Estimate of energy wasted by network-connected equipment

FINAL REPORT

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Chapter 1: Introduction

The objective of this study is to estimate the energy wasted by network-connected equipment due to excess connectivity and that could be saved through better power management policies. A baseline (2008) estimate of total energy consumption by network-connected equipment is made and projected to 2015 and 2020. This serves as a basis for an estimate of energy wasted as a result of excess connectivity and/or the use of sub-optimal technologies instead of cost-effective improved technology.

First, a short background to the topic is provided. Next, total energy consumption by network-connected equipment is estimated using a top-down approach based on available data at world, regional and country levels (such as for the EU and the United States), and weighted extrapolation where this data is not available (Step 1). Then, annual energy wasted by excessive connectivity is estimated as the difference between a business–as-usual case and an improved case (Step 2). Finally, technology trends and market predictions are used to project two energy scenarios, business-as-usual and improved, to 2020 (Step 3).

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Chapter 2: Background

Network-connected equipment is used in almost all sectors. It includes both mobile devices and devices that are plugged in. The focus of this study is on devices that operate on mains power and which are therefore associated with buildings but even mobile devices usually rely on buildings for recharging. Buildings are responsible for around 40% of the world's total primary energy demand (2 914 million tonnes of oil equivalent (Mtoe) in 2005),[1] and 24% of CO_2 emissions.[2] Buildings are mostly in the residential and services sectors but there is also some energy consumption related to buildings in the industry, agriculture and forestry sectors.

Energy use in buildings includes heating, cooling, lighting and appliances. Appliances are the fastest-growing source of household energy demand, with consumption in International Energy Agency (IEA) countries increasing by 57% from 1990 to 2005 to account for 59% of total household electricity use.[3] Appliances are also of growing importance in the services sector in the form of office equipment.

For this reason, Asia-Pacific Partnership (APP) countries are actively creating energy efficiency policies aimed at appliances, such as Minimum Energy Performance Standards (MEPS) and energy labelling as well as a range of voluntary programmes in order to reduce energy consumption or slow its growth. Naturally, larger appliances such as refrigerators and washing machines were targeted first, but there is growing recognition of the significance of smaller appliances. For example, there has been an attempt to deal with energy use by set-top boxes, which convert television broadcast signals to a video stream, in the context of the IEA.

A wide range of small appliances (computers, mobile phones, personal audio equipment and other home electronics) are becoming ever more pervasive and more complex in terms of functionality and power modes, especially in more developed countries. In some less developed countries, increased access to electricity is also a driver. Computers alone are estimated to account for around 2% of worldwide energy consumption, around half of which may be wasted.[4] Electronic home entertainment and information and communications equipment now account for more than 20% of residential electricity use in most countries.[5] Mobile networks have been growing at extremely fast rates worldwide. Large appliances (refrigerators, freezers, washing machines, dishwashers and televisions), on the other hand, now represent only around 50% of household appliance electricity consumption in IEA countries, and this share is still falling.[6]

A wide variety of electrical and electronic household and office equipment feature standby power modes, and annual sales volumes at the global level are very large and constitute a significant source of energy consumption. A general definition of standby power is the electricity consumed by devices while switched off or not performing its primary functions. Electricity consumption related to standby mode in a typical Japanese or Australian home corresponds to around 10-11%

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[1] IEA (2008) *Energy Technology Perspectives 2008*, OECD/IEA, Paris
[2] IEA (2006), *Energy Technology Perspectives: Scenarios and Strategies to 2050*, OECD/IEA, Paris.
[3] IEA (2008) *Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis*, OECD/IEA, Paris.
[4] World Business Council for Sustainable Development (WBCSD) (2008) *Energy Efficiency in Buildings: Business realities and opportunities*, WBCSD, Geneva.
[5] IEA (2008) *Energy Technology Perspectives 2008*, OECD/IEA, Paris.
[6] IEA (2008) *Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis*, OECD/IEA, Paris.

of total electricity consumption,[7] in the United States about 5% and in the EU between 5 and 10%.[8] The amount of consumption in commercial buildings and factories is not known.[9] APP countries have been making good progress on standby power, notably through the IEA 1-Watt initiative. However, better incentives are still needed in some areas, for example to target television service providers.

The Lot 6 Ecodesign preparatory study identified networked standby as a concern.[10] Network-connected power refers to the energy consumed by the requirement for a product to stay connected to a network, even though no primary function is being performed. Network here refers to the internet but also local intranets, clusters of products that manage themselves, mobile networks, etc.[11]

The issue is in fact a broader one of rising energy consumption by network-connected equipment in general, whether in standby or other modes. The IEA breaks down energy use into three main components: activity, structure and intensity. Similarly, the electricity consumption of network-connected equipment can be determined by activity (stocks of network-connected equipment), structure (the mix of types of equipment, each with different energy use profiles) and intensity (a given product type can be more or less energy-intensive depending on user behaviour, power modes, etc.). There are several general trends in network-connected energy that can be seen at world level:

- network connectivity is being added to products which would not previously have had such functionality (televisions, white goods, power meters within smart grids, etc.);
- demand for the availability of traditionally network-connected equipment is increasing (e.g. home and office computers);
- greater quantities of new network-connected products are entering the market (e.g. home media servers, digital picture frames, tablets);
- products are spending more time in higher power modes (e.g. active instead of standby) because of network-related requirements and due to a lack of effective power management strategies;
- power consumption in lower power modes is increasing (e.g. network interfaces require more power in standby modes in order to maintain a network link);
- networks are tending towards faster speeds and higher bandwidth, which increases power in the absence of effective power management.

