Mobile Device Efficiency

Final Report

Report Prepared for IEA 4E EDNA by Viegand Maagøe
November 2022
The Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP), has been supporting governments to co-ordinate effective energy efficiency policies since 2008.

Fifteen countries have joined together under the 4E TCP platform to exchange technical and policy information focused on increasing the production and trade in efficient end-use equipment. However, the 4E TCP is more than a forum for sharing information: it pools resources and expertise on a wide range of projects designed to meet the policy needs of participating governments. Members of 4E find this an efficient use of scarce funds, which results in outcomes that are far more comprehensive and authoritative than can be achieved by individual jurisdictions.

The 4E TCP is established under the auspices of the International Energy Agency (IEA) as a functionally and legally autonomous body.

Current members of 4E TCP are Australia, Austria, Canada, China, Denmark, the European Commission, France, Japan, Korea, Netherlands, New Zealand, Switzerland, Sweden, UK and USA.

Further information on the 4E TCP is available from: www.iea-4e.org

The EDNA Annex (Electronic Devices and Networks Annex) of the 4E TCP is focussed on a horizontal subset of energy using equipment and systems - those which are able to be connected via a communications network. The objective of EDNA is to provide technical analysis and policy guidance to members and other governments aimed at improving the energy efficiency of connected devices and the systems in which they operate.

EDNA is focussed on the energy consumption of network connected devices, on the increased energy consumption that results from devices becoming network connected, and on system energy efficiency: the optimal operation of systems of devices to save energy (aka intelligent efficiency) including providing other energy benefits such as demand response.

Further information on EDNA is available at: edna.iea-4e.org

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1 Executive summary

In this report the energy use of mobile devices is analysed, followed by a comparative overview of existing policies addressing the energy efficiency of mobile devices. Based on this policy overview, the gaps have been identified and policy measures addressing these gaps are recommended.

A mobile device is defined as: "A portable device to be used for extended periods of time without connection to the mains supply using a built-in battery or other kind of energy source. Large transportation devices such as electrical vehicles are not included in the analyses, as they are treated in separate legislative frameworks from all the other mobile devices and driven by a very different policy agenda tied to the goal of decarbonising the transport sector.

1.1 Energy use of mobile devices

The global energy use of mobile devices is calculated from an estimated world stock for each product type and the average annual energy consumption per product. It is important to note that the report only provides rough estimates and that there are significant uncertainties related to the used figures and assumptions. According to this estimation, the stock of all mobile devices will almost double in 2030 compared to 2020 (from 17 to 32 billion devices). Smartphones are in 2020 representing the largest share of the stock with 6 billion smartphones in use globally, followed by mobile phones, tablets, and wireless (Bluetooth) headsets. Products that will experience the highest growth in stock from 2020 to 2030 are wearables, handheld GPS, and tablets.

In general, mobile devices have a rather low annual energy consumption per unit because they are battery operated and the running time on a full battery load is an important issue for the functionality of the product, which then is an incentive for the manufacturers to reduce the energy consumption and thereby increase battery run time. However, some mobile devices have a relatively high annual energy consumption per unit in the use phase, especially products using energy for moving the product itself. Such products are among others drones, robot lawnmowers, e-mopeds, and robot vacuum cleaners. Other mobile devices have low energy consumption per unit but a high total energy consumption of the stock due to the very high number of products in the stock. Such devices are for instance smartphones, tablets, portable battery-driven tools, and wireless (Bluetooth) headsets.

Totally, the annual energy consumption for the mobile devices studied is expected to double in the period from 2020 to 2030 (from 153 to 339 TWh per year). Tablets, notebooks, smartphones, robot lawnmowers and E-mopeds are the products that are expected to have the highest energy consumption off all mobile devices in 2030.

1.2 Energy efficiency policies for mobile devices

An overview of energy efficiency policy measures for mobile devices around the world (primarily in EDNA member countries) is outlined, where the similarities and differences between the schemes regarding scope, test methods, metrics, and requirements are identified and described.

We assessed various schemes addressing energy efficiency and environmental aspects, but only few policy measures for mobile devices were identified. Except for tablets and notebooks, the investigated programmes do not include energy efficiency requirements for mobile devices. But some programmes incorporate requirements for external power supplies (EPS) supplied with mobile devices and embedded battery chargers. On component level policy measures were only identified for EPS and battery chargers. The investigated programmes are primarily:

- The EU Ecodesign Directive and EU Labelling Regulation and implementing measures within these framework
- US Department of Energy (DoE) appliance standards and rulemaking
- TCO Certified
- Energy Star
- EPEAT/ecolabel
• Australia MEPS and Energy Rating label (in conjunction with New Zealand where appropriate)
• New Zealand energy efficiency regulations (NZ regulations)
• Top Runner Japan
• Energy Efficiency Labelling and Standard Korea
• Canada’s Energy Efficiency Act and Energy Efficiency Regulations

The only mandatory policy measures identified for mobile devices are the EU Ecodesign Regulation (MEPS) for notebooks, the Japanese Top Runner approach for notebooks and the MEPS implemented for notebooks in Australia/New Zealand.

Various voluntary schemes exist for notebooks, and they all relate to the ENERGY STAR Programme for energy efficiency, which seems to be the most widely used specifications for computers. Besides the ENERGY STAR Programme itself, it is also used as a basis for TCO Certified, EPEAT, EU GPP, EU ecodesign and various ecolabels.

For components and equipment related to mobile devices there are various policy measures in place for EPS (including mandatory minimum efficiency requirements), one measure for battery chargers embedded in or separate from the device (US DoE mandatory requirements), and requirements for internal power supplies in computers. For other components no relevant measures have been identified.

1.3 Gap analysis

Several gaps are identified from the overview of policy measures and the detailed analysis of the existing measures regarding scope, metrics etc. These gaps are found even for devices or components where some regulations are in place.

Computers
For computers, all regions in the assessment have requirements, however, slates and tablets are only to some extent covered by energy efficiency requirements, showing some inconsistencies in the scope of regulations for computers. The Top Runner program (Japan) and the AS/NZS MEPS do not include requirement for slates and the EU Ecodesign Regulation and the ENERGY STAR Specification to some extent exclude slates and tablets based on power consumption, screen size or functions. In general, small handheld computer devices seem to be exempted either based on screen size or power consumption or by mentioning them as exempted products in the legislation.

Even though all the identified efficiency requirements are based on TEC (total/typical energy consumption), the metrics and requirements vary significantly from program to program and from region to region. This seems inappropriate for computers, which to a very high extent are placed on the global marketplace. Lack of harmonisation of metrics and requirements are identified as a huge gap.

Examples of other identified gaps are lack of requirements for active mode for slates and tablets, insufficient and varying requirements for internal power supply, lack of harmonisation of standards (some regions use IEC standards, while others have their own standards), and lack of limits for low power modes and power management requirements.

Other mobile devices (than computers)
No energy efficiency measures were identified for other mobile devices. For some devices this is not considered as a gap because the relevance of energy efficiency measures for the use phase is low (except for some horizontal issues described below), but resource efficiency requirements are probably highly relevant. However, for smartphones, robot and handheld vacuum cleaners, and motor operated devices (for instance lawnmowers) lack of energy efficiency requirements are considered as gaps, because of the high energy consumption of the devices in the use phase (for smartphones due to the high number of devices).

Components (EPS and battery chargers)
Various measures exist for EPS including mandatory requirements, with Japan as the only country where no requirements are found for EPS. However, still various gaps were identified regarding coverage of the requirements and
harmonization of the used metrics. Examples of EPS that are not covered by requirements in some regions are EPS for handheld power tools, means of transport, motor operated products, medical equipment, and EPS with nameplate output above 250 W.

No mandatory requirements were identified for wireless power supplies (which are not EPS because these per definition are wired). This is also considered as a gap because the use of wireless power supplies/chargers is increasing.

Only one measure was identified for battery chargers, and this is the US DoE’s energy conservation standard. It covers batteries that are wholly embedded in another consumer product, wholly separate from another consumer product, or partially embedded in another consumer product. Lack of energy efficiency requirements for battery chargers including requirements for the battery maintenance mode is a huge gap and will be addressed in the section of this report dealing with policy recommendation. No power limits for this mode have been identified although the battery maintenance mode is part of the metric to calculate the unit energy consumption in the DoE energy conservation standard for battery chargers.

Other components (than EPS and battery chargers)
For components other than EPS, battery chargers, and internal power supplies, no component requirements are identified. In general, very efficient components are used in mobile devices due to the importance of the battery operation time on a full battery load. Only for the DC motor used in motor operated equipment, lack of requirements is considered as a gap, because motor operated devices are among the products with the highest energy consumption per device per year, as well as among the products with the highest annual energy consumption of the stock. An increase of the motor efficiency will have a high influence on the energy consumption of these devices (depending on the user profile).

Horizontal gaps
Horizontal gaps are identified regarding power consumption in standby mode (especially networked standby), requirements for battery maintenance mode, and for aspects related to use and programming of apps and software.

Only the EU has mandatory power limits for standby and networked standby. In general, the standby consumption is low for mobile devices including networked standby due to the importance of high battery run time. But some products might still have a high energy consumption in standby mode for instance charging/docking stations for motor operated products and probably also for various mobile audio devices. The number of mobile devices in the stock is foreseen to rise steeply in the coming years and the large majority of these are foreseen to be internet connected. Lack of mandatory power limits is therefore considered as a gap.

No power limits have been identified for the battery maintenance mode. The battery maintenance mode is for instance not covered by the EU horizontal standby regulation because the charger in this mode is performing functions beyond standby functionality (as defined in the regulation). The only identified measure for battery maintenance mode is in the US DoE power conservation standard for battery chargers, where it is included in the metric for calculation of the UEC (Unit Energy Consumption). This is considered as a huge gap because many devices placed in a docking station for charging (for instance vacuum cleaners) will often stay in a battery maintenance mode with a relatively high-power consumption, once the battery is fully charged.

The use and programming/design of apps and software have a large influence on the energy consumption of mobile devices such as mobile devices such as notebooks and smartphones. Recent research by the German Environment Agency has shown significant differences in the energy consumption of different software application products with the same functionality. No mandatory legislation has been identified dealing with energy efficiency of software related issues and programming of apps, however, the German ecolabel the Blue Angel has developed basis criteria for purchasing of resources and energy efficient software products (DE-UZ 215).

1.4 Policy options to improve energy efficiency
Policy options to address the identified gaps are recommended for mobile computer devices, smartphones, vacuum cleaners, EPS, and battery chargers. In addition, a number of horizontal policy measures are suggested.
In general, for mobile devices with low unit energy consumption in the use phase, it is recommended to focus on horizontal measures with requirements for components such as EPS (including standardised MEPS and unbundling), battery charging systems and durability of the battery. For mobile devices with higher unit energy consumption, product specific requirement should be considered in combination with horizontal requirements. Relevant mobile devices with high unit energy consumptions are motor operated products such as robot lawn movers, e-mopeds, battery-driven vacuum cleaners including robots, drones, and notebooks and tablets.

**Computers (mobile types)**

For computers the most important recommendation is to ensure a high degree of harmonisation of the legislation dealing with efficiency of computers worldwide. This covers the harmonisation of measurement standards, international cooperation regarding establishment of new efficiency metrics (including active mode) for notebook computers including slates and tablets, the inclusion of slate and tablets in existing policy measures for computers (slates could also be included legislation together with smartphones as proposed in the EU), and the implementation of more ambitious requirements for internal power supplies (at least in line with the ambition level in the AS/NZS MEPS).

**Smartphones**

For smartphones, as first step it is recommended to follow the EU ecodesign preparatory work and consider the usefulness of this for a broader cooperation. The EU proposes to use the battery endurance as a basis for development of an energy efficiency classification (energy label with an A-G-scale) for smartphones and slate tablets. In the longer term, it could however also be used for development of minimum efficiency requirements.

