category, WAN interface number and type, and LAN interface number and type. We gathered the data reported in the U.S. for 2016 through 2019. After duplicate data points were removed the dataset contained about 400 data points. U.S. VA participant shipments are estimated to represent about 80 % of broadband access equipment and no more than 50 % of LAN equipment in the U.S. (Dayem and Granda 2020).

RESULTS

We first examine idle power for the function-based product categories outlined in Table 1, see Table 2.

We expect that some WAN interfaces require more power than others; power depends on the medium (e.g., copper, fibre, air) over which data is transmitted. Segmenting by WAN interface type, however, still shows a widespread in idle power, particularly for xDSL and DOCSIS equipment (Figure 3 left). WAN interface categories show at least a 2x and at most a 5x spread in power between the lowest and highest power products in the group. For IADs, additional LAN functions can explain some of the spread.

Most of the LAN equipment in the datasets contain both wired Ethernet and wireless Wi-Fi interfaces, and show a widespread in power draw within function-based product categories (Figure 3 right). The data hints that increasing product functionality increases power draw, however some level 3 products use less power than some level 1 products.

We next analyse the available component characteristics for models in the c't and U.S. VA datasets to determine which characteristics show a relationship to power draw. Figure 4, Figure 5, and Figure 6 show component characteristics that appear to have some relationship to power: the number of Ethernet ports, maximum Wi-Fi data rate, and the number of Wi-Fi radios, respectively. Although linear regression analysis of the data yield low correlation and therefore low predictive value of a linear relationship between the function capacity and power, visual

1. Data on power consumption of SNE devices in the on-mode is collected for the EU Broadband Code of Conduct, but this data is not publicly available.

Table 2. Idle power consumption for function-based SNE categories.

SNE category	Power consumption	
	Range: min … max (W)	*Average (W)*
Broadband access equipment		
IAD (n=167)	2,5 … 27	11
Modem (n=32)	4,3 … 12	8,0
LAN equipment		
Level 1 (n=24)	1,2 … 8,7	3,6
Level 2 (n=9)	2,7 … 6,3	4,4
Level 3 (n=19)	2,6 … 15	7,5
2-unit mesh (n=8)	5,7 … 15	10
3-unit mesh (n=30)	3,6 … 29	15

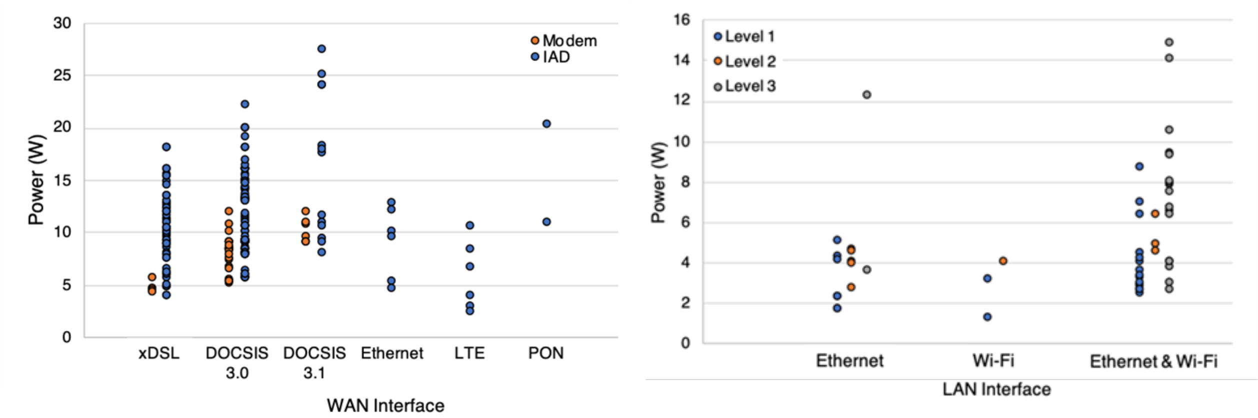
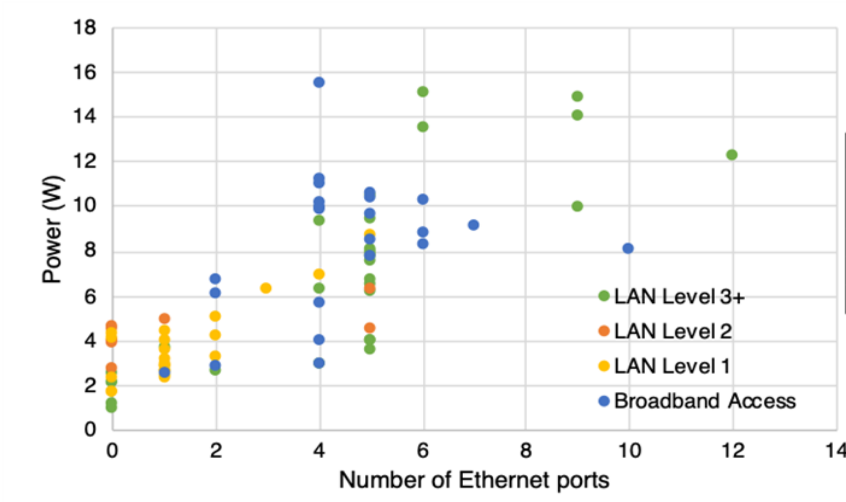