[7] Energy Efficient Strategies (2006) *2005 Intrusive Residential Standby Survey Report*, report for E3.
[8] Bertoldi, P., Aebischer, B., Edlington, C., Hershberg, C., Lebot, B., Lin, J., Marker, T., Meier, A., Nakagami, H., Shibata, Y., Siderius, H.P. and C. Webber (2002) *Standby Power Use: How Big is the Problem? What Policies and Technical Solutions Can Address It?*, available at www.managenergy.net/download/ACEEE2002-paper569.pdf.
[9] IEA (2009a) *IEA Scoreboard 2009: Key Energy Trends Over 35 Years*, OECD/IEA, Paris. Accessed at: http://iea.org/textbase/nppdf/free/2009/scoreboard2009.pdf.
[10] BIO (2006-2007) *Preparatory study Lot 6 for Ecodesign of stand-by and off-mode* (all applications covered: computers, TV, ICT, telephone, small appliances), European Commission (DG TREN), in the framework of the Ecodesign Directive (2005/32/EC). Available at www.ecostandby.org.
[11] Mobile networks are a particularly interesting case because they are now huge and mobile products have some low energy characteristics that have not yet been applied to mains-connected products.

So while there are more energy-efficient devices and quick diffusion of new technology, current trends taken together point towards greatly increased power consumption associated with network functionality. An indirect indicator of this is that Cisco forecasts that by 2015 total IP traffic will be four times larger than in 2010.

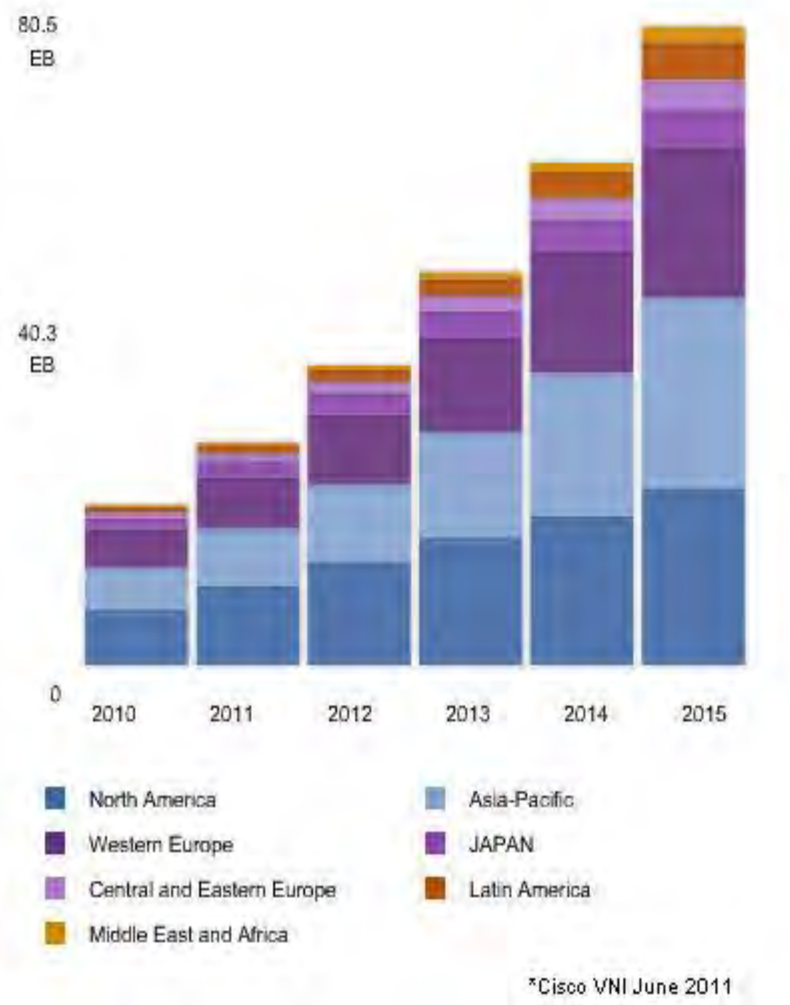

Figure 1: Forecast total monthly IP traffic by region, 2010-2015[12]

This study aims to contribute to understanding of the scale of network-connected energy consumption at the global and regional levels, what improvement potential may exist and how that improvement can be realised. There are many aspects of network-connected technology that could have much lower energy attributes. Some of these technologies are yet to be developed, at least for mains-connected products, so there is necessarily some uncertainty in estimating the total potential energy savings from improved network-connected energy characteristics. In general, savings estimates in this study are based on technologies that are currently in development or are proven. There are of course additional savings possible from technologies that are still at the research and development stage.

[12] Cisco Visual Networking Index (2011). Accessed at: www.cisco.com/en/US/netsol/ns827/networking_solutions_sub_solution.html. Includes business and consumer segments; fixed Internet, mobile and non-Internet IP; web and other data, Internet video, video to TV, file sharing, gaming, video communications, voice communications and business data.

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Step 1: Calculating energy used

The first step in estimating the energy wasted by excess network connectivity is the estimation of energy consumption by network-connected equipment by region and country. The geographical scope of the study is worldwide and results are given both in aggregate and split into the following countries and regions:

Table 1: Countries and regions analysed

World	
APP countries	*Regions*[13]
Australia	Africa
Canada	Asia excluding Japan and Korea
China	Europe
India	Former USSR
Japan	Latin America
South Korea	Middle East
United States	North America
	Australia, Japan, Korea and New Zealand

Complete and consistent data on the breakdown of energy use by appliances is not available, even in OECD countries. In many countries, no data is available. However, the data and estimates that do exist in the literature allow certain inferences to be made about some aspects of energy consumption.