**Vacuum cleaners**

It is recommended to develop policy measures for robots and portable (cordless) vacuum cleaners based on the Annual Energy Consumption, which should include both the energy consumption for vacuuming and the power consumption in battery maintenance mode. A formula specifically targeted robots and cordless vacuum cleaner should be developed. In addition, it is proposed to set requirements for the battery maintenance mode and other low power modes (could be horizontal requirements), and for the run time of the battery (from full load) at max. power consumption correlated to cleaning performance.

**Battery chargers**

For battery chargers it is recommended to develop requirements based on the method used by the US DoE supplemented with power limits for the maintenance mode and other relevant low power modes. The potential for more demanding requirements that the US DoE requirements should also be investigated. Harmonisation of the requirements between regions is strongly recommended. It is important that the requirements also cover battery chargers embedded in other products.

**EPS and wireless power supplies**

For EPS the most important recommendation is to ensure the harmonization of measurement standards and metrics for energy efficiency worldwide. This also involves the implementation of legislation for EPS in regions without energy efficiency measures for EPS. In addition, it is recommended to extend the scope of existing legislation to cover types of EPS that are currently exempt from requirements or not covered.

As it is expected that more and more mobile devices in the future will be charged via a wireless power supply instead of an EPS it is recommended to develop requirement for wireless power supplies. Development of policy options for wireless EPS will require more knowledge on the product and development of a test procedure. A test procedure should also consider the consumer behaviour and that this might be different for wireless power supplies than for the EPS, that per definition are wired.

**Horizontal policy measure**

For many mobile devices, standby power consumption especially in networked standby contributes largely to the total energy consumption over its lifetime. Therefore, it is recommended to consider ambitious requirements for power consumption in networked standby to prevent a huge increase in energy consumption due to a large number of mobile
devices with internet connection. It is proposed to go for a networked standby power limit below 0.5 W, which is more than twice as much as for smartphones. Requirements should also include power management to be ensure that products switch from active mode to networked standby.

Other horizontal recommendations are to develop ambitious requirement (power limits) for the power maintenance mode, which is relevant for various mobile devices and development of energy efficiency strategies and policies for the use and programming of apps.

The development of energy efficiency policies for use and programming of apps will be very complex because the energy consumption depends on both hardware, software, design and functionality of applications and the consumer behaviour (at least). The first steps in a policy development process could be to establish an overview of the problems and possible solutions. Next steps could be to create awareness among developers of hardware, software and apps and users, and develop practical guidelines and tools for developers and recommendation for users on how to use their devices and applications more efficiently. Practical guidelines could be implemented in a later step as policy measures/design standards around the world for development of software and applications.

Finally, it is also recommended to develop horizontal energy efficiency requirements for DC-motors. DC-motors are used in various mobile devices such as robot vacuum cleaner, lawn mowers, e-bikes etc., which are all characterized by having a high energy consumption per unit.
2 Introduction

The objective of this task defined by the Request for Proposal is to:

- Examine the energy used by mobile devices (connected and otherwise).
- Investigate policy options to improve their energy efficiency (including the power supply, the battery charging equipment, and the device itself, as well as the impact of various battery chemistries).
- Assess the similarities and differences between mobile device energy efficiency policies around the world. Compare their scope, test methods, metrics, MEPS, etc. and identify any gaps.
- Identify pathways towards international harmonization of policies for mobile devices.

This report is much focused on the policy options and policies for more energy efficient mobile devices that the EDNA members and other policy makers and stakeholders can use in their work. The report will provide a set of actionable policy recommendations, or at least topics for policy makers to consider, including recommendations that take into account how the policies can be harmonized internationally. The background for the policies and the recommendations is an analysis of energy consumption for mobile devices and policy options for improvements.

The subject is highly relevant due to the ongoing development towards more mobile devices. The number of mobile devices is increasing, though many of them are substituting stationary devices. Mobile devices are often used more than stationary devices of the same type and more devices are being sold. E.g. the computing work provided by a desktop computer is now typically provided by a combination of a laptop computer, a tablet and a smartphone and often supplemented by data centre computing work, though the data centre computing work is typically the same for desktop computers. Furthermore, these mobile devices are always or mostly always on, and always or almost always connected while in use.

On the other hand, the specific energy consumption per device has been reduced substantially for mobile devices compared to stationary devices mainly due to a focus on longer battery life.
3 Definition of Mobile Devices

It is important to clearly define the scope for the analysis, i.e. which mobile devices are considered in this study. The scope is mobile devices mainly used in households, in the public sector and in the office and commercial sectors at a global level. A mobile device is defined as:

“A portable device to be used for extended periods of time without connection to the mains supply by the use of a built-in battery or other kind of energy source.” Most definitions concerns internet connected mobile devices, but this study also includes types of mobile devices, which are typically not connected (for instance portable power tools).

Examples of products that fit this definition are listed in Table 1 below.

<table>
<thead>
<tr>
<th>Internet connected devices</th>
<th>Products investigated in other studies</th>
<th>Other mobile devices</th>
<th>Transportation devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Smartphones</td>
<td>• Unmanned aircrafts (drones)</td>
<td>• Grooming appliance (shavers, hair trimmers, toothbrushes)</td>
<td>• Small transportation devices: E-Mopeds, E-bikes, segways, monowheels, e-scooters etc.</td>
</tr>
<tr>
<td>• Tablets</td>
<td>• Portable battery-driven tools</td>
<td>• Mouse and keyboard</td>
<td>• Electric vehicles (cars, motorbikes, vans, trains etc.)</td>
</tr>
<tr>
<td>• Notebooks/laptops</td>
<td>• Household vacuum cleaners (battery driven)</td>
<td>• Battery operated toys</td>
<td></td>
</tr>
<tr>
<td>• Wearables/smart-watches</td>
<td>• Robot lawn movers</td>
<td>• Medical therapeutic devices</td>
<td></td>
</tr>
<tr>
<td>• Handheld gaming consoles</td>
<td></td>
<td>• Medical diagnostic devices</td>
<td></td>
</tr>
<tr>
<td>• E-readers</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>• Portable media players</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Portable speakers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Wireless headsets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Mobile internet devices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Handheld GPS</td>
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<td></td>
<td></td>
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<tr>
<td>• Industrial smart sensors</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Examples of products fitting the definition of “mobile devices”

The larger transportation devices will not be considered further in this report. While electric vehicles are in the product category with the highest energy consumption of all the products listed above, they are not included in the scope as they are treated in separate legislative frameworks from all the other devices that is driven by a very different policy agenda tied to the goal of decarbonising the transport sector. Smaller transportation devices, however, are more similar to the personal mobile devices listed in the table and are therefore included in the further analysis.

The total energy consumption will be estimated for the products in Table 1 (except electric vehicles), and these products will also be in focus in the review of relevant legislation and standards.

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1 Examples of definitions:
https://www.igi-global.com/dictionary/design-mobile-learning-museums/18836
https://www.lexico.com/definition/mobile_device
https://www.dictionary.com/browse/mobile-device
https://csrc.nist.gov/glossary/term/mobile_device
https://www.techopedia.com/definition/23586/mobile-device
https://en.wikipedia.org/wiki/Mobile_device
https://www.definitions.net/definition/mobile+device

All sites accessed 27/09/2021

4 Energy use of mobile devices

The aim of this section is to analyse the energy used by the mobile devices defined above. The estimated energy consumption is based on various sources provided in Table 16 in Annex A. Only for a few products more detailed data are available for instance from EU ecodesign and energy labelling product studies (only covering EU). Generally, the energy consumption is calculated on the basis of fragmented data from different sources, and thus entails large degrees of uncertainties and should be considered as estimates. However, these estimates give a good overview of which products consume more or less energy and thus where to focus politically when the goal is to decrease overall energy consumption.

The approach to the energy calculations has been to collect data on:

- Total world stock of each product type
- Annual energy consumption per product/year

If needed, modifications were made to the data found, e.g. scaling up of the stock from one region to the world, or averaging annual energy consumption of a product type across different sources. All assumptions and approaches have been described in detail below.

These figures were collected as of today (or most recent year) with a look into the near future (2030) regarding expected developments, especially for products and areas where many changes are expected to take place.

4.1 Energy consumption of the individual product types

This section provides an estimate of the energy consumption of the individual products that fit within the defined scope and provides an indicative stock of devices on the market today and in 2030. Furthermore, an estimated total annual energy consumption is presented in the end of the section. The method for finding and calculating the stock and total energy consumption is described in “Appendix A: Method description of stock and energy consumption”.

4.1.1 Unit Energy consumption

The annual unit energy consumption (UEC) of the devices in scope is shown in Figure 1. UEC is the annual energy consumption of a device, which is dependent on the energy consumption of the device in each mode or state (power draw in watt) and the corresponding time in each mode or state over a year (use hours) based on the use pattern, including active use and standby mode.³

Products with high UEC are typically characterised by having high energy consumption and being used for many hours during a year. E.g. a robot lawnmower runs for many hours each year and have a relatively high energy consumption compared to e.g. a smartphone.

Looking at Figure 1, it is clear that Unmanned Aircrafts System (drones) is an outlier with a very high UEC. The statistics for Unmanned Aircrafts Systems include both data for industrial UASs used for commercial use and hobby use. The commercial UASs have a very high UEC (estimated to 1290 kWh), because they are built to carry out “heavy” duty tasks and are being used for many hours per year, whereas the hobby drones have “low” UEC (36 kWh), because they are used relatively few hours in a year⁴,⁵.

Products with very low UEC are characterised by a very low active use, examples hereof are portable speakers and personal care products. Other products with very low UEC may be used for many hours, but managed to keep energy

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³ In this report UEC is used for the annual energy consumption of the product (Unit Energy Consumption). In the US, UEC is for batteries considered the non-useful energy consumed to charge a battery over the course of a year (the energy wasted during charging).


⁵ The UEC shown in Figure 1 represent a weighted average between UEC of commercial and hobby UASs. The weighted average is based on registrations in USA. https://www.faa.gov/uas/resources/by_the_numbers/
consumption very low, because the battery capacity is very limited due to the preferable small and light design. Examples hereof are industrial smart sensors, wearables, handheld GPS, feature-phones, smartphones and wireless headsets.

Figure 1: Annual Unit Energy Consumption (UEC) of mobile devices including both active mode and low power modes.

4.1.2 Stock

Figure 2 shows the total estimated current stock and the expected future stock in 2030 of all mobile devices included in this study. It is expected that the stock of all mobile device will almost double in 2030 compared to 2020. The forecast is a very rough estimate with considerable uncertainties, however, market forecasts for almost all products show that growth is expected (see Compound Annual Growth Rates and sources behind these rates in Appendix A, table 33 and table 2). A general significant growth of mobile devices is therefore expected, and the growth is also aligned with other studies that expect a substantial increase in sales and stock of lithium batteries\textsuperscript{6,7,8}, which is the battery type used in almost all mobile devices. Furthermore, the stock development is aligned with the technological development, resulting in decreasing prices of lithium batteries rapidly\textsuperscript{9,10}, making mobile devices the preferred choice when considering performance, mobility and price.

\textsuperscript{6} https://www.un.org/development/desa/dpad/publication/frontier-technology-issues-lithium-ion-batteries-a-pillar-for-a-fossil-fuel-free-economy/
\textsuperscript{7} Circular Energy Storage (2020) https://www.circularenergystorage-online.com/copy-of-placed-on-market-3 Q3 2021
\textsuperscript{8} Batteries in the Nordics – changing for circularity, The Nordic council of Ministers. NOT PUBLISHED YET.
\textsuperscript{9} https://www.iea.org/news/strong-policy-and-falling-battery-costs-drive-another-record-year-for-electric-cars
\textsuperscript{10} https://www.iea.org/news/a-rapid-rise-in-battery-innovation-is-playing-a-key-role-in-clean-energy-transitions
It is important to notice that increase in stock does not entail an increase in number of all devices on the global market, since for some products, the increase in stock of mobile devices is accompanied by a decrease of other products that are not battery-driven. E.g. robot lawnmowers replace petrol powered lawnmowers.

Figure 2: Total stock of all mobile devices in scope

Figure 3 shows the stock of each product type. The largest stock product category is represented by smartphones with 6 billion smartphones in use in the world\textsuperscript{11}, which is close to full market saturation (according to statistics, the world population in 2020 is 7.7 billion people\textsuperscript{12}, though many people have more than one phone). This means that the stock of smartphones is therefore expected not to grow as much as other products.