Figure 3. Power consumption by (left) WAN interface and (right) LAN interface.

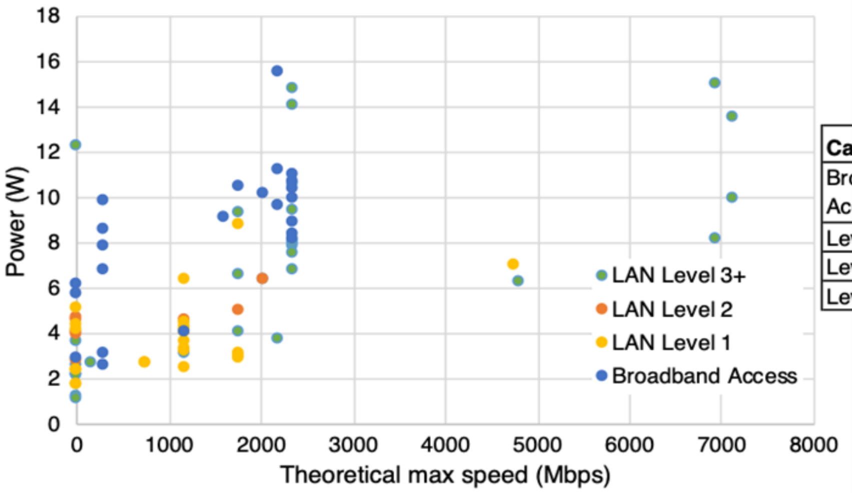


Category	n	R^2
Broadband Access	23	0.14
Level 1	22	0.74
Level 2	9	0.42
Level 3+	29	0.65

Figure 4. Power versus number of Ethernet ports by product category and simple linear regression results. Data from c't dataset.

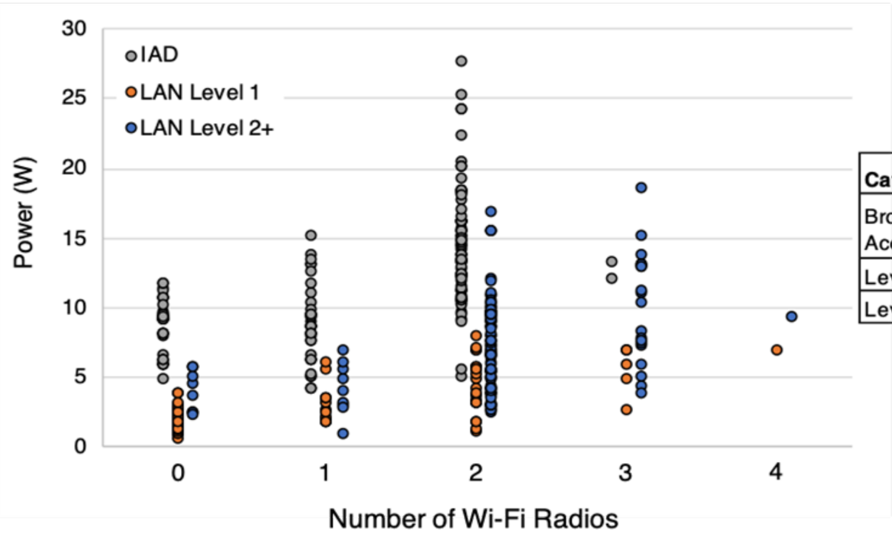
inspection of the data suggests a trend toward higher power with increased capacity of the component factor in question. For example, products with more Ethernet ports generally draw more power than products with fewer ports (Figure 4). Similarly, products that have the capacity to transmit more data tend to draw more power than products that have lower data capacity (Figure 5), and products that contain more Wi-Fi radios trend toward higher power than products with fewer radios (Figure 6).