The starting point for this analysis is electricity consumption by country in TWh, as published by the IEA. In order to calculate how much of that electricity consumption is for network-connected equipment, the share of buildings in electricity consumption is then applied. This ranges from over 70% in the United States and the Middle East, down to 45% in many Asian and Former USSR countries, where the share of industrial consumption has not yet declined as much.[14]

"Electronics" (defined as devices whose primary function is information) accounts for around 11% of buildings electricity in the United States.[15] Lanzisera et al.[16] estimate that "network equipment" (defined as devices that primarily switch and route Internet Protocol packets from a

[13] These regions are based on those used by the International Energy Agency. Definitions are provided in Section 8.
[14] Waide, P. (2009) "Appliance energy policy and technical standards: Plugging the gaps", presentation, OECD/IEA, Paris. "Buildings" in a policy context usually corresponds to the IEA residential, services and agriculture sectors.
[15] Nordman (2009) "What the Real World Tells Us about Saving Energy in Electronics", paper presented at 1st Symposium on Energy Efficient Electronic Systems (E3S), CITRIS / UC Berkeley, 11 June, 2009, see www.citris-uc.org/events/E3S.
[16] Lanzisera, S., Nordman, B. and R.E. Brown (2010) "Data Network Equipment Energy Use and Savings Potential in Buildings", paper presented at ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar.

source to a destination) consumed 18 TWh in 2008, or 0.6% of United States buildings electricity. More pertinently, Nordman estimates that "all devices with a digital network connection" account for around 150 TWh, or 5% (and rising).[17] These references are drawn from the report *Standby Power and Low Energy Networks: Issues and Directions* carried out for the APP and IEA 4E.[18]

Where **E** is the total consumption of electricity, **B** the share of buildings in total electricity and **N** the share of network-connected equipment in buildings electricity, $\mathbf{E_{ne}}$ the energy consumed by all network-connected equipment is:

$$E_{ne} = E \times B \times N$$

In order to determine the electricity consumption of network-connected equipment in other countries, the 5% result for the United States is extrapolated using the ICT Development Index (IDI) to take into account the fact that levels of IT development vary by country.[19] The IDI was developed by the International Telecommunication Union (ITU), the United Nations agency for information and communication technology issues. It is designed to evaluate the level of IT development of a country using three criteria: access to technology, use patterns and user skills. It covers all countries within the scope of this study and was specifically developed to rate the presence and access to ICT in the different countries.

Table 2: ICT Development Index: Indicators and weights[20]

ICT access	Reference value	Weight	
		% of access	% of total
1. Fixed telephone lines per 100 inhabitants	60	20	
2. Mobile cellular telephone subscriptions per 100 inhabitants	170	20	
3. International Internet bandwidth (bits/s) per Internet user	100 000	20	40
4. Proportion of households with a computer	100	20	
5. Proportion of households with Internet access at home	100	20	
ICT use	**Reference value**	**Weight**	
		% of use	**% of total**
6. Internet users per 100 inhabitants	100	33	
7. Fixed broadband internet subscribers per 100 inhabitants	60	33	40
8. Mobile broadband subscriptions per 100 inhabitants	100	33	
ICT skills	**Reference**	**Weight**	

[17] Nordman (2009) "What the Real World Tells Us about Saving Energy in Electronics", paper presented at 1st Symposium on Energy Efficient Electronic Systems (E3S), CITRIS / UC Berkeley, 11 June, 2009, see www.citris-uc.org/events/E3S.

[18] Harrington, L. and B. Nordman (2010) *Standby Power and Low Energy Networks – issues and directions*, report for APP and IEA 4E Standby Annex.

[19] ITU (2010) *Measuring the Information Society*, ITU, Geneva. Available at www.itu.int/ITU-D/ict/publications/idi/2010/Material/MIS_2010_without_annex_4-e.pdf.

[20] Ibid. The values of the IDI indicators were transformed into the same unit of measurement using distance to a reference measure. The reference values were either 100 or obtained through a statistical procedure. The value of 100 000 for internet bandwidth corresponds to a log value of 5.

	value	% of skills	% of total
9. Adult literacy rate	100	33	
10. Secondary gross enrolment ratio	100	33	20
11. Tertiary gross enrolment ratio	100	33	

The IDI is used to extrapolate the energy consumed by network-connected equipment in the United States to the rest of the countries and regions within the scope of the study. Considering that **I** is the IDI index of a country and $\mathbf{I_{US}}$ is the IDI Index of the United States, we can say that the adjusted IDI index of a country $\mathbf{I_{aj}}$ can be calculated with this formula:

$$I_{aj} = I \times \frac{1}{I_{us}}$$

Therefore the energy consumption of network-connected equipment of a country is:

$$E_{ne} = E \times B \times N \times I \times \frac{1}{I_{us}} = E \times B \times N \times I_{aj}$$

The output of this step is an estimate of the electricity consumption of network-connected equipment by country that can be aggregated to give totals for APP and world regions (Table 3).

Table 3: Electricity consumption by APP country and world region, 2008

Country/Region		Electricity consumption[21] (TWh)	Electricity consumption of network-connected equipment[22] (TWh)
Region[23]	Africa	562	5.38
	Asia excluding Japan and Korea	4 863	45.98
	Europe	3 595	105.35
	Former USSR	1 326	19.28
	Latin America	904	15.17
	Middle East	672	15.33
	North America	4 939	169.44
	Australia, Japan, Korea, New Zealand	1 742	47.91
World		*18 603*	*423.85*
APP countries[24]		*10 364*	*249.09*

The Lot 26 preparatory study estimates a total of 174 TWh consumed in 2010 in the EU-27 by network-connected equipment. The figure for Europe in 2008 shown in Table 3 is considerably lower (105 TWh), despite including some European countries that are not part of the European Union. The EU-27 figure (not shown in Table 3) would be 95 TWh. Part of the difference between these two figures might be explained by the growth of the stock between 2008 and 2010. If the growth rate for Europe used in this study is applied to the EU-27 figure, consumption in 2010

[21] IEA (2010) *Key World Energy Statistics 2010*, OECD/IEA, Paris. Gross production + Imports - Exports – Losses.
[22] BIO estimates.
[23] Totals, i.e. including APP countries.
[24] Australia, Canada, China, India, Japan, Korea, United States.

would be 107 TWh. The remaining difference may be explained by the fact that the Lot 26 preparatory study used a broader bottom-up approach, while the present study uses a top-down approach.