Some of the products that will experience the highest growth in stock are wearables, handheld GPS and tablets. These products will also end up being the products with high stock.

\textsuperscript{11} Statistic is based on subscriptions worldwide. See sources in appendix A.

\textsuperscript{12} https://data.worldbank.org/indicator/SP.POP.TOTL
4.1.3 Total annual energy consumption of all mobile devices

As a consequence of the growing stock, the total annual energy consumption of mobile devices worldwide is expected to grow to more than the double in 2030 compared to 2020. In this study the device energy consumption (UEC) is assumed to be constant for the whole forecast period. The total annual energy consumption of all mobile devices is shown in Figure 4.
Figure 5 shows the total annual energy consumption by product in 2020 and expected in 2030. Tablets, notebooks, smartphones, robot lawnmowers and E-mopeds are some of the products that are expected to consume the most energy of all products. It is important to note that this report only provides rough estimates of the total energy consumption and that there are significant uncertainties tied to the numbers. One of the most sensitive parameters is the UEC of smartphones, therefore the UEC from different sources have been further investigated.

The energy consumption of smartphones is very sensitive to the total annual energy consumption because the stock of smartphones is very high. The energy consumption of smartphones is reported in an ICT study\textsuperscript{13} conducted for the European Commission to be 3.9 kWh/year, however, a recent EU Ecodesign preparatory study on mobile phones, smartphones and tablets has estimated the consumption to be around 7 kWh/year\textsuperscript{14}. Another study that investigated the energy consumption of consumer electronics in U.S. homes in 2017\textsuperscript{15}, determined the energy consumption of smartphones to be 4.5 kWh/year. In this report the energy consumption of 4.5 kWh/year from the U.S. study has been used as a conservative estimate.

\textsuperscript{14} Ecodesign preparatory study on mobile phones, smartphones and tablets 2021. https://op.europa.eu/en/publication-detail/-/publication/a7764be4-853d-11eb-af5d-01aa75ed71a1/language-en
Many of the devices use the same type of components or functions and by aggregating horizontally the similar components or functions, it is possible to consider the potential policy options based on component or function. For some components such as internal or external power supplies, it may be easier to set requirements for similar components and functions that are common to a broad group of different products, than to set requirements to the individual products. A pre-condition is that the components are well-defined and can be measured separately from the complete product.

Figure 6 shows the aggregated stock of similar components or functions. The selected components and functions for each product type can be found in Appendix B. The variety of components and function within a product group can be significant, e.g. some robot lawnmower have a simple control unit that can be programmed locally, while more advanced models have network capabilities and therefore need more components and functions. In Figure 6 only the most basic components and functions of the products are shown, but the stock might be higher, if the components and functions of e.g. more advanced models are included.

It is important to notice that Figure 6 only reflects similar components and functions in devices today; it does not include any assumptions about future components and functions in products (e.g. an expectation of all E-bikes having
networked capabilities in the future). The increase in stock of similar components and functions is therefore only a reflection of the increase in stock of devices as shown in Figure 3.

The development of technology and decreasing prices of technology might lead to increased use of specific components and functions. The development of IoT (Internet of Things) is growing rapidly: in 2021 sources report 10 billion active IoT devices, this includes both stationary and mobile devices, while it is estimated that in 2030 25 billion IoT devices will be active. With the current trend of IoT, it is assumed that most of the mobile devices in scope will be smart devices, and thus connected, and the number of connected mobile devices might therefore reach 32 billion in 2030 (including smartphones, tablets and notebooks that are not considered IoT, because they are computational units). This will also lead to networked standby energy consumption of all mobile devices including devices that nowadays rarely have networked standby\(^{17}\) e.g. E-bikes, E-scooters and power tools.

External power adaptors and batteries are also inevitable large product groups as all mobile devices are equipped with a battery that needs charging. External power adaptors have been divided into three product groups: wired, wireless and docked. It is estimated that most products are still charged by wire, but wireless adapters have also gained larger market shares recent years. Due to the rapid development of lithium batteries in the latest years, it is assumed that all mobile devices use this type of batteries. Devices with lithium batteries need a battery management system, and battery management system is therefore also a product group of special interest.

Other components of interest based on stock size and consumption levels are diodes, processors, sensors, speakers and displays. It is important to state that Figure 6 only shows how many devices have the specific component or function. The figure does not show how many components per device are used, nor the development of components used in mobile devices (e.g. increase in use of sensors in mobile devices). Furthermore, Figure 6 does not provide any information about energy consumption of the components or functions.

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\(^{16}\) [https://dataprot.net/statistics/iot-statistics/](https://dataprot.net/statistics/iot-statistics/) accessed 29/10/2021

Figure 6: Stock of similar components and functions for all mobile devices
5 Energy efficiency policies for mobile devices around the world

In this section, an overview of energy efficiency policy measures for mobile devices around the world (primarily EDNA member countries) is established and the similarities and differences between the schemes regarding scope, test methods, metrics, and requirements are described. From this analysis and information, the potential gaps of these policies are identified.

The main focus of the identified policies is on measures to improve the energy efficiency in the use phase for the devices and the most important related components. Table 2 shows an overview of the most relevant measures identified for mobile devices and related components such as EPS and battery chargers. For notebook computers, there are various other voluntary measures addressing the energy efficiency in the use phase (not shown in the table). These are more regional and national environmental labels such as for instance the German Blue Angel and the Nordic Swan and procurement guidelines for instance the EU Green Public Procurement Criteria (GPP), which for energy efficiency in the use phase are based on ENERGY STAR for computers.

<table>
<thead>
<tr>
<th>Product / component</th>
<th>USA</th>
<th>Australia/New Zealand</th>
<th>EU</th>
<th>Japan</th>
<th>Korea</th>
<th>Canada</th>
<th>Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laptops/ notebooks</td>
<td>ENERGY STAR</td>
<td>EECA, E3 programme</td>
<td>Ecodesign MEPS for total energy consumption Requirements for EPS supplied with the laptop/notebook</td>
<td>Top Runner Sales weighted target for energy consumption per fiscal year</td>
<td>n.a.</td>
<td>n.a.</td>
<td>TCO certified Based on ENERGY STAR</td>
</tr>
<tr>
<td></td>
<td>Max. limit for typical energy consumption, EPS requirements, power management</td>
<td>Requirements based on Typical Energy Consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE appliance standard</td>
<td>Requirement for EPS supplied with the laptop/ notebook and embedded battery chargers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tablets/slates</td>
<td>ENERGY STAR</td>
<td></td>
<td>Ecodesign MEPS for total energy consumption Requirements for EPS supplied with the tablet</td>
<td>Top Runner Sales weighted target for energy consumption per fiscal year</td>
<td>n.a.</td>
<td>n.a.</td>
<td>TCO certified Based on ENERGY STAR</td>
</tr>
<tr>
<td></td>
<td>Max. limit for typical energy consumption, EPS, power management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>DOE appliance standard</td>
<td>Requirement for EPS supplied with the tablet and embedded battery chargers</td>
<td>EPEAT/eco-label</td>
<td>Refers to ENERGY STAR specifications for computers and internal power supplies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>----------------</td>
<td>--------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smart phones/ Mobile phones</td>
<td>DOE appliance standard</td>
<td>Requirement for EPS supplied with the phone and embedded battery chargers</td>
<td>n.a.</td>
<td>n.a.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacuums (robots and portable)</td>
<td>DOE appliance standard</td>
<td>Requirement for EPS supplied with vacuum and embedded battery chargers</td>
<td>n.a.</td>
<td>KEA Energy Efficiency Labelling and Standard Standby label for cordless phones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External power supplies (EPS)</td>
<td>DOE appliance standard</td>
<td>Requirement for EPS supplied with vacuum and embedded battery chargers</td>
<td>EECA, E3 programme Requirement for EPS Ecodesign Requirements for EPS</td>
<td>KEA Energy Efficiency Labelling and Standard MEPS (details not known) MEPS Requirements in line with the DOE appliance standard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery chargers</td>
<td>Efficiency standard for battery chargers including when embedded in products</td>
<td>n.a.</td>
<td>n.a.</td>
<td>KEA Energy Efficiency Labelling and Standard MEPS (details not known) MEPS Requirements in line with the DOE appliance standard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal standby requirements</td>
<td>DOE Procurement requirement for federal government to buy</td>
<td>n.a.</td>
<td>Ecodesign Power limits, power management and availability of standby</td>
<td>KEA Energy Efficiency Labelling and Standard e-standby power label</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18 New ecodesign and energy labelling regulations are under preparation. These expect to cover cordless and robot vacuum cleaners but probably not handheld vacuum cleaners
products with standby ≤ 1 W

Table 2: Overview of policy schemes covering mobile devices and type of requirements depending on regions/countries. Blue colour: Mandatory requirements. Orange colour: Voluntary schemes. See more details below. N.a. in the table means that no policy schemes have been identified.

5.1 Examples of programmes covering mobile devices

Generally, standards, MEPS, labelling, certification and top runner approaches have had a significant influence on energy efficiency globally and is expected to have triggered a halving of energy consumption of some home products. However, only a few mobile devices have been targeted by product specific requirements. Except for tablets and notebooks, the investigated programmes do not include energy efficiency requirements for mobile devices. However, some programmes include requirements for EPS supplied with mobile devices and embedded battery chargers. In addition, requirements for the EPS and battery chargers (including when embedded in products) as separate products exist.

The investigated programmes are shortly described below.

5.2 Relevant policy programmes

5.2.1 EU Ecodesign Directive and relevant regulations within this framework

The Ecodesign Directive is the EU framework for setting mandatory energy efficiency requirement and requirements for other significant environmental impacts in the life cycle of energy related products. The emphasis is on products with large energy savings potentials. However, also horizontal regulations addressing specific issues with large energy saving potentials have been implemented (standby and external power supplies). The mandatory requirements should be met by all products included in the scope of implementing measures placed on the EU market.

Within the framework of the ecodesign directive, the energy efficiency of mobile devices is addressed by:

- (EC) No 1275/2008 with regard to ecodesign requirements for standby, off mode and electric power consumption of electrical and electronic household and office equipment. Amended by regulation (EU) No 801/2013 to include limits for networked standby and to require power management for networked equipment.
- (EU) 2019/1782 laying down ecodesign requirements for external power supplies.
- (EU) No 617/2013 setting ecodesign requirements for computers and computer servers (including requirements for tablet and notebooks).

The standby regulation covers devices in the following categories: household appliances, information technology equipment intended primarily for use in the household sector, consumer equipment, toys, leisure, and sports equipment. However, the standby regulation does not apply to equipment placed on the market with a low voltage external power supply (an external power supply with a nameplate output voltage of less than 6 volts and a nameplate output current greater than or equal to 550 milliamperes) to work as intended and therefore various mobile devices are not within the scope of the regulation. The regulation is currently under review.

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21 Achievements of Energy Efficiency Appliance and Equipment Standards and Labelling Programmes 2021. 4E for the IEA
23 COMMISSION REGULATION (EU) 2019/1782
24 COMMISSION REGULATION (EU) No 617/2013
The EU ecodesign standby regulation dictates under which conditions electric appliances placed on the market in EU should automatically go to standby, off or networked standby modes and includes maximum limits for the power consumption for these low power modes. The battery maintenance mode i.e. topping up when charging level reaches a certain limit, which is very relevant for mobile devices, is not a standby mode because it is a key function and the standby regulation do not include power limits for this mode. However, if charging is paused when the desired charging level is reached, the appliance is considered to be in standby.

For some products the standby requirements have recently been included in the product specific regulations to better adapt the standby requirements to the functional requirements of the product regarding relevant low power modes, the power requirements for these modes and the time before the product should be switch to power-saving modes by the power management system. For standby, off mode and networked standby, the product specific regulations in most cases align with the requirements in the horizontal regulation. See a more about standby in Section 6.5.