Given that any SNE product can contain a number of component characteristics that may impact its power consumption, we performed multiple variable regression analyses on the U.S. VA dataset, segmented by product type, to determine whether multiple characteristics of a product can predict the power consumption of the product. The analysis shows significant correlation (p-value < 0,01: dark green; p-value<0,05: light green) of several functions, particularly the number and type of Wi-Fi interfaces, to power; see Table 3.



Category	n	R^2
Broadband Access	23	0.48
Level 1	22	0.25
Level 2	9	0.48
Level 3+	29	0.37

Figure 5. Power versus theoretical maximum Wi-Fi speed by product category and simple linear regression results. Data from c't dataset.



Category	n	R^2
Broadband Access	145	0.33
Level 1	89	0.51
Level 2+	133	0.18

Figure 6. Power versus number of Wi-Fi radios by product category and simple linear regression results. Data from U.S. VA dataset.

Table 3. Results multiple variable regression analysis on power consumption with components as independent variables for product categories analysed.

	IAD		All LAN Equipment		Level 1		Level 2+	
Component	*p-value*	*coefficient*	*p-value*	*coefficient*	*p-value*	*coefficient*	*p-value*	*coefficient*
Ethernet ports	0,60	-0,157	0,043	0,128	0,21	0,078	0,042	0,232
802.11n radios, low power	0,38	0,653	< 0,01	0,898	< 0,01	0,668	0,11	0,601
802.11ac radios, low power	0,28	1,00	< 0,01	1,50	< 0,01	1,91	< 0,01	1,24
Additional chains, low power	< 0,01	2,00	< 0,01	0,507	0,067	0,669	0,034	0,532
802.11n radios, high power	< 0,01	2,89	< 0,01	1,07	< 0,01	1,29	0,22	0,555
802.11ac radios, high power	< 0,01	3,49	< 0,01	2,56	0,013	0,762	< 0,01	3,13
Additional chains, high power	0,67	-0,198	< 0,01	0,385	0,52	0,262	0,45	0,142
HPNA	0,34	0,876	n/a	n/a	n/a	n/a	n/a	n/a
G/hn	n/a	n/a	< 0,01	2,37	0,019	1,43	< 0,01	2,45
MoCA	0,092	1,43	< 0,01	2,56	0,010	1,36	< 0,01	3,23
Phone ports	< 0,01	0,850	n/a	n/a	n/a	n/a	n/a	n/a
USB 2 ports	0,16	0,623	< 0,01	1,12	0,56	0,307	0,028	0,870
USB 3 ports	0,94	-0,056	< 0,01	2,74	0,67	0,481	< 0,01	2,59
Bluetooth	n/a	n/a	0,72	0,183	0,27	0,679	0,78	0,191
Additional application processor	0,98	-0,020	0,18	0,685	0,014	1,98	0,54	0,417
Adjusted R^2 of multiple variable regression	0,63		0,81		0,73		0,74	
Intercept	6,98		0,907		1,04		1,27	

The analysis yields a moderate predictive ability to estimate power from multiple characteristics together, with adjusted R^2 values ranging from 0,63 to 0,81. In other words, a relationship between some component characteristics and power does exist, and relationship describes some but not all of the variation in the datasets. This finding leads us to conclude that additional factors, which could include power scaling, component choice, and other product characteristics, may have considerable impact on the power consumption of the product.

SAVINGS OPPORTUNITIES AND POTENTIAL

Opportunities for efficiency improvements

Pathways to improving the energy efficiency of SNE have been outlined by several researchers, e.g., Dangl (2019), Gray (2018), Harrington and Nordman (2014), and include the following three strategies.

Powering down unused components: this includes powering down unconnected network interfaces, especially wired interfaces that can be designed to detect whether or not a cable is attached.