For further comparison, the study for an Amended Ecodesign Working Plan gives year 2007 figures of 100 TWh for electronics ("end-uses in signal processing, storage, local open or closed loop control") and 200 TWh for electromagnetic applications other than light sources ("such as displays (including TVs) and communication equipment (including wireless)").[25] Meanwhile, a study by BIO estimated 2005 electricity consumption related to ICT end-user equipment at 158 TWh.[26] However, the product categories used in those studies do not refer specifically to network-connected equipment.

A study of the Australian residential sector[27] estimates the total energy consumption of IT equipment (PCs, laptops, printers, networks etc.) and entertainment equipment (TVs, game consoles, video players etc.) in Australia in the year 2005 at 5.6 TWh. The growth rate of energy consumption in households in Australia is estimated at between 2.5% and 5% or more per year.[28] This would give a figure of between 6.03 TWh and 6.5 TWh for the year 2008. The calculations following the methodology explained above give a result for Australia of 7.6 TWh consumed by network-connected equipment in 2008. This means a difference of between 15% and 20% with respect to previous studies, although the specific scope of products included might not be the same.

In conclusion, it can be said that the results obtained in this study by following the methodology explained above are in the same order of magnitude as the results presented in previous studies, with a variation of between around 10% and 20%.

[25] VHK (2011) *Study for the Amended Ecodesign Working Plan*, Interim Report.
[26] BIO (2008) *Impacts of ICT on energy efficiency*, European Commission DG INFSO, Brussels.
[27] Australian Department of the Environment, Water, Heritage and the Arts (2008) *Energy use in the Australian residential sector.*
[28] Energy Efficient Strategies (2006) *2005 Intrusive Residential Standby Survey Report*, report for E3.

Step 2: Calculating energy wasted

The energy wasted by network-connected equipment can be estimated as the difference in energy consumption between the Best Available Technology (BAT) and the average product in the market. The two critical elements are powering down all unnecessary functions when they are not required, and reducing the power required for the functions themselves. This study aims to make a top-down estimate of the energy that is being wasted, rather than a bottom-up estimate by appliance, power mode, function, etc. The scope of the study is all network-connected equipment, which can be classified according to whether they are for professional or domestic use, and grouped as in Table 4:

Table 4: Product groups within the scope of the study[29]

	Domestic	Professional
Desktop PC	X	X
Notebook PC	X	X
Display	X	X
Network-Attached Storage device (NAS)	X	
Inkjet Printer	X	X
Electro Photography Printer	X	X
Phones	X	X
DSL Gateway	X	
Simple TV	X	
Simple Set-Top Box (STB)	X	
Complex TV	X	
Complex STB	X	
Simple Player/Recorder	X	
Complex Player/Recorder	X	
Game Console	X	

These product groups include machines connected to external networks (through a DSL gateway, DTV connection, etc.) as well as other equipment connected to internal networks with or without intermediate equipment, such as routers. These could be game consoles, audio receivers, media players, etc., connected via data cables or PC, printers and other IT equipment connected via routers or gateways.

The functioning of these internal and external IT networks is similar: a router or gateway is needed to distribute the connection traffic between the different equipments, and a standby mode is required in order to maintain a network link. Digital media networks and other internal networks without routers or gateways also have a standby function in which the device is not performing its primary function but is ready to receive a signal and pass into on mode. It is useful

[29] Based on Fraunhofer IZM and BIO (2011) *Preparatory study Lot 26 for Ecodesign of Networked standby*, European Commission (DG ENER), in the framework of the Ecodesign Directive (2005/32/EC), available at www.ecostandby.org.

to distinguish between edge devices and network equipment (where the main function is to maintain network links) because their function and energy-saving potential are quite different.

Household electrical appliance categories such as fridges or air conditioning systems that might become network-connected in the near future are considered negligible (around 5% of the market) in terms of today's stock.[30] Therefore, they are excluded from the assessment. Electric vehicles, which might also be considered network-connected in future, are also excluded, as are many smaller product groups (e.g. network-connected projectors) whose presence in the market is still very low.

Table 5: Products included as network-connected equipment in the next decade

	Home	Office
Fridges	X	
Washing machines	X	
Dishwashers	X	
Air conditioning/heating	X	X
Ovens	X	
Vacuum cleaners	X	
Intelligent blinds	X	X
Security systems	x	X

The average current power management setting in network-connected equipment is actually the absence of a power management scheme. Devices enter an "idle" state, a mode in which the device is on, but not processing any data. Typically between 8 and 25 W but sometimes as high as 125 W, this is a mode of reduced functionality that does not disturb the low-level processes of the machine and retains active traffic processing for a quick resume-time-to-application – generally no applications are running.

Advanced power settings in network-connected equipment include several low power modes, which consume less energy and maintain minimum network traffic. The automatic selection of these low power modes in a minimum period of network inactivity allows the maximum energy savings without requiring changes in user interaction.