The EU ecodesign regulation\(^\text{26}\) on energy efficiency for external power supplies (EPS) does not include battery chargers, where the EPS is directly connected to the battery. Generally, the no-load power must not exceed 0.5 W, and the active efficiency follows a specified calculation based on the nameplate power of the power supply.

For mobile phones and smart phones, the EU is currently developing an ecodesign policy measure (an energy label is also considered) planned for adoption in 2022. See more in Section 6.3.2

The EU is continuously working to review existing regulations and to prepare new regulations for products with high energy saving potentials in accordance with the current ecodesign and energy labelling working plan and with the review obligations in the current regulations.

With relevance for mobile devices, the following EU preparatory and review studies have been carried out for:

- Mobile phones, smart phones, and tablets
- Batteries (proposal for a separate regulation)\(^\text{27}\)
- Review of computer regulation
- Review of vacuum cleaner ecodesign regulation (EU) No 666/2013, which includes the assessment of a possible requirement for mobile vacuum cleaners (robots and cordless) and new energy label regulation.
- Other products included in an ICT Impact study\(^\text{28}\), which among others pointed out home audio equipment as a topic for future EU policy options (for instance smart Wi-Fi speakers).

In addition, on March 30, EU published its new Ecodesign and Energy labelling Working Plan for 2022-2024\(^\text{29}\). The working plan points out the priorities of the European Commission for ecodesign and energy labelling for the coming years.

5.2.2 **EU Energy Labelling Framework**

The EU Energy Labelling Framework establishes mandatory energy labelling requirements for products placed in the market in the EU (using an A-G scale for energy efficiency, where A is for the most energy efficient products). So far, no energy labelling regulation has been implemented for mobile devices. However, energy label regulations are under preparation for smart phones and mobile phones, vacuum cleaners (including robots and cordless types) and computers including laptops.

\(^{26}\) Commission Regulation (EC) No 278/2009

\(^{27}\) European Commission, 2020, Batteries and accumulators


5.2.3 US Department of Energy (DoE) appliance standards and rulemaking

The US Department of Energy (DOE) implements minimum energy conservation standards for selected appliances and equipment, and currently covers more than 60 different products\(^{30}\) within the following categories:

- Heating ventilation & air conditioning
- Lighting
- Electronics
- Bathroom & Plumbing
- Kitchen Appliances
- Laundry

Covered products must meet the energy conservation standard, when manufactured and distributed in commerce. An overview of all certified products can be found in the US Department of Energy’s Compliance Certification Database\(^ {31}\). Manufacturers have certified that the listed products are in compliance with relevant requirements in order to legally offer their products for sale in the U.S.

There are no DOE minimum energy conservation standards for mobile devices but for battery chargers\(^ {32,33}\) to be used with and in mobile devices and for external power supplies\(^ {34,35}\). This will be further analysed in the Section 6.4.2.

DOE follows a four-phase process when reviewing existing and developing new standards. Information on recent updates, current standards and test procedures, waivers, exceptions, and exemptions, statutory authority, and historical information can be found on specific product pages for each product\(^ {36}\). There is currently no energy conservation standard for computers.

5.2.4 TCO Certified

TCO Certified is a world-wide sustainability certification scheme for IT products. The criteria are designed to drive social and environmental responsibility throughout the product life cycle. A new generation of the TCO was launched at the end of 2021\(^ {37}\). The scheme covers 11 product categories including computers, mobile devices, display products and data centre products. Compliance is independently verified, both pre and post certification. TCO Certified is a third-party certification and meets the requirements of ISO 14024 Ecolabel Type 1 and has been approved by the Global Ecolabelling Network. All verification is carried out by independent verification organisations in accordance with ISO 17025, the international standard for competence requirements applied to testing and calibration laboratories. TCO is owned by the Swedish Confederation of Professional Employees but work globally.

With relevance for mobile devices TCO criteria exist for smartphones, tablets, notebooks, all-in-one PCs, and headsets (no requirements related to energy in the use phase for headsets). For tablets and notebooks TCO Certified refers to ENERGY STAR for Computers version 8.0 (the most recent specification). The TCO certified criteria for smartphones\(^ {38}\)

\(^{30}\)Doe Appliance and equipment standards https://www.energy.gov/eere/buildings/standards-and-test-procedures,
\(^{31}\)US Department of Energy’s Compliance Certification Database https://www.regulations.doe.gov/certification-data/#q=Prod-
\(^{32}\)Code of Federal Regulations at 10 CFR 430.32(z) https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-
\(^{33}\)Appliance and Equipment Standard Rulemakings and Notices for battery chargers: https://www1.eere.energy.gov/buildings/appli-
\(^{34}\)Code of Federal Regulations at 10 CFR 430.32(w) https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-
\(^{35}\)Appliance and Equipment Standard Rulemakings and Notices for EPS: https://www1.eere.energy.gov/buildings/appliance_stand-
\(^{36}\)https://tccertified.com/industry/tco-certified-generation-9/

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and headsets\textsuperscript{39} include specific requisites for the EPS supplied with the device, related to energy efficiency and use of standardised EPS.

With regard to energy efficiency the power supply delivered with the device must meet at least the International Efficiency Protocol requirement for level VI\textsuperscript{40}.

With respect to standardisation the requirements are:

A. The product must carry a USB Type C standardized receptacle (port) for USB Power Delivery according to the standard EN/IEC 63002:2017 or newer - Identification and communication interoperability method for external power supplies used with portable computing devices.

or

B. The product must have a built-in wireless charging capability that complies with Qi Wireless Power Transfer System, Power Class 0 Specification version 1.2.4, or future revisions.

5.2.5 ENERGY STAR

ENERGY STAR is the US government-backed symbol for energy efficiency for a wide variety of products and is a joint venture programme between US EPA (Environmental Protection Agency) and US DoE. Products that earn the ENERGY STAR label are independently certified to meet strict standards for energy efficiency and use all caps set by the US EPA and US Department of Energy. ENERGY STAR is a voluntary program whereby manufacturers can choose to submit their products for ENERGY STAR certification based on meeting the ENERGY STAR specifications. The basis for developing new criteria is that around 25% of the products on the market should be able to comply at the time of publishing the criteria.

The ENERGY STAR Programme specifications are developed for a wide range of products within heating and cooling, household appliances, heating, lighting, office equipment, electronics, building products. Specifications are also in place for other products such as electric vehicle charger and smart home energy management systems.

With regard to mobile devices on product level, ENERGY STAR specifications only exist for notebook computers and tablets. With relevance for mobile devices, the ENERGY STAR Programme does also have programme requirements for external power supplies\textsuperscript{41}. Previously the programme also had a specification for battery charging systems\textsuperscript{42} but it was decided to sunset the specification in end of 2014\textsuperscript{43}.

It has been checked whether any mobile devices are covered by the following specifications – but they are not. Products within the scope of ENERGY STAR are listed below:

- The ENERGY STAR specification for audio/video\textsuperscript{44} covers mains-connected products that offers audio amplification and/or optical disc player functions and it specifically excludes primarily battery-powered products (e.g., MP3 players, portable DVD players, portable, gaming systems) and wireless microphone systems.
- The ENERGY STAR Specification for telephones\textsuperscript{45} does not include cellular phones (mobile phones) and smartphones (but have requirements for cordless phones).

\textsuperscript{40} https://www.energystar.gov/ia/partners/prod_development/downloads/efficiency_challenge.pdf
\textsuperscript{41} https://www.energystar.gov/ia/partners/product_specs/program_reqs/EPS_Eligibility_Criteria.pdf
\textsuperscript{42} https://www.energystar.gov/sites/default/files/private/battery_chargers_prog_req_v2.pdf
\textsuperscript{43} https://www.energystar.gov/products/spec/battery_charging_systems_specification_version_2_0.pdf
\textsuperscript{44} https://www.energystar.gov/sites/default/files/Final%20Version%203.0%20AV%20Program%20Requirements%208Rev%20Dec-2014%20.pdf
5.2.6 EPEAT/ECOLABEL

The Global Electronics Council (GEC) manages and sets the policies for the EPEAT (Electronic Product Environmental Assessment Tool) ecolabel. GEC meet the requirements of ISO 14024, which is necessary for managing a Type 1 ecolabel.

EPEAT is a global ecolabel for the IT sector. EPEAT helps purchasers, manufacturers, resellers, and others buy and sell environmentally preferable electronic products. While the scheme is global, it seems primarily used in the US and Canada.

EPEAT has requirements for devices within these product groups:

- Computer and displays
- Imaging equipment
- Mobile phones
- Photovoltaic modules and inverters
- Servers
- Televisions

For mobile phones the EPEAT criteria is based on UL 110 Edition 2 - 2017 Standard for Sustainable Mobile Phones. The standard does not include efficiency requirements for the use phase.

For computers, the requirements are based on IEEE standards 1680 vrs. 1 2018 and 1a 2020. The requirements for energy consumption in the use phase are based on the ENERGY STAR requirements in effect at the time of declaration of the product (vrs. 1). Vrs. 1a adds minimum Energy Efficiency Requirements for internal power supply based on ENERGY STAR requirements for internal power supply in effect at the time of declaration. It is possible to gain one or two points for efficiency of the internal power supply, as shown in Table 3.

EPEAT ecolabel for wearables is expected to come in 2022.

<table>
<thead>
<tr>
<th>Efficiency limit</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>One full 80 Plus efficiency level above the minimum efficiency level requirement as specified in the US ENERGY STAR specification</td>
<td>1</td>
</tr>
<tr>
<td>Two full 80 Plus efficiency level above the required equivalent efficiency level requirement as specified in the US ENERGY STAR specification</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3: Efficiency limit levels and associated points (Source EPEAT)

5.2.7 Australia MEPS/Energy Rating (in conjunction with also New Zealand where appropriate)

In Australia, The Greenhouse and Energy Minimum Standards Act 2012 (GEMS Act) provides the framework for mandatory minimum energy performance standards (MEPS) and energy efficiency labelling. Products are included in the programme if the community would benefit from their regulation. Technical and economic analyses are undertaken in the development and negotiation of targets and timetables. MEPS, labelling, and test method standards that are called up by regulation, are set to be the equivalent of the world’s best practices, where possible.

The energy-rating label allows consumers to compare the energy efficiency of domestic appliances, thereby providing manufacturers with an incentive to continuously improve the energy performance of their appliances. The label includes two main features. First, it rates the energy efficiency of an appliance on a scale of 1 to 10 stars or 1 to 6 stars (in half-star increments). In this case, the more stars, the more efficient the appliance is compared to other models of similar size and capacity. Second, the label displays an estimated energy consumption figure based on typical use of the appliance (usually in kWh/year).
Various products are covered by MEPS and or labelling for instance: air conditioners, refrigerators/freezers, televisions, lamps, electric motors, distribution transformers, computers, and external power supplies (EPS).

Of mobile devices, only computers are covered with MEPS (no energy labelling of computers). In addition, the requirements for EPS are relevant for mobile devices. The computer requirements cover portable computer/notebooks but not tablets and slates. The MEPS requirements for computers are maximum TEC (Typical Energy Consumption) under specified test conditions. TEC is a measure of the computer’s typical energy consumption based on assumed hours in each mode. The TEC requirements can be found in section 4.5 of AS/NZS 5813.2:2012. If less than 201 units are supplied the computer does not have to comply with the TEC requirement but should comply with the requirements for the power supply in the AS/NZS 4665.2:2005 standard.

The Energy Rating programme does not include requirements for battery chargers.

5.2.8 New Zealand

In New Zealand the legislative instrument for product energy efficiency is the Energy Efficiency (Energy Using Products) Regulations 2002 (NZ Regulations). It is enforced by the New Zealand Regulator, the Energy Efficiency and Conservation Authority (EECA).

Under the Equipment Energy Efficiency (E3) programme, New Zealand and Australia regulate the energy efficiency of products in both countries. The regulations cover products for homes, commercial and industrial use. E3 includes 2 measures: Minimum Energy Performance Standard (MEPS) and Mandatory Energy Performance Labelling (MEPL). Products must meet the MEPS to be sold in New Zealand.