Adjusting processing power to data processing needs: electronic circuits consume less power when operating at lower speeds; therefore, energy consumption can be reduced by adjusting the speed at which the device operates to more closely match the data needs (Harrington and Nordman 2014). Connected network interfaces and central components should use strategies to scale their power to the data processing or traffic load, such as Energy Efficient Ethernet (EEE) for Ethernet interfaces. This power scaling strategy is often referred to rate adaptation. Research shows that SNE devices do not implement aggressive power scaling and can consume up to 85 % of their maximum power draw when in idle state (Fiandrino et al. 2017, Gray 2018).

Increase efficiency of hardware components: energy efficiency of SNE can be improved by using more efficient components. This includes using power supplies that are efficient at maximum and, if the product implements power scaling, low load points.

Savings potential

Previous studies estimate that the energy consumption of SNE devices can be reduced by 20 to 50 %. The low end of the range assumes power supply efficiency improvements and implementing EEE (Lanzisera et al. 2010). The high end of the range estimates savings achieved via aggressive power scaling of network interfaces and other component (Lanzisera et al. 2010, Dangl 2019). Near-term savings potential may be estimated by identifying the most efficient products on the market, and assuming that all products adopt those power levels. An analysis of the U.S. VA data from 2018 suggests that SNE energy use could be reduced by approximately 15 % if they adopt best-on-market efficiency (Dayem and Granda 2020). We apply the range of potential energy savings to the total energy use of residential SNE estimated by the EDNA total energy model version 2 (Ryan et al. 2021) (Table 4). This yields a global estimated savings potential of 32 to 91 TWh per year after stock turnover.

Energy efficiency policies for SNE

INTRODUCTION: CHALLENGES TO REGULATE ICT PRODUCTS

Why is it so hard to regulate the energy efficiency of ICT products, according to the EU framework? First, the Ecodesign Directive stipulates that requirements shall aim for the least life cycle cost point. This assumes that there is a relation between the efficiency and the price of a product: more energy efficient products have higher purchase prices, but use less energy and therefore have lower lifetime costs. However, for ICT products the assumption of a positive relation between efficiency and price is flawed (Siderius 2014); the relationship between efficiency and price is a spurious one: a product may be more expensive because it has better performance (which is often unrelated to efficiency), brand recognition, or additional features. Because a direct link between efficiency and cost does not exist, the least life cycle cost methodology cannot be used to set requirements.

Second, the methodology requires insight into (future) design options to make products more efficient, and – indirectly – insight into development of the performance and functionality of the product. However, manufacturers are not willing to disclose information, including costs, on these developments, and certainly not on new features and functionalities. Moreover, manufacturers cannot predict which new developments will become mainstream on the longer run.

A third point is that the process for setting requirements takes time, which increases the uncertainty about the actual

Table 4. Estimated SNE energy use and potential savings by region in 2021.

Region	Total Energy Use (TWh/yr)	Savings Potential Estimates (TWh/yr)		
		Best-on-market energy efficiency	*Power supply efficiency & power scaling*	
			Low	*High*
Far East and China	79	14	16	39
West Europe	27	4,7	5,3	13
North America	20	3,4	3,9	9,8
Latin America	15	2,6	2,9	7,3
Africa and Middle East	13	2,4	2,7	6,7
Central and Eastern Europe	13	2,3	2,7	6,7
Asia Pacific	10	1,7	1,9	4,8
Indian Subcontinent	6,8	1,2	1,4	3,4
Global	180	32	37	91

performance and functionality of the products to which the requirements would apply. Is the product that is analysed during the preparatory phase still on the market when the requirements come into force?

Finally, it is difficult to assess the energy savings potential of ICT products that can be realized by applying regulatory measures. This is partly due to the difficulty in estimating future product and market developments as noted above, certainly when focusing on specific products. Another issue is that apparently large efficiency improvements happen without any regulatory intervention. For example, mobile product designs push efficiency improvements to lengthen battery runtime and reduce thermal impacts, absent regulations. And in general, each successive chip generation is more efficient. On the other hand, mains-connected ICT product design prioritizes the implementation of new or improved functionalities on a quick timeframe because a premium price can be charged for the newest features. Consumers rarely demand energy efficiency in such products.