These low power states vary between different manufacturers. In the ENER Lot 26 preparatory study some generic advanced power states are defined as follows:

- LowP1: A hypothetical low power state – about 50% reduction in energy consumption over Idle; this is not generally seen today in current products but is achievable through the use of multi-core processors, voltage and frequency scaling, power islands, etc. However, note that these power savings are related to the main function, which is not necessarily associated with network functionality;
- LowP2: A "sleep" mode that is entered automatically after a period of inactivity (but can be programmed or manually invoked by the user). The product

[30] Fraunhofer IZM and BIO (2011) *Preparatory study Lot 26 for Ecodesign of Networked standby*, European Commission (DG ENER), in the framework of the Ecodesign Directive (2005/32/EC), available at www.ecostandby.org.

maintains network connectivity in this mode and has a delay of less than 10 seconds associated with it;

- LowP4: Similar to a "hibernate" or "soft-off" power mode with Wake-On-LAN (WOL) functionality. The delay for re-entering active mode is generally greater than 10 seconds.

Wasted energy is defined as the amount of energy consumed that is not necessary for the provision of the functionality expected by the user. Not all energy consumed during standby and idle modes can be described as wasted, since such modes are considered part of the product's functionality. Indeed, an acceptable level of performance is a prerequisite for any power management system to be successful in the long term. Also, the development of energy-efficient smart grids implies multiple home networks and embedded communications in a wide range of appliances and equipment. However, if careful consideration is not given to the design and implementation of low energy networks within smart grids, there could be significant energy use associated with this network expansion.

The performance of an average product can be compared with the best available product identified as a benchmark of the upper limit of improvement potential that is achievable within a reasonable timeframe and without adversely affecting functionality. According to the results of the Lot 26 preparatory study,[31] the energy saving potential in the EU-27 for network-connected equipment by means of optimised power management settings is 20.08% of the total energy consumed by this kind of equipment in 2020.

The figure of 20.08% was calculated assuming mandatory implementation of a power-down sequence in all network-connected equipment, activated by default when the equipment remains "idle" for a defined period of time. This sequence is different for each type of equipment: one phase for "High network availability equipment", one phase for "Medium network availability equipment", and two phases for "Low network availability equipment". This power management system is intended to create an active power management while providing flexibility and convenience in the use of the equipment.

The characteristics of the phases are as following:

- "High Network Availability":
  - Default delay time 20 minutes
  - Power down target ≤ 12 Wh/h
  - Resume time to application < 1 second
- "Medium Network Availability":
  - Default delay time 20 minutes
  - Power down target ≤ 6 Wh/h
  - Resume time to application ≤ 15 second

[31] Fraunhofer IZM and BIO (2011) *Preparatory study Lot 26 for Ecodesign of **Networked standby**,* European Commission (DG ENER), in the framework of the Ecodesign Directive (2005/32/EC), available at www.ecostandby.org.

- "Low Network Availability" (in two phases):
  - Phase 1: Default delay time 20 minutes
  - Phase 1: Power down target not specified (12 W as orientation)
  - Phase 2: Default delay time 20 minutes after start of phase 1
  - Phase 2: Power down target ≤ 3 Wh/h

The range of potential energy savings for network equipment given by Lanzisera et al. (2010) is 20-50%, based on full market penetration of efficient technologies. So 20.08% can be considered a realistic if conservative estimate of savings based on technology available in the short term. However, it should be borne in mind that the products concerned are different since Lot 26 considered a more complete set of network-connected equipment than Lanzisera et al.

Another point of comparison is the potential 33% reduction in electricity use by ICT in 2020 estimated by BIO (2008).[32] In order to calculate that improvement potential, various improvement scenarios from existing EuP preparatory studies were compiled along with other relevant data for products not covered by EuP studies. However, that estimate included the full range of improvement options, not just network-related ones. Some of the general improvements or trends included in the analysis are:

- Ongoing miniaturisation of hardware elements, with lower power requirements;
- More mobile devices using rechargeable batteries and external power supplies encourage power management in ICT devices;
- More multifunctional devices are substituting multiple single function devices;
- Advanced power management with automatic shift into network standby, power control, etc.;
- Advanced display technologies with high potential to reduce energy consumption.

In the hypothetical case of all the products featuring non-operating mode power consumption of 1 W or less (following the IEA *1-Watt* plan), the average power per household could be reduced from 92.2 Watts to 32.3 Watts, as shown in the Energy Efficient Strategies study,[33] which means an average reduction of power consumption of around 65%. This savings potential could be assumed to be towards the upper limit of technical potential with respect to today's technologies.

Assuming the same improvement potential for all countries, as presented in Table 3, the energy saving potential of network-connected equipment worldwide would be 85 TWh based on Lot 26 estimates for the EU; 140 TWh based on BIO (2008) estimates; and 275 TWh technical potential (Table 6).

[32] BIO (2008) *Impacts of ICT on energy efficiency*, European Commission DG INFSO, Brussels.

[33] Energy Efficient Strategies (2006) *2005 Intrusive Residential Standby Survey Report*, report for E3.

Table 6: Energy wasted by network-connected equipment worldwide, 2008

Country/Region		Energy wasted (TWh) 20.08% savings potential	Energy wasted (TWh) 33% savings potential	Energy wasted (TWh) 65% savings potential
Regions	Africa	1.08	1.78	3.49
	Asia excluding Japan and Korea	9.23	15.22	29.87
	Europe	21.15	34.87	68.44
	Former USSR	3.87	6.38	12.53
	Latin America	3.05	5.02	9.86
	Middle East	3.08	5.07	9.96
	North America	34.02	56.08	110.08
	Australia, Japan, Korea, New Zealand	9.62	15.86	31.13
World		85.11	140.29	275.36
Total APP		*50.02*	*82.44*	*161.83*

The calculations based on the Lot 26 preparatory study assume the same power management characteristics in the current stock of network-connected equipment worldwide: on-mode and idle mode without an advanced power management system. User behaviour is not included in the estimates since, as mentioned earlier, the advanced power management achieves automatic low power modes independent of any changes in user interaction.