New Zealand MEPS and MEPL requirements are outlined on the EECA website under current product standards. A table summarising the testing, MEPS and energy rating labelling standards is also available on the EECA website.

A number of regulatory requirements are under review. None of the reviews mentioned in the EECA homepage are dealing with mobile devices.

Products registered in Australia are also considered registered under the NZ Regulations, and the product can be supplied in New Zealand provided the energy performance characteristics of that item comply with the standards for that item’s product class. New Zealand product registrations are not recognised in Australia.

MEPS covers external power supplies (including power supplies sold (packaged) with products, such as laptops and mobile phones) which:

- are designed for mains input power (normally 230V AC), and
- have a maximum output power of less than or equal to 250W, and
- have a single output voltage (either AC or DC), or
- multiple outputs that are user selectable (multiple output but only one is active at a time and is selectable through a selector switch).

The MEPS requirements for EPS are minimum efficiency levels under specific test conditions. The MEPS levels are listed in Section 4 of AS/NZS 4665.2:2005.

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49 https://www.eeca.govt.nz/regulations/regulatory-requirements-under-review/
5.2.9 Top Runner Japan

The Japanese Government promotes energy efficiency through regulation and economic incentives including the Top Runner Programme (efficiency standard) for automobiles and residential electric appliances. The objective of the Top Runner Programme is to promote energy savings in the residential, commercial and transport sectors by implementing efficiency standard for specified products.

The Top Runner Programme is mandatory for companies (manufacturers and importers of specified products), to fulfil the efficiency targets by the targeted years, which encourages competition and innovation among the companies without increasing market prices. Manufacturers are required to achieve such targets (by a weighted average method) for all their products per category for each predetermined target year.

The programme was introduced in 1998 to curb energy consumption in residential, commercial and transport sectors. This programme initially covered 11 items in 1998 and was expanded to 31 items in 201351,52.

The programme covers various products including for instance the following household appliances, electronics, lighting, heating, TV sets, air conditioners, routers, switches, passenger cars and building materials53. Only the requirements for computers are of relevance for mobile devices. For computers, only notebooks are targeted as computers mainly used with built-in power supply instead of being connected to power line are excluded54.

5.2.10 Energy Efficiency Labelling and Standard Korea55

Korea Energy Agency mandates Energy Efficiency Labelling and Standard of commonly used products that consume large amount of energy. The aim is to accelerate development of energy efficiency technology and encourage consumers to purchase energy saving products.

Energy Efficiency Labelling and Standard was introduced in 1992. This programme includes labelling of products with an energy efficiency rating ranging from level 1 to 5. Production and sales of products that do not meet the minimum energy performance standards are banned, which in turn will promote energy saving products.

The programme targets a long list of products (in total 35 products) including household appliances, lamps, heating and cooling products, motors, electric transformers, televisions and adaptors and chargers. No mobile devices are covered by labelling and energy efficiency standards.

The programme also includes a specific section targeting standby consumption e-Standby Power56. The program was implemented in 1999 to promote standby power saving devices. Devices that meet the government’s standby power saving standards are labelled with an energy saving logo, while those that do not meet the standards should bear a standby power warning label. The e-Standby Power Program covers various mobile devices such as computers (but maybe only desktops computers), cordless telephones, wireless routers (in total 21 items).

5.2.11 Canada Energy efficiency regulations

Canada’s Energy Efficiency Act and Energy Efficiency Regulations57 are administered by Natural Resources Canada (NRCan)58. The energy efficiency regulations require labelling of various products and that products imported into Canada or shipped between provinces or territories bear an energy efficiency verification mark from a certification body accredited for energy efficiency verification/certification by the Standards Council of Canada.

52 https://www.enecho.meti.go.jp/category/saving_and_new/saving/enterprise/equipment/council/
55 https://dco.energy.or.kr/renew_eng/energy/appliances/labeling.aspx
56 https://dco.energy.or.kr/renew_eng/energy/appliances/program.aspx
57 https://laws-lois.justice.gc.ca/eng/regulations/SOR-2016-311/
The Energy Efficiency Regulations apply to energy-using products in the categories: household appliances, water heaters, heating and air-conditioning equipment, lighting products, electronic products, refrigeration equipment, and other commercial and industrial products.

Of relevance for mobile devices the programme includes requirements for external power supplies\(^{59}\) and battery chargers\(^{60}\). These requirements are aligned with the approaches used by US DoE for these products with regard to scope, metrics and measurement methods.

For EPS, the use of a Roman numeral is accepted as an alternative to the energy efficiency verification mark if:
- it is labelled with a mark in accordance with the U.S. Department of Energy publication entitled “International Efficiency Marking Protocol for External Power Supplies”
- a certification body has verified the information related to the product’s energy performance that is provided
- it is labelled with the same model number as that used when the information was verified

5.2.12 Other programs

Various other programmes exist at national level worldwide, but it is considered that the conclusion will be the same as for the addressed programs – that only few requirements are in place for energy efficiency in the use phase for mobile devices.

5.3 Requirements for mobile devices

5.3.1 Laptops, notebooks, and tablets

Laptops and tablets, especially the more powerful products, have higher energy consumption in the use phase compared to various other mobile devices and use phase energy efficiency requirements for these products are included in various programmes among others in the EU ecodesign, TCO Certified, ENERGY STAR, Australia/New Zealand MEPS (AS/NZS MEPS), Topten.eu, EPEAT, Top Runner (only laptops) and EU GPP (Green Public Procurement). Various programmes such as the TCO Certified and EPEAT refers to the US ENERGY STAR specifications and are not further dealt with in this section.

5.3.1.1 Comparison of the scope

The scope of programmes dealing with computers varies from programme to programme (region to region). One major difference is that not all the programmes are dealing with slates (Australia/New Zealand and Japan). The same is the case for mobile thin clients. In Japan neither slates nor tablets are covered by the Top Runner programme.

There are some differences in the coverage regarding screen size. The EU ecodesign requirements only apply to slates, tablets and other portable computers with a screen of at least 22.86 cm (9 inches) while the US ENERGY STAR includes tablets and slates with a diagonal size greater than 6.5 inches and less than 17.4 inches.

An overview of scopes for selected programmes is shown in Table 4. It is an overview of important aspects and not a comprehensive description of the scope and all exclusions.

\(^{59}\) https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/guide-canadas-energy-efficiency-regulations/external-power-supplies/6909

\(^{60}\) https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/guide-canadas-energy-efficiency-regulations/battery-chargers/21821
<table>
<thead>
<tr>
<th>US ENERGY STAR(^{41})</th>
<th>Australia/New Zealand(^{42})</th>
<th>EU Ecodesign computers(^{43})</th>
<th>Top Runner (Japan)(^{44})</th>
</tr>
</thead>
</table>
| **ENERGY STAR** specification includes** Notebook (portable) computers**  
A computer designed portability  
- to be operated for extended periods of time both with and without a direct connection to an ac mains power source;  
- includes an integrated Display, a non-detachable, mechanical keyboard (using physical, moveable keys), and pointing device.  
**Slates/Tablets**  
- Includes an integrated display with a diagonal size greater than 6.5 inches and less than 17.4 inches;  
- Lacking an integrated, physical attached keyboard in its as shipped configuration;  
- Includes and primarily relies on touchscreen input;  
- Includes and primarily relies on a wireless network connection;  
- Includes and is primarily powered by an internal battery (with connection to the mains for battery charging, not primary powering of the device).  
Excluded are among others: 
Handheld computers and Slates/Tablets which contain cellular voice capability  
**Portable All-In-One-Computer**  
- Includes an integrated display with a diagonal size greater than or equal to 17.4 inches;  
- Lacking keyboard integrated into the physical housing of the product in its as-shipped configuration; | The AS/NZS MEPS includes Notebook computers  
Computer designed for portability  
- to be operated for extended periods of time either with or without a direct connection to the mains power;  
- includes an integrated display and are capable of being powered by an integrated battery or other portable battery source;  
- most notebooks use an external power supply and have an integrated keyboard and pointing device.  
Tablets includes a touch-sensitive screen and physical keyboard when shipped (considered as notebooks in the Standard).  
Excluded are: Slate computers, hand-held computing and gaming devices, smart phones, game consoles, thin clients, mobile workstations. Slates are type of computer without a physical keyboard, relying solely on touch screen input, having solely a wireless network connection and are primarily powered by an internal battery.  
More information in the standard: AS/NZS 5813.2:2012 + A1: | Computer regulation includes: 
**Notebook (portable computer)**  
Computer designed for portability:  
- to be operated for extended periods of time with or without a direct connection to the main;  
- which utilize an integrated display, with a viewable diagonal screen size of at least 22.86 cm (9 inches);  
- are capable of operation on an integrated battery or other portable power source.  
**Slates** includes an integrated touch-sensitive display but does not have a permanently attached physical keyboard.  
**Tablets** includes both an attached touch-sensitive display and an attached physical keyboard  
Both slates and tablets are considered being subtypes of notebooks.  
**Mobile thin client**  
Notebook computer that relies on a connection to remote computing resources (e.g. computer server, remote workstation) to obtain primary functionality and has no rotational storage media integral to the product.  
Excluded are among others:  
- Game consoles  
- Notebooks with idle state power consumption less than 6 W | The Top Runner program includes:  
- Notebook computer  
- Slate computers  
- 2-in 1-computers  
Excluded from criteria  
Slate computers and 2-in-1 computers that have dedicated internal batteries which allow them to be used even when electricity is not supplied through a power cable; namely, slate computers, notebook computers and other client PCs  
Excluded from scope  
Thin clients, point-of-sale terminals, e-book readers, calculators, game consoles, handy terminals, computers that are primarily developed and sold for embedding in switchboards, control panels, electrical appliances, automobiles, etc. |

---


\(^{44}\) https://www.jeita.or.jp/page_file/20200626170837_iYhg84oBEEm.pdf, https://home.jeita.or.jp/page_file/20200626170837_iYhg84oBEEm.pdf, Explanation of the Act on the Rational Use of Energy (FY 2022 Target Criteria), 2019 JEITA IS-536

Page 26
• Includes and primarily relies on touchscreen input;
• Includes wireless network connection e) Includes an internal battery.

**Mobile thin client**
A Thin Client, designed specifically for portability and meeting the definition of a Notebook Computer.

<table>
<thead>
<tr>
<th>Table 4: Overview of scope for programmes dealing with computers – only for mobile devices included in the scope.</th>
</tr>
</thead>
</table>

Some of the measures specify that the power supply delivered with the portable computer device should comply with the relevant requirements for EPS while it for instance in the EU ecodesign regulation for EPS is specified in the regulation that requirements for power supplies is applicable for computers.

**Important gaps in scope**

**Slates/tablets**
The Top Runner programme (Japan) and AS/NZC MEPS do not include requirement for slates. The Top Runner programme does probably not or only to some extent include portable computers.

The EU ecodesign regulation and ENERGY STAR Specification also exclude to some extent slates and tablets. The Ecodesign regulation excludes notebooks (including slates and tablets) with idle state power consumption less than 6 W and the ENERGY STAR specification excludes handheld computers and slates/tablets which contain cellular voice capability.

**Mobile thin clients**
Mobile thin clients are covered neither by the Top Runner programme nor by AS/NZS MEPS.

**Screen size**
The ENERGY STAR Specification includes slates and tablets with integrated displays with a diagonal size greater than 6.5 inches and less than 17.4 inches, but not ones with smaller or bigger dimensions. The EU ecodesign regulation does not include notebook computers with an integrated display, with a viewable diagonal screen below 22.86 cm (9 inches).

5.3.1.2 **Comparison of metrics for portable computer devices**

A comparison of requirements for computers (portable devices only) for selected programs is shown in Table 5. It is an overview of important aspects and not a comprehensive description of all requirements and elements.

All the programs include requirements for Typical Energy Consumption (TEC) (in EU called total energy consumption). The programs also include efficiency requirements for internal power supply (except the TOP Runner program). The TEC for the products is calculated and should be smaller than or equal to maximum allowed values which include allowances depending on the computer type/category and functionality.