The technical and market characteristics of ICT products are interwoven: the market of ICT products is characterized, driven or sometimes dominated by the technology development of the main component, the chip. New chip generations offer increased integration, new functionalities and increased performance, often with increased efficiency. Or stated the other way around, product development of ICT products depends on the generation of chip technology that is used. Products with the newest generation in general offer newer/more functions and increased performance and are sold at a premium price. However, when production continues, learning effects and marketing (the more units are sold the less exclusive they are and the lower the price premium can be) result in quickly decreasing prices until the generation is superseded by the next with better performance and/or new features.

DEFINING AN EEI FOR SNE

Energy efficiency metrics for ICT equipment are often formulated in one of the following ways:

1. the power consumption while the device is delivering a standard performance, or
2. the power consumption of the device for delivering a standard performance relative to a reference power consumption for delivering a standard performance: an energy efficiency index (EEI): $EEI = P_{measured}/P_{reference}$

The reference power consumption can account for the performance of the product and (additional) functions. This could take the following format:

$P_{reference} = P(f(performance)) + \sum P(\text{allowance for additional functions})$

The reference level can relate to the most efficient products (on the market or theoretically possible), products of average efficiency, or the least efficient products on the market.

The challenge in both cases is to define what "standard" is, especially in the case of product types that offer a range of performance levels or additional functions. In case of a) (power measurement while delivering a standard performance) this challenge is shifted to a large extent from the measurement (conditions) to setting the requirements, see e.g., the (discontinued) Energy Star specification for SNE. In case of b) (EEI), as indicated above, the reference power consumption could take additional functions into account, see e.g., the EEI for displays in the ecodesign regulation.

The challenges with regulating SNE devices are related to establishing a reasonable metric of comparison, for several reasons. First, performance is developing or improving all the time; therefore, the metric a) is difficult to apply because an estimate of the impact of the improved performance on the power consumption is needed. Second, the number of possible additional functions or characteristics can become very large. Recognizing functions with allowances can become opaque, meaning that it is difficult to distinguish between necessary and unnecessary allowances. Furthermore, each allowance is designed to be effective when applied alone, so the combination of allowances for one product may provide more allowance than necessary because of synergies between features.

There are two ways to deal with this problem. The first is to take only the main function(s) into account while testing and assume that the power consumption of the (not used) additional functions is controlled by the power management of the device. This would mean that no allowances are given to additional functions, but it would also mean that the overhead resulting from additional functions would not be accounted for. Products with additional functions would risk not meeting the target. The second option is to combine a relatively lenient power consumption limit, with an ambitious (energy) label. The effect of not meeting the requirement (of the endorsement label) or having a less efficient score on the energy label is less serious than if the metric is used for a MEPS where not meeting the requirement means that the product cannot be placed on the market.

SETTING MINIMUM EFFICIENCY TARGETS AND ENERGY LABEL CLASSES

Minimum efficiency requirements through ecodesign and energy labels are the two mandatory product efficiency measures in the EU. Admittedly, energy consumption for an *individual* SNE product is a small portion of a typical consumer's energy usage, and of little concern in the buying decision, especially compared to performance and features. Nevertheless, an energy label can be a useful instrument to reducing energy use of SNE. The first reason is practical: for products covered by an energy labelling regulation the manufacturer must upload product data into the product database (EPREL). This data becomes publicly available to follow market developments and to use in a revision of the ecodesign requirements. Second, several SNE devices, notably modems and set-top boxes, often are provided by a service provider, rather than purchased by the consumer. The energy label can help to implement procurement of more efficient devices, e.g., by a management decision to only procure A-label products. Furthermore, the energy label can also be used to provide information on resource efficiency aspects, notably on repairability, e.g., a repair score.

As discussed above, a strict least life cycle cost approach does not work for SNE products. However, it is possible to use an alternative that serves the same goal, i.e., the total cost of ownership is lower for the more efficient products. Using the EEI as metric, a target is set at a not too stringent level, e.g., cutting off 30 % of the market. As an example, we calculated the EEI of the products (IAD and LAN equipment) in the U.S. VA dataset with the reference power consumption calculated with

Table 5. Results for MEPS and Energy label applied to the U.S. VA dataset.