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Step 3: Projections of energy use and waste

This step projects the energy wasted by network-connected equipment to 2015 and 2020. Two cases are analysed: a business-as-usual case with current on-mode and idle mode characteristics, and an improved case with higher penetration of more advanced power management systems. Note that these projections are partly based on expert judgement and assumptions.

In the residential sector, the numbers and types of appliances owned are driven by income, population, geography, cultural and other factors. Demand in households in different countries and even within countries can vary enormously. The United Nations projects that world population will continue to grow over the projection period, and since household sizes are declining, the number of households is projected to grow even faster. Economic development, accompanied by urbanisation and changing lifestyles, is proceeding apace in many countries, despite the financial crisis and economic slowdown at world level. The situation is similar, if not quite as striking, for office equipment.

Network-connected appliances are relatively new and are still being developed, so demand for them is not expected to saturate to the same degree as some larger appliances. Lanzisera et al. (2010) project 6% annual growth of energy consumption of network equipment over 2008-2012 in the United States and 7% at world level.[34] As the growth of network-connected equipment is correlated with that of network equipment, similar growth rates can reasonably be applied to network-connected equipment in general. In order to take into account the higher growth rate at world level, regional growth rates are adjusted according to trends in IP traffic growth and the relationship between IP traffic growth and energy consumption growth in the United States.[35]

Note that the percentage increase in household energy consumption over 1990-2005 was not very different in OECD countries (+22%) and non-OECD countries (+18%).[36] Energy costs are a larger share of household income in developing countries, which should increase the incentive to adopt more efficient appliances as they become available at reasonable prices.

Countries have seen marked improvements in the unit energy consumption of large appliances since 1990, with the exception of televisions. However, total energy consumption in the EU for example fell only in the cases of refrigerators and washing machines. For other appliances, improved efficiency was offset by higher levels of ownership and use. In this study, for network-connected equipment, the business-as-usual scenario assumes that unit efficiency improvements only partially offset rising levels of ownership, new functionalities and more intensive use patterns.

Cisco forecasts that the number of networked devices per capita worldwide will reach one during 2011 and two by 2015, thereby increasing the potential amount of time and number of ways a

[34] Lanzisera, S., Nordman, B. and R.E. Brown (2010) "Data Network Equipment Energy Use and Savings Potential in Buildings", paper presented at ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar.
[35] Cisco (2011) *Cisco Visual Networking Index: Forecast and Methodology, 2010-2015*, Cisco. Accessed at: www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf.
[36] IEA (2008) *Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis*, OECD/IEA, Paris.

user can be connected to a network.[37] In addition, screen space will increase to 8 billion square feet by 2015, average residential broadband speed will increase fourfold and computing power will continue to increase as multicore systems increase their market share. All of these trends point to greatly increased energy consumption. Furthermore, Cisco identifies emerging trends not included in its forecasts that could increase traffic much more, such as cloud gaming, live TV over Internet or 3D TV.[38]

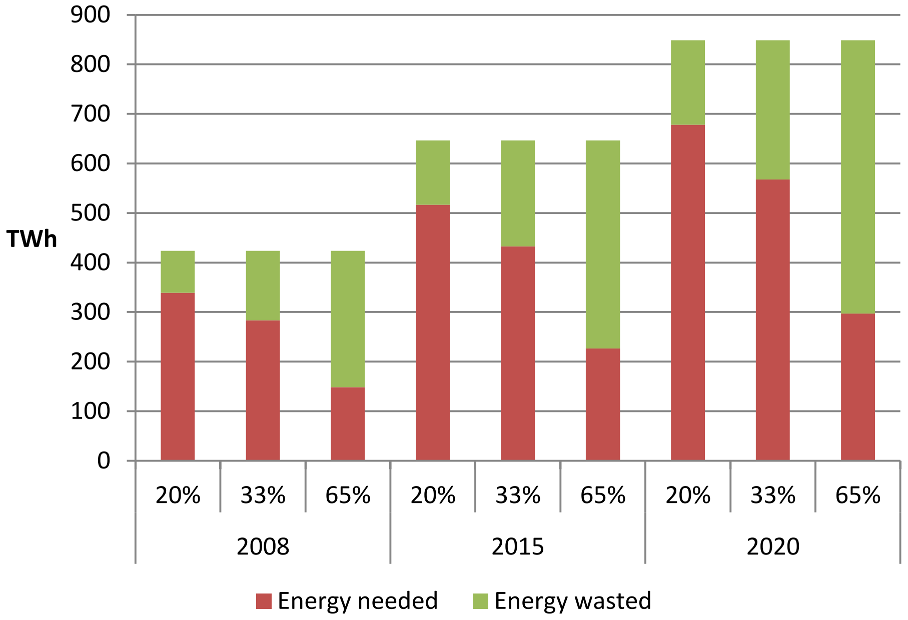
It is assumed that energy consumption growth rates decline slightly from 2012 onwards. The yearly growth rate is assumed to decline by 2% per year for the rest of the projection period, i.e. from 7.5% on average 2008-2015 to 6.3% on average 2015-2020 at world level. This is a similar decline to that projected in *World Energy Outlook 2009* for the rate of growth of world final electricity consumption (from 2.7% in 2007-2015 to 2.4% in 2015-2030).[39] The fact that the rate of growth of network-connected power is greater than that of total power consumption in all regions reflects a growing share of network-connected power.

The percentages of energy savings potential due to advanced power management and technical improvement options used in the previous step (20.08%, 33% and 65%) have been maintained in the projections. The results are shown in Table 7 and the figure below.