The metrics used for the calculation of the typical energy consumption have some similarities but also vary considerably from measure to measure. The annual energy consumption TEC is in all the measures defined as the weighted average of the energy efficiency of different modes in accordance with the expected period it will spend in each operation mode (operational mode weighting).
Both the Top Runner and the AS/NZS MEPS include work mode in the metric to calculate TEC, but the share of time spent in the mode is 0 %, so in practice the work mode is not included. The operational mode weighting varies from programme to programme.

All the programmes except the TOP Runner include requirements for Internal Power Supply (IPS) but the ambition level varies. Only the ENERGY STAR Specification includes requirements for efficiency at 10 % of rated output power. While the Top Runner and AS/NZS MEPS refer to national standards

Only the EU ecodesign regulation includes power limits for low power modes.

<table>
<thead>
<tr>
<th>Legislation</th>
<th>Scope (relevant for mobile devices)</th>
<th>Metrics for energy efficiency in the use phase and measurement standards for portable computer devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU Ecodesign</td>
<td>Notebook computers designed specifically for portability including tablets, slates, computers and mobile thin clients. See more in Table 4.</td>
<td>Requirements for total energy consumption</td>
</tr>
<tr>
<td>Commission Regulation (EU) 617/2013</td>
<td></td>
<td>E\textsubscript{TEC} shall be determined using the following formula: E\textsubscript{TEC} = (8 760/1 000) \times (0,60 \times P\textsubscript{off} + 0,10 \times P\textsubscript{sleep} + 0,30 \times P\textsubscript{idle})</td>
</tr>
<tr>
<td>Requirements took effect from 1. July 2014</td>
<td></td>
<td>where all P\textsubscript{x} are power values in the indicated mode/state as defined in the definition section, measured in Watts (W) according to the procedures indicated in Annex III.</td>
</tr>
<tr>
<td>Mandatory MEPS</td>
<td></td>
<td>The annual total energy consumption (E\textsubscript{TEC} in kWh/year) shall not exceed:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(a) Category A computer: 27.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) Category B computer: 36.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(c) Category C computer: 60.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The following capability adjustments apply:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(a) memory: 0,4 kWh/year per GB over base, where base memory is 4 GB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) additional internal storage: 3 kWh/year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(c) discrete television tuner: 2.1 kWh/year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(d) discrete graphics card (dGfx) (for the first and each additional discrete graphics card (dGfx))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Higher values are allowed for notebooks with higher capability (See more in Regulation (EU) 617/2013, Annex 1, point 1.4.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power limits for Sleep Mode, Lowest Power State, Off Mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Power demand in sleep mode shall not exceed 3,00 W in notebook computers (if WOL function enabled and allowance of 0,7 W can be applied).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Power demand in the lowest power state shall not exceed 0,50 W (additional 0,5 W in case of status display).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal power supply efficiency requirement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(a) 85 % efficiency at 50 % of rated output power</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) 82 % efficiency at 20 % and 100 % of rated output power</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(c) power factor = 0,9 at 100 % of rated output power.</td>
</tr>
</tbody>
</table>

\[^{66}\] New EU ecodesign requirements for computers are under preparation. And these are foreseen to be very much in line with the current ENERGY STAR Specification for computer (v. 8.0).
**Internal power supplies with a maximum rated output power of less than 75 W are exempt from the power factor requirement.**

**Power Management requirement**

The computer shall be placed on the market with the display sleep mode set to activate within 10 minutes of user inactivity.

When in sleep mode, the response to ‘wake events’, should happen with a latency of ≤ 5 seconds from the initiation of a wake event to the system becoming fully usable including rendering of display.


### ENERGY STAR

**ENERGY STAR Programme Requirements for computers**

Version 8.0

Effective Date: October 15, 2020

**Voluntary labelling**

Notebook computers designed specifically for portability including tablets, slates, computers, portable All-In-One Computers, and mobile thin clients. See more in Table 4.

### Requirements for total energy consumption

Requirements based on annual total energy consumption (TEC).

Calculated Typical Energy Consumption ($E_{TEC}$) for Desktop, Integrated Desktop, and Notebook Computers per Equation 1 shall be less than or equal to the maximum TEC requirement ($E_{TEC\_MAX}$) per Equation 2.

$E_{TEC} = \frac{8760}{1000} \times (P_{OFF} \times T_{OFF} + P_{SLEEP} \times T_{SLEEP} + P_{LONG\_IDLE} \times T_{LONG\_IDLE} + P_{SHORT\_IDLE} \times T_{SHORT\_IDLE})$

With the mode weighting factors as shown in table 5 of the ENERGY STAR specification.

$E_{TEC\_MAX}$ shall be calculated using the following formula (equation 2), where the various allowances appear from the ENERGY STAR Specification. The allowances vary depending on the type of computer.

$E_{TEC\_MAX} = (1 + \text{ALLOWANCE}_{PSU} + \text{ALLOWANCE}_{PBD}) \times (\text{TEC\_BASE} + \text{TEC\_MEMORY} + \text{TEC\_GRAPHICS} + \text{TEC\_DISPLAY} + \text{TEC\_SWITCHABLE} + \text{TEC\_MOBILE} + \text{TEC\_STORAGE})$

The TEC\_MEMORY, TEC\_DISPLAY, TEC\_STORAGE, etc. are functionality adders (allowances) to the basic energy consumption depending on the type and functionality of the computer. The allowances appear from the ENERGY STAR specification.

**Requirement for internal power supply with rated output of 500 W and below**

(a) 0.80 minimum efficiency at 10 % of rated output power
(b) 0.82 minimum efficiency at 20 % and 100 % of rated output power
(c) 0.85 minimum efficiency at 50 % of rated output power

Minimum power factor = 0,9 at 50 % of rated output power.

**Requirement for internal power supply with rated output above 500 W appears from table 2 in the ENERGY STAR specification**

**Power management requirements**

Products shall include power management features in their “as-shipped” condition as specified in Section 3.3 and Table 3 of the specification.

---

## Resume time requirements

Notebooks should wake from sleep with a latency of less than 5 seconds.


### Top Runner

**Mandatory – sales weighted**

Japan

Laptops/notebooks only (called client computers)

Excluded: Ones mainly used with built in power supply instead of being connected to power line.

See more in Table 4.

### Weighted average

In the target fiscal year and each subsequent fiscal year, the weighted average value obtained by weighting energy consumption efficiency with shipment volume shall not be above the target standard value which is a weighted average value obtained by weighting standard energy consumption efficiency with shipment volume.

### Energy efficiency requirements

The energy efficiency of a client computer uses the typical energy consumption TEC, and is defined as the weighted average of the energy efficiency of four different modes - off mode, sleep mode, short idle mode, and long idle modes – measured under the prescribed testing environment in accordance with JIS C 62623:2014, expressed in units of kWh/year by the following formula:

\[
\text{TEC}_{\text{entained}} = (\sum 1000^6 \times [P_{\text{eff}} \times T_{\text{eff}} + P_{\text{sleep}} \times T_{\text{sleep}} + P_{\text{idle}} \times T_{\text{idle}} + P_{\text{idle}} \times (T_{\text{idle}} + T_{\text{work}})])
\]

\[
\text{where } T_{\text{eff}} + T_{\text{sleep}} + T_{\text{idle}} + T_{\text{idle}} + T_{\text{work}} = 100\%.
\]

With operational mode weighting as shown below:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Desktop Computers</th>
<th>Notebook Computers</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_{\text{off}}</td>
<td>45%</td>
<td>25%</td>
</tr>
<tr>
<td>T_{\text{sleep}}</td>
<td>5%</td>
<td>35%</td>
</tr>
<tr>
<td>T_{\text{idle}}</td>
<td>15%</td>
<td>10%</td>
</tr>
<tr>
<td>T_{\text{idle}}</td>
<td>25%</td>
<td>30%</td>
</tr>
<tr>
<td>T_{\text{work}}</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

The target criteria for energy efficiency for notebooks E (in kWh/year) depends on CPU (P-score) and screen size and are:

- **P score less than 8 and screen size greater than or equal to 15 inches**
  \[
  E = 7.75 + \text{TEC}_{\text{memor}} + \text{TEC}_{\text{int\_display}} + \text{TEC}_{\text{storage}} + \text{TEC}_{\text{graphic}}
  \]

- **P score less than 8 and screen size less than 15 inches (E in kWh/year)**
  \[
  E = 5.21 + \text{TEC}_{\text{memor}} + \text{TEC}_{\text{int\_display}} + \text{TEC}_{\text{storage}} + \text{TEC}_{\text{graphic}}
  \]

- **P score greater than or equal to 8:**
  \[
  E = 5.21 + \text{TEC}_{\text{memor}} + \text{TEC}_{\text{int\_display}} + \text{TEC}_{\text{storage}} + \text{TEC}_{\text{graphic}}
  \]

---

The TECMEMORY, TECINT_DISPLAY TEC STORAGE, etc. are functionality adders (allowances) to the basic energy consumption. The allowances appear from the TOP Runner specification.

No requirements for internal power supply, power management or power limits for low power modes were identified for this measure.

Energy consumption efficiency shall be annual energy consumption (kWh/year) measured by a method stipulated in JIS C 62623 (2014). Newer version of the standard from 2019 exists.

Australia – New Zealand MEPS

Notebook computers designed specifically for portability including tablets,

Slates are excluded and mobile thin clients are excluded.

See more in Table 4.

Requirements for total energy consumption

Requirements based on annual total energy consumption (TEC).

TEC (Typical Energy Consumption) is a measure of the computer’s typical energy consumption. The TEC requirements can be found in section 4.5 of AS/NZS 5813.2:2012.

TEC for each computer type shall be calculated using the following formula:

\[ TEC_{\text{calculated}} = \frac{8710}{100} \cdot (P_{\text{off}} \times T_{\text{off}} + P_{\text{sleep}} \times T_{\text{sleep}} + P_{\text{idleL}} \times T_{\text{idleL}} + P_{\text{idleS}} \times T_{\text{idleS}} + P_{\text{work}} \times T_{\text{work}}) \]

With the relevant operational mode weighting appearing from the table below.

<table>
<thead>
<tr>
<th>Operational Mode Weighting – Integrated Computers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode Weighting</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>( T_{\text{off}} )</td>
</tr>
<tr>
<td>( T_{\text{sleep}} )</td>
</tr>
<tr>
<td>( T_{\text{idleL}} )</td>
</tr>
<tr>
<td>( T_{\text{idleS}} )</td>
</tr>
<tr>
<td>( T_{\text{work}} )</td>
</tr>
</tbody>
</table>

The minimum performance standard is expressed by the TECMEPS (TEC_{\text{CALCULATED}} \leq TEC_{\text{MEPS}}) where:

\[ TEC_{\text{MEPS}} = TEC_{\text{BASE}} + TEC_{\text{dGfx}} + TEC_{\text{MEMORY}} + TEC_{\text{STORAGE}} + TEC_{\text{TV}} + TEC_{\text{AUDIO}} + \text{Additional TEC}_{\text{dGfx}} \]

The TECBASE, TECdGfx, TECMEMORY, TECINT_DISPLAY TEC STORAGE, etc. are functionality adders (allowances) to the basic energy consumption. The allowances appear from the standard AS/NZS 5813.2:2012.

Requirement for internal power supply with rated output of 500 W and below

(a) 0.85 minimum efficiency at 20 % of rated output power

(b) 0.87 minimum efficiency at 50 % of rated output power

(c) 0.85 minimum efficiency at 100 % of rated output power

Minimum power factor = 0.9 at 100 % of rated output power.

External power supply

For deemed-to-comply computers using an external power supply (EPS), the EPS shall be compliant with performance mark V as per AS/NZS 4665 (series).

Power Management:

All notebook computers shall be shipped with default times to sleep after user inactivity of less than 15 minutes for display/monitor and 30 minutes for computer.
Limits for low power modes

No limits were identified for low power modes.
Method of measurement as set out in AS/NZS 5813.1 and the MEPS as specified in AS/NZS 5813.2.