Product	EEI		MEPS		Savings	
	Range: min…max	*average*	*Level*	*% pass*	*MEPS*	*Energy label*
IAD (n=144)	57 … 170	105	120	71	11%	10%
LAN equipment (n=221)	27 … 301	101	110	71	14%	14%

the significant coefficients in Table 3. In that case, the reference power consumption relates to the average efficiency of products in the dataset. By setting a minimum requirement (MEPS) of EEI≤120 for IAD and EEI≤110 for LAN equipment, 71 % of the products would pass. The average power consumption would decrease 11 % and 14 %, respectively. The resulting EEI range is large enough to accommodate an A-G scale, including an empty A class as required by the regulation. Assuming that the label would stimulate manufacturers to develop products that achieve the next energy label class, e.g., C becomes B, D becomes C, this would save another 10 % respectively 14 %. Table 5 summarizes the results.

Selecting the appropriate entry into force date is another parameter of a product efficiency measure. It is proposed that the average price decrease of the product guides the setting of the entry into force date, as follows. Calculate the average price p_{MEPS} of the products that remain on the market when applying the target level (at the time of analysis T_0). This price should decrease to the average price of products p_0 on the market before applying the target level. The reasoning is – as with the least life cycle cost methodology – that consumers do not need, on average, to pay more and because the remaining products are more efficient, the total life cycle costs are lower. Assuming that the price of the product decreases exponentially over time with time constant c, the entry into force date T_1 can be calculated by $T_1–T_0=-\ln(p_{MEPS}/p_0)/c$. The U.S VA dataset does not contain prices, but we can get an indication of the period $T_1–T_0$ with the following assumptions. We take c=-0,30, the average value found in Siderius (2014) and assume as a worst case that $p_{MEPS}/p_0=2$, i.e., the average price of the products that remain on the market is twice the average price of all products. This results in a period of 2,3 years; taking into consideration that the preparation of a regulation will take at least a year and the period between the publication and entry into force of the requirements is also a year, it is likely that the period $T_1–T_0$ will be longer than 2,3 years and therefore will ensure that consumers on average will not pay more for the more efficient products. Further note that the entry into force date of product information requirements, including labelling, can differ from the entry into force date for the requirements.

It has been argued that consistency and a long-term approach are important to secure persistent savings from any product efficiency policy. This means that the procedure described above should be repeated regularly. The procedural challenge is to keep such revisions as frequent and short as possible.

Conclusions and recommendations

SUMMARY AND CONCLUSIONS

This paper presents on energy efficiency policies for SNE devices that can deal with the technical and market characteristics of those products. After developing a categorization for SNE devices, we used literature and several datasets to analyse the relations between components and idle power consumption. Using multivariate regression, we found that various components, notably the number and type of Wi-Fi interfaces, correlated with power. Because the relations do not describe all of the variation in the datasets, this suggests that energy savings opportunities exist in products on the market today, and policies that encourage efficient components and design strategies may yield significant energy savings. We defined an energy efficiency index (EEI) using a reference power consumption based on the results of the regression analysis. This EEI can be used to set minimum efficiency requirements and energy label classes. Setting a moderate efficiency requirement that would remove around 30 % of the products from the market, would result in savings that are comparable with other estimates: around 20 TWh per year worldwide after stock turnover. The proposed EEI offers a more simple and transparent solution than other (voluntary) approaches.

DISCUSSION AND RECOMMENDATIONS

This paper showed that an energy efficiency policy for SNE devices based on an EEI works in principle. However, we have the following points for discussion and recommendations. First, we conducted our analysis using the U.S. dataset, which contains the most information on product functions. Since SNE devices are traded worldwide and are technically based on worldwide standards, e.g., for Wi-Fi, we argue this is a reasonable first step. However, the EU market must be assessed when following the formal process for setting ecodesign requirements and energy label classes. The second point is that we used the categories from the U.S. Voluntary Agreement. We recommend a broader analysis be developed for the ecodesign process, with more generic categories and the flexibility to incorporate new developments within the period until the revision. Most voluntary agreements exempt products or functions that are outside what was on the market when setting the requirements and take these into account only in the next revision. For a mandatory approach however, this would create a loophole. The third point is that data on product features and power consumption is a key element to developing any energy efficiency policy. Therefore, voluntary agreements should publish this data for each individual model in the agreement.

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