Table 7: Projected energy consumption and waste by network-connected equipment worldwide

	Energy wasted, 2015 (TWh)			Energy wasted, 2020 (TWh)		
Country/Region	20.08% savings potential	33% savings potential	65% savings potential	20.08% savings potential	33% savings potential	65% savings potential
Africa	1.78	2.93	5.75	2.45	4.04	7.94
Asia excl. Japan and Korea	14.27	23.53	46.18	18.90	31.16	61.15
Europe	32.34	53.31	104.64	42.52	70.08	137.57
Former USSR	6.08	10.02	19.66	8.13	13.39	26.29
Latin America	4.94	8.15	16.00	6.76	11.14	21.86
Middle East	5.07	8.36	16.40	6.99	11.53	22.63
North America	50.86	83.83	164.56	65.90	108.62	213.21
Australia, Japan, Korea, NZ	14.44	23.79	46.71	18.75	30.91	60.66
World	129.78	213.92	419.90	170.40	280.87	551.31
Total APP	*75.19*	*123.94*	*160.77*	*97.54*	*243.28*	*315.57*

[37] Cisco (2011) *Cisco Visual Networking Index: Forecast and Methodology, 2010-2015*, Cisco. Accessed at: www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf.
[38] Cisco (2011) *Entering the Zettabyte Era*, part of the Cisco Visual Networking Index initiative. Accessed at: www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/VNI_Hyperconnectivity_WP.html.
[39] IEA (2009) *World Energy Outlook 2009*, OECD/IEA, Paris.



900
800
700
600
500
400
300
200
100
0
TWh
20%
33%
65%
20%
33%
65%
20%
33%
65%
2008
2015
2020
Energy needed
Energy wasted

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Conclusions

The objective of this study was to estimate the energy wasted by network-connected equipment due to excess connectivity and that could be saved through better power management policies. Total energy consumption by network-connected equipment is estimated using a top-down approach based on available electricity consumption data, and weighted extrapolation using an index of ICT development. It is estimated that in 2008, total energy consumption by network-connected equipment was 424 TWh. Based on market trends, this is projected to increase to 646 TWh in 2015 and 849 TWh in 2020 – double the 2008 level.

The lower-end estimate of wasted energy is around 20%, as a result of excess connectivity and/or the use of sub-optimal technologies instead of cost-effective improved technology. This 20% of energy could be saved by means of implementation of power management and power-level reduction policies. The maximum estimate (technical potential) is around 65% of energy, assuming a low-power state of 1 W for all network-connected equipment. This large amount of energy savings would require both technical improvement of the products and components, and the implementation of effective power management policies on them.

The amount of energy wasted by excessive connectivity is estimated then between 85 TWh and 275 TWh in 2008, rising to between 130 TWh and 420 TWh in 2015 and between 170 TWh and 551 TWh in 2020, an amount superior to the entire electricity consumption of all network-connected equipment in North America in 2008.

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References

Australian Department of the Environment, Water, Heritage and the Arts (2008) *Energy use in the Australian residential sector*.

Bertoldi, P., Aebischer, B., Edlington, C., Hershberg, C., Lebot, B., Lin, J., Marker, T., Meier, A., Nakagami, H., Shibata, Y., Siderius, H.P. and C. Webber (2002) *Standby Power Use: How Big is the Problem? What Policies and Technical Solutions Can Address It?*, available at www.managenergy.net/download/ACEEE2002-paper569.pdf.

Bio Intelligence Service (2006-2007) *Preparatory study Lot 6 for Ecodesign of stand-by and off-mode* (all applications covered: computers, TV, ICT, telephone, small appliances), European Commission (DG TREN), in the framework of the Ecodesign Directive (2005/32/EC), available at www.ecostandby.org.

- (2008) *Impacts of ICT on energy efficiency*, European Commission DG INFSO, Brussels.

- (2010-2012) PrimeEnergyIT, European Commission (Intelligent Energy Europe project aiming to provide market support for energy efficient IT infrastructure).

Cisco (2011) *Cisco Visual Networking Index: Forecast and Methodology, 2010-2015*, Cisco. Accessed at: www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf.

- (2011) *Entering the Zettabyte Era*, part of the Cisco Visual Networking Index initiative. Accessed at: www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/VNI_Hyperconnectivity_WP.html.

Energy Efficient Strategies (2006) *2005 Intrusive Residential Standby Survey Report*, report for E3.

Fraunhofer IZM and Bio Intelligence Service (2009-2011) *Preparatory study Lot 26 for Ecodesign of Networked standby*, European Commission (DG ENER), in the framework of the Ecodesign Directive (2005/32/EC), available at www.ecostandby.org.

Harrington, L. and B. Nordman (2010) *Standby Power and Low Energy Networks – issues and directions*, report for APP and IEA 4E Standby Annex.

International Energy Agency (IEA) (2006), *Energy Technology Perspectives: Scenarios and Strategies to 2050*, OECD/IEA, Paris.

- (2008) *Energy Technology Perspectives 2008*, OECD/IEA, Paris.

- (2008) *Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis*, OECD/IEA, Paris.

- (2009) *World Energy Outlook 2009*, OECD/IEA, Paris.

- (2009) *IEA Scoreboard 2009: Key Energy Trends Over 35 Years*, OECD/IEA, Paris. Accessed at: http://iea.org/textbase/nppdf/free/2009/scoreboard2009.pdf.

- (2010) *Key World Energy Statistics 2010*, OECD/IEA, Paris.

ITU (2010) *Measuring the Information Society*, available at www.itu.int/ITU-D/ict/publications/idi/2010/Material/MIS_2010_without_annex_4-e.pdf.

Lanzisera, S., Nordman, B. and R.E. Brown (2010) "Data Network Equipment Energy Use and Savings Potential in Buildings", paper presented at ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar, accessed at: http://eec.ucdavis.edu/ACEEE/2010/data/papers/2195.pdf.