<table>
<thead>
<tr>
<th>Limits for low power modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No limits were identified for low power modes.</td>
</tr>
<tr>
<td>Method of measurement as set out in AS/NZS 5813.1 and the MEPS as specified in AS/NZS 5813.2.</td>
</tr>
</tbody>
</table>

Table 5: Comparison of metrics for portable computer devices

Important gaps in metrics

No regions/programmes include requirements for active modes (work mode). $P_{\text{work}}$ (work mode power) is mentioned in some of the metrics (AS/NZS MEPS and Top Runner) but $T_{\text{work}}$ (the time in work mode) is 0 % of the time. So $P_{\text{work}}$ has no influence on the requirement.

Some regions lack requirements for internal power supplies, low power modes, and power management. It is expected that the US will explore active mode requirements for the next revision.

The requirements for energy efficiency and the metrics for calculation of efficiency vary significantly from region to region both with regard to included modes, assumed operation time in the different modes, and with regard to adders (allowances).

EU, and Australia/New Zealand do not have requirements for internal power supplies at 10 % of rated output power, and Japan does not at all have requirement for efficiency of internal power supply.

US and EU refer to international IEC standards (with some modifications), while Japan and Australia/New Zealand refer to national standard. These have not been compared in detail, but there might be lack of harmonisation.

The US does not have mandatory minimum efficiency standards for computers as the ENERGY STAR is a voluntary program.

5.3.2 Smartphones and mobile phones

Various schemes include requirements for smartphones and mobile phones. However, none of them have energy efficiency requirements for the use phase. The most common requirements are covering the EPS supplied with the phone.

EU requirements under preparation

The EU is preparing ecodesign/energy labelling regulations for smartphones, mobile phones, and tablets. Currently, it is not envisaged that minimum energy efficiency requirements for the use phase of smartphones/mobile phones will be included in an ecodesign regulation, but only resource efficiency and information requirements are foreseen.

The preparatory study\(^{71}\) proposes an energy label for smartphones with an EEI (Energy Efficiency Index) based on the battery endurance (operation time on a full charge while talking, web browsing, video playback, and standby/inactive). The metric is not only about actual energy savings in use, but also indirect energy savings through extended product lifetime.

The proposed energy efficiency classification for smartphones is shown in Table 6. The same approach can according to the study be used for mobile phones (feature phones) and tablets. Due to only a moderate spread in energy efficiency among cordless phones in the market, an energy label for these products is not appropriate.

\(^{71}\) [https://op.europa.eu/da/publication-detail/-/publication/a7784be4-853d-11eb-af5d-01aa75ad71a1/language-en](https://op.europa.eu/da/publication-detail/-/publication/a7784be4-853d-11eb-af5d-01aa75ad71a1/language-en)
Table 6: Energy efficiency index (normalised battery endurance) as basis for defining energy efficiency classes for smartphones

The following information is proposed to be shown on the label:

- supplier’s name or trade mark;
- supplier’s model identifier;
- the (energy) efficiency class;
- battery endurance per cycle, active use only in h per full battery charge, rounded to full hours;
- battery endurance in cycles, in ranges ≥500, ≥600, ≥700, ≥800, ≥900, ≥1000, ≥1100, ≥1200, ≥1300, ≥1400;
- ingress protection rating;
- environmental impact score;
- the QR code with access to the product information sheet.

The overall battery endurance score is calculated as shown in Figure 7.

Overall battery endurance (END_{device}) in hours is calculated as follows:

(a) smartphones:
\[
END_{\text{device}} = \frac{24 \times \text{END}_{\text{active}}}{\text{END}_{\text{nominal}} + \text{END}_{\text{rest}} + \text{END}_{\text{idle}}}
\]

(b) mobile phones other than smartphones:
\[
END_{\text{device}} = \frac{24 \times \text{END}_{\text{active}}}{\text{END}_{\text{nominal}} + \text{END}_{\text{rest}} + \text{END}_{\text{idle}}}
\]

(c) tablets:
\[
END_{\text{device}} = \frac{24 \times \text{END}_{\text{active}}}{\text{END}_{\text{nominal}} + \text{END}_{\text{rest}} + \text{END}_{\text{idle}}}
\]

The energy efficiency index (EEI) of a mobile phone or tablet shall be calculated using the following equation:

\[
EEI = \frac{END_{\text{device}}}{C_{\text{rated}}}
\]

Where:
- \(C_{\text{rated}}\) is the rated battery capacity in mAh.

Figure 7: Proposal for energy efficiency index for smartphone, mobile phones, and tablets in ecodesign preparatory study (based on battery endurance).
The preparatory study also proposes ecodesign requirements regarding resource efficiency such as\textsuperscript{72}:

- Design for repair and reuse (availability of spare parts, access to repair and maintenance information, maximum delivery times and price of spare parts, disassembly requirement, requirements for preparation for reuse)
- Design for reliability including ensuring of a minimum 500 cycles at 80\% remaining charge capacity, battery management and software upgrades and updates.
- Information requirements for instance an obligation to provide information regarding EEI, minimum battery endurance in number of cycles, instructions for battery maintenance

For cordless phones, although there are no requirements on design for reliability, ambitious requirements for networked standby are proposed which go beyond the EU horizontal standby requirement of 2 W for networked standby. See Figure 8.

\begin{center}
\begin{tabular}{|l|}
\hline
1. LOW POWER MODES \\
Manufacturers, importers or authorised representatives shall ensure, that devices meet the following requirements: \\

(1) the networked standby power consumption of cordless phones \\
- shipped with a base station shall not exceed 0,4 W; \\
- shipped with a charging cradle without base station functionality shall not exceed 0,2 W. \\

(2) devices shall be configured in their factory settings to cut off the radio signals of the base station and handset (or handsets) in network standby mode. The base station must switch off its radio signal in this operating mode regardless of the number of registered handsets. This must also be ensured in the event of 'faulty operation'. Resetting the device to the factory settings must restore the configuration described above.

\hline
\end{tabular}
\end{center}

\textbf{Figure 8: Proposed networked standby requirement for cordless phones (source: Preparatory study for mobile phones, smartphones, and tablets)}\textsuperscript{73}

The following scopes are proposed in the preparatory study for mobile phones, smartphones, cordless phones and tablets:

- 'mobile phone' means a cordless handheld electronic device designed for long-range voice communication over either a cellular telecommunications network or a satellite based telecommunications network, requiring a SIM card, eSIM or similar means to identify the connected parties. It is designed for battery mode usage, and connection to mains via an external power supply is mainly for battery charging purposes;
- 'smartphone' means a mobile phone characterized by Wi-Fi connectivity, mobile use of internet services, and the ability to accept original and third-party software applications. A smartphone has an integrated touch screen display with a diagonal size between 4 and 7 inches. Devices with more than one and/or foldable displays are characterized as smartphones if at least one of the displays falls into the size range in either opened or closed mode;
- 'cordless phone' means a cordless handheld electronic device designed for long-range voice communication over a landline telecommunications network, which is connected to a base station through a radio interface. It is designed for battery mode usage, and connection to mains via an external power supply is mainly for battery charging purposes;

\textsuperscript{72} Ecodesign preparatory study on mobile phones, smartphones, and tablets. Final Report. Fraunhofer IZM, Fraunhofer ISI, VITO. February – 2021. Details can be found in section 41, Annex: Input to legislation.

\textsuperscript{73} https://op.europa.eu/da/publication-detail/-/publication/a7764be4-853d-11eb-af5d-01aa75ed71a1/language-en
‘tablet’ means a type of notebook computer designed for portability that includes an integrated touch-sensitive display with a diagonal size greater than 7 inches but does not have an integrated, physical attached keyboard in its as-shipped configuration. A tablet relies on a wireless network connection, which might or might not be a telecommunications network, and is primarily powered by an internal battery (with connection to the mains for battery charging, not primary powering of the device). A tablet is furthermore characterized by an operating system, mobile use of internet services, and the ability to accept original and third-party software applications.

5.3.3 Vacuum cleaners

No measures have been identified for robots and portable (cordless) vacuum cleaners. The European Commission has carried out a review study for the vacuum cleaner regulations (ecodesign and energy labelling) in which possible requirements for cordless (battery operated) and robot vacuum cleaners were assessed. The study showed that the maintenance mode consumption makes up a large part of annual energy consumption for robots and cordless vacuum cleaners, especially for robots.\(^7\)

On this background the review study proposed new formulas for calculation of the Annual Energy Consumption (AE) for cordless and robot vacuum cleaners which included the power consumption in battery maintenance mode.

Proposed formulas to calculate the Annual Energy Consumption (AE) for cordless and robot vacuum cleaners are the following:

Cordless vacuum cleaner:

\[
AE = 4 \times \left(\frac{87}{4}\right) + 200 \times 0.001 \times ASE \times \frac{1 - 0.20}{dpu - 0.20} + \frac{M_h \times 8026}{1000}
\]

Robot vacuum cleaner:

\[
AE = \left(\frac{E_{measured}}{RCF \times 20}\right) \times \left(\frac{87}{4}\right) + 200 \times 0.001 \times \frac{Avg \, dpu}{dpu} + \frac{M_h \times 8445}{1000}
\]

where \(M_h\) is the maintenance power in “charged and docked” mode in watts and the mentioned values 8026 and 8445 are the number of hours in this mode for respectively cordless and robot vacuum cleaners (based on data in the review study). ASE is the average specific energy consumption.

The review study did also propose power limits for the battery maintenance mode, which is a mode not covered by the standby regulation because the functionality in this mode is beyond reactivation function and information display and therefore not considered as standby.

The proposed limits for maintenance mode are:

- For cordless vacuum cleaners: 0.5 to 1.0 W
- For robot vacuum cleaners: 2.0 W.

A higher power limit is proposed for robots because they should be able to wake up on a signal of their Local Area Network (WOL=Wake On LAN). The 2 W is in line with the current EU ecodesign power limit for networked standby in the horizontal standby regulation.

The power consumption should be measured as an average value over 24 hours to allow the docking stations to use more power for a short time to perform relevant tasks such as updates and checking of charging status.

It is foreseen that the European Commission will put forward the new proposal for regulations before end of 2022.

5.3.4 Other mobile devices

There are in general very few energy efficiency requirements for the use phase of mobile devices, which makes sense because mobile devices in many cases have a very low energy consumption in the use phase. For other mobile devices than notebooks and tablets, no requirements for energy efficiency in use phase have been found. However, for some products requirements are under preparation in the EU (for cordless and robot vacuum cleaners, smartphones, and mobile phones (these are described above).

Various regional programmes have energy efficiency requirements for EPS supplied with mobile devices (EU Ecodesign, US Doe, US ENERGY STAR and Australia/New Zealand, and the US Department of Energy (DOE) have requirements for battery chargers including when embedded in the product.

No energy efficiency requirements have been found for small transportation devices such as e-mopeds, e-bikes, segways, mono-wheels, e-scooters etc.

The ENERGY STAR Programme has a specification for Electric Vehicle Supply Equipment, but this is outside the scope of this study.

5.4 Requirement for components

Very few programmes address components for mobile devices except EPS and battery chargers. In general, it must also be expected that energy efficient components are used in mobile devices because they are battery operated. Furthermore, often, it is challenging to define the components in a harmonised way and to measure the energy consumption or energy efficiency for the specific components.

This section describes relevant requirements for components with focus on EPS and battery chargers.

5.4.1 External power supplies (EPS)

Various regions have mandatory energy efficiency requirements for external power supplies (EPS).

The US DoE requirements for EPS cover both direct and indirect operation EPS. For indirect operation EPS the requirements are only applicable for Class A EPS.

5.4.1.1 Comparison of Scope - EPS

EU, US, Canada, Australia/New Zealand, and Korea all have mandatory minimum energy efficiency requirements for EPS. No requirements for EPS are found in Japan. The TCO certified criteria for smartphones and headsets have criteria for EPS supplied with the device. The requirements relate to energy efficiency and use of standardised EPS.