VHK (2011) *Study for the Amended Ecodesign Working Plan*, Interim Report.

Waide, P. (2009) "Appliance energy policy and technical standards: Plugging the gaps", presentation, OECD/IEA, Paris.

World Business Council for Sustainable Development (WBCSD) (2008) *Energy Efficiency in Buildings: Business realities and opportunities*, WBCSD, Geneva.

Regional definitions

AFRICA: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Western Sahara Zambia and Zimbabwe.

ASIA EXCLUDING JAPAN AND KOREA: Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Cook Islands, East Timor, Fiji, French Polynesia, India, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macau, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Palau, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Chinese Taipei, Thailand, Tonga, Vanuatu and Vietnam.

EUROPE: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Former Yugoslav Republic of Macedonia, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

FORMER USSR: Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

LATIN AMERICA: Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, St Kitts and Nevis, Saint Lucia, Saint Pierre et Miquelon, St. Vincent and the Grenadines, Suriname, Trinidad, Turks and Caicos Islands, Uruguay and Venezuela.

MIDDLE EAST: Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates and Yemen.

NORTH AMERICA: Canada, Mexico and United States.

AUSTRALIA, JAPAN, KOREA AND NEW ZEALAND.

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ICT development index

Country	IDI 2008	Country	IDI 2008
Albania	3.12	Djibouti	1.57
Algeria	2.65	Dominican Rep,	2.91
Angola	1.4	Ecuador	2.95
Argentina	4.38	Egypt	2.7
Armenia	2.94	El Salvador	2.61
Australia	6.9	Eritrea	1.08
Austria	6.72	Estonia	6.41
Azerbaijan	3.18	Ethiopia	1.03
Bahrain	5.67	Fiji	2.81
Bangladesh	1.41	Finland	7.02
Belarus	4.07	France	6.55
Belgium	6.36	Gabon	2.16
Benin	1.35	Gambia	1.62
Bhutan	1.62	Germany	6.95
Bolivia	2.62	Ghana	1.75
Bosnia and Herzegovina	3.65	Greece	6.03
Botswana	2.3	Guatemala	2.53
Brazil	3.81	Guinea	0.93
Brunei Darussalam	5.07	Guinea-Bissau	0.97
Bulgaria	4.87	Haiti	1.31
Burkina Faso	0.98	Honduras	2.5
Cambodia	1.7	Hong Kong, China	7.04
Cameroon	1.4	Hungary	5.64
Canada	6.49	Iceland	7.23
Cape Verde	2.62	India	1.75
Chad	0.79	Indonesia	2.46
Chile	4.2	Iran (I,R,)	3.08
China	3.23	Ireland	6.52
Colombia	3.65	Israel	6.19
Comoros	1.46	Italy	6.15
Congo	1.48	Jamaica	3.54
Congo (Dem. Rep)	1.16	Japan	7.12
Costa Rica	3.46	Jordan	3.33
Côte d'Ivoire	1.45	Kazakhstan	3.47
Croatia	5.53	Kenya	1.69
Cuba	2.66	Korea (Rep,)	7.68
Cyprus	5.37	Kuwait	3.64

Czech Republic	5.45	Kyrgyzstan	2.65
Denmark	7.53	Laos P,D,R	1.74
Lithuania	5.55	Singapore	6.95
Luxembourg	7.71	Slovak Republic	5.38
Macao, China	6.29	Slovenia	6.26
Madagascar	1.31	South Africa	2.79
Malawi	1.28	Spain	6.27
Malaysia	3.96	Sri Lanka	2.51
Maldives	3.54	St. Vincent and the Grenadines	4.59
Mali	1.19	Sudan	1.57
Malta	5.82	Swaziland	1.9
Mauritania	1.57	Sweden	7.85
Mauritius	3.44	Switzerland	7.19
Mexico	3.25	Syria	2.76
Moldova	3.37	Tajikistan	2.25
Mongolia	2.71	Tanzania	1.17
Montenegro	4.57	TFYR Macedonia	4.32
Morocco	2.68	Thailand	3.27
Mozambique	1.05	Togo	1.36
Myanmar	1.71	Trinidad & Tobago	3.83
Namibia	2.04	Tunisia	3.06
Nepal	1.34	Turkey	3.9
Netherlands	7.37	Turkmenistan	2.38
New Zealand	6.81	Uganda	1.3
Nicaragua	2.18	Ukraine	3.87
Niger	0.9	United Arab Emirates	6.11
Nigeria	1.65	United Kingdom	7.07
Norway	7.11	United States	6.54
Oman	3.45	Uruguay	4.34
Pakistan	1.54	Uzbekistan	2.25
Panama	3.66	Venezuela	3.67
Papua New	1.08	Viet Nam	3.05
Paraguay	2.75	Yemen	1.52
Peru	3.27	Zambia	1.42
Philippines	2.87	Zimbabwe	1.51
Poland	5.29	Burkina Faso	0.98
Portugal	5.77	Cape Verde	2.62
Qatar	4.68	Chad	0.79
Romania	4.73	Comoros	1.46
Russia	4.54	Djibouti	1.57
Rwanda	1.19	Gambia	1.62
Saudi Arabia	4.24	Guinea	0.93

Senegal	1.49	Guinea-Bissau	0.97
Serbia	4.23	Lesotho	1.46
Seychelles	3.64	Madagascar	1.31
Malawi	1.28	Uganda	1.3
Mali	1.19	Bhutan	1.62
Mauritania	1.57	Fiji	2.81
Mauritius	3.44	Laos P,D,R	1.74
Niger	0.9	Macao, China	6.29
Rwanda	1.19	Maldives	3.54
Seychelles	3.64	Papua New	1.08
Swaziland	1.9		

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