The scope of the identified measures is very similar, though they differ in certain aspects. One difference is that the ecodesign regulation and the US DoE requirements also covers multiple voltage output external power supplies able to convert AC power input from the mains power source into more than one simultaneous output at lower DC or AC voltage. For all the identified measures the scope includes EPS whose nameplate output power is less than or equal

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76 https://www.energystar.gov/sites/default/files/Final%20Version%201.0%20EVSE%20Program%20Requirements.pdf
to 250 W. Only DoE and Canada have in addition requirements for direct operation non-Class A EPS with a nameplate output above 250 W. An overview of the scopes is shown in Table 7.

**Important gaps in scope for EPS**

**Wireless power supply**

None of the programmes described in Table 7 includes requirements for wireless power supplies. This is considered a relatively important gap because an increase in devices with wireless power supply is envisaged and because the losses are larger for wireless power supplies than for wired EPSs. The only measure identified for wireless power supplies is the TCO Certified criteria for smart phones and headsets, which require (as one of two solutions) that the product has a built-in wireless charging capability that complies with Qi Wireless Power Transfer System, Power Class 0 Specification version 1.2.4, or future revisions (See section 6.2.4).

**Restricted application of EU ecodesign regulation**

The EU ecodesign requirements only apply to product types included in Annex A of the regulation. This means for instance that power supplies for handheld tools are not covered. In addition, means of transport of persons and goods are not included in the scope of the ecodesign directive, which excludes products such as e-bikes and e-scooters.

**EPS for motor operated products**

The DoE requirements do not cover EPS that charges the battery of a product that is fully or primarily motor operated. Also, the ecodesign regulation does not cover some motor operated product if they are for means of transport of persons and goods or not included in the product groups in Annex to the regulation. This means for instance that EPS for lawn movers, drones, vacuum cleaners and various handheld tools are not covered by the DoE requirements.

**EPS for medical equipment**

EPS for medical equipment are not covered by any of the programmes. Medical equipment is excluded from various energy efficiency requirements because of importance of reliability. However, an EPS must be considered as a very durable component and inclusion in programmes could be considered.

**EPS with nameplate output above 250 W**

EU ecodesign and AS/NZS requirements do not cover EPS with nameplate output above 250 W (non-class A EPS), though some EPS for mobile devices fall in this category. In addition, it is unclear whether the EU ecodesign and AS/NZS requirements cover indirect EPS.

<table>
<thead>
<tr>
<th>Comparison of scope for measures for EPS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US DoE (and Canada)</strong>&lt;sup&gt;80&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Energy conservation standard includes:</strong></td>
</tr>
<tr>
<td>Class A EPS (direct and indirect operation EPS) Non-Class A EPS (Direct operation EPS).</td>
</tr>
<tr>
<td>Class A EPS is defined as EPS which:&lt;sup&gt;83&lt;/sup&gt; • is designed to convert line voltage AC input into lower voltage AC or DC output;</td>
</tr>
</tbody>
</table>

---


<sup>81</sup> [https://www.eeca.govt.nz/regulations/equipment-standards/](https://www.eeca.govt.nz/regulations/equipment-standards/)


<sup>83</sup> The standard also includes requirements for Non-Class A EPS for direct operation EPS.

<sup>84</sup> Includes multiple voltage output external power supply which means an external power supply able to convert AC power input from the mains power source into more than one simultaneous output at lower DC or AC voltage.
• is able to convert to only 1 AC or DC output voltage at a time;
• is sold with, or intended to be used with, a separate end-use product that constitutes the primary load;
• is contained in a separate physical enclosure from the end-use product;
• is connected to the end-use product via a removable or hard-wired male/female electrical connection, cable, cord, or other wiring; and
• has nameplate output power that is less than or equal to 250 W.

Non-Class A EPS includes EPS:
• With a nameplate output greater than 250 W;
• Which are able to convert to more than one AC or DC output voltage simultaneously;
• Are especially excluded from the coverage under the class A EPS definition in EISA 2009 by their application (See exclusion below).

Exempted from no-load requirements:
• AC-AC EPS;
• EPS with nameplate output of 20 W or more, certified for security and life safety alarms.

Exclusions: EPS that
I) requires Federal Food and Drug Administration listing and approval as a medical device
II) powers the charger of a detachable battery pack or charges the battery of a product that is fully or primarily motor operated.

Excluded are:
• DC input power or battery powered equipment;
• DC to DC converters;
• power supplies within the scope of AS/NZS 4879 or IEC 61347.1.13;44
• external power supplies with multiple simultaneous output voltages;
• EPS designed to charge more than one type of battery;
• a transformer or converter for an extra low voltage lamp and electronic control-gear for an LED module;
• medical equipment, provided it is listed in the Australian Register of Therapeutic Goods.

Table 7: Overview of scope for measures dealing with EPS

5.4.1.2 Comparison of metrics – EPS

The energy efficiency requirements for EPS for selected programmes are shown in Table 8. There are requirements for average active efficiency and no-load. The metrics are in all cases based on the nameplate output power Po. The EU requirements are like the US DoE requirements for direct operation EPS with nameplate output not greater than to 250 W.

The requirements for AS/NZS MEPS are less demanding than the EU and US requirements both regarding no-load efficiency and average active efficiency but the structure of the metrics for active average efficiency is in line with the structure used in the EU and the US. The standards do also include marks for high efficiency AC-DC and AC-AC EPS.

44 Standards related to lamps and lamps control gears.
45 Products included in Annex A: Household appliances, Information technology, consumer equipment, electrical and electronic toys, leisure and sport equipment.
(Mark IV and V) where mark V is the most ambitious. But even the requirements for mark V are a little less ambitious than the EU and US requirements.

<table>
<thead>
<tr>
<th>Legislation</th>
<th>Scope</th>
<th>Metrics for energy efficiency in the use phase and measurement standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU Ecodesign Commission Regulation (EU)</td>
<td>See Table 7</td>
<td>Average active efficiency requirements</td>
</tr>
<tr>
<td>Mandatory MEPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$P_0 \leq 1.0 \text{ W}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$1 \text{ W} &lt; P_0 \leq 49.0 \text{ W}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$P_0 &gt; 49.0 \text{ W}$</td>
</tr>
</tbody>
</table>

Energy efficiency requirements no-load

| | | AC-AC external power supplies, except low voltage and multiple voltage output external power supplies | AC-DC external power supplies, except low voltage and multiple voltage output external power supplies | Low voltage external power supplies | Multiple voltage output external power supplies |
| | | $P_0 \leq 49.0 \text{ W}$ | $0.21 \text{ W}$ | $0.10 \text{ W}$ | $0.10 \text{ W}$ | $0.30 \text{ W}$ |
| | | $P_0 > 49.0 \text{ W}$ | $0.21 \text{ W}$ | $0.21 \text{ W}$ | $0.21 \text{ W}$ | $0.30 \text{ W}$ |


US DoE/Canada Energy Conservation Standard Mandatory

| Direct Operation EPS | For direct operation EPS the requirements are similar to the ecodesign requirements shown above. Test procedure is described in DOE standards specified at 10 CFR 430, Subpart B, Appendix Z, https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430#Appendix-Z-to-Subpart-B-of-Part-430 |

US DoE/Canada Energy Conservation Standard Mandatory

| Indirect operation EPS (only for Class A EPS) | Requirement for energy efficiency in active mode and No-load mode |
| | Active mode |
| | | Nameplate output | Required efficiency (decimal equivalent of a percentage) |
| | Less than 1 watt | 0.5 times the Nameplate output. |
| | From 1 watt to not more than 51 watts | The sum of 0.09 times the Natural Logarithm of the Nameplate Output and 0.5. |
| | Greater than 51 watts | 0.85. |

| | No-load mode |
| | Nameplate output | Maximum consumption |
| | Not more than 250 watts | 0.5 watts. |
EPS (including power supplies sold (packaged) with products, such as laptops and mobile phones) which
See Table 7

The MEPS requirements are a minimum efficiency under test conditions. The MEPS levels are listed in section 4 of AS/NZS 4665.2:2005.

**Minimum energy efficiency requirements:**

When measured in accordance with AS/NZS 4665.1:2005, a single output AC-DC or AC-AC external power supply shall meet both the no-load power consumption and average active mode efficiency requirements specified for an Energy Performance Mark III in AS/NZS 4665.1:2005 (Appendix A).

The standards also include marks for high efficiency AC-DC and AC-AC EPS (Mark IV and V) where mark V is the most ambitious.

**Standards:**


This AS/NZS standard draws upon a test method published in 2003 by the US Environmental Protection Agency (EPA) as part of the ENERGY STAR program, following input from several countries including Australia. This AS/NZS Standard is technically similar to the EPA standard.

**Table 8: Metrics for EPS**

<table>
<thead>
<tr>
<th>Mark II</th>
<th>Mark III</th>
</tr>
</thead>
<tbody>
<tr>
<td>No load power consumption requirements</td>
<td>Active mode efficiency requirements</td>
</tr>
<tr>
<td>Nameplate output power (P_no) W</td>
<td>Nameplate output power (P_no) W</td>
</tr>
<tr>
<td>0 to &lt;10</td>
<td>0 to &lt;10</td>
</tr>
<tr>
<td>10 to ≤250</td>
<td>1 to &lt;49</td>
</tr>
<tr>
<td>≤0.75</td>
<td>≥0.5</td>
</tr>
<tr>
<td>≤1.0</td>
<td>≤0.75</td>
</tr>
</tbody>
</table>

The measures for energy efficiency of EPS in both the US, EU and Australia/New Zealand all have metrics for the active mode average efficiency based on Po and requirements for no load power. While the requirements in the EU and the US are very similar for direct operation EPS with nameplate output not greater than 250 W, the requirements in Australia/New Zealand are less demanding both regarding no-load power and average active efficiency. Even though there are larger similarities for EPS than for notebooks computers, there is a gap regarding harmonisation of the requirements.

The measurement standards are harmonised to a large extent and based on the US EPA standard.

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5.4.2 Battery chargers

Only few measures exist for battery chargers. The only identified measures are included in the Energy Conservation Standard for battery chargers implemented by DoE\textsuperscript{88,89} (and Canada\textsuperscript{90}) and the Energy efficiency standard in Korea. The following describes the DoE requirements (as no details have been identified for Korea).

A battery charger is defined as a device that charges batteries for consumer products, including battery chargers embedded in other consumer products. The batteries may be wholly embedded in another consumer product, wholly separate from another consumer product, or partially embedded in another consumer product. Functionally, the batteries are a power conversion device used to transform input voltage to a suitable voltage for charging batteries used to power consumer products.

The regulated battery chargers power consumer products such as:

- Cellular and cordless phones
- Cordless power tools and car battery chargers
- Battery-powered children’s toys
- Electric toothbrushes and shavers (wet environment, inductive connection)
- Tablets and laptops
- Digital cameras, portable music players, smart watches, and headphones

The requirements cover various product classes as shown in Table 9. Also, chargers with inductive connection for use in wet conditions are in the scope for batteries with capacities less than or equal to 5 Wh.

Exempted from the requirements in the US are batteries that requires Federal Food and Drug Administration (FDA) listing and approval as a life-sustaining or life-supporting device in accordance with section 513 of the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 360(c)).

Exempted from the requirements in Canada are devices that charge the battery of a vehicle other than a wheelchair, golf cart or low-speed vehicle, a device that charges the battery of a medical device, a wireless battery charger, other than a wireless battery charger that is inductive and designed for wet environments, and a backup battery charger.

Battery chargers manufactured must have a unit energy consumption (UEC) less than or equal to the prescribed “Maximum UEC” standard when using the equations for the appropriate product class and corresponding rated battery energy as shown in Table 9.

The unit energy consumption UEC (in kWh/yr), is calculated from the battery discharge energy ($E_{\text{disch}}$) in watt hours (Wh), 24-hour energy consumption ($E_{24}$) in watt hours (Wh), maintenance mode power ($P_{\text{m}}$) in watts (W), standby mode power ($P_{\text{sb}}$) in watts (W), off mode power ($P_{\text{off}}$) in watts (W), and duration of the charge and maintenance mode test ($t_{\text{cd}}$) in hours (hrs) for all battery chargers other than uninterruptible power supplies (UPSs); and average load adjusted efficiency ($E_{\text{avg}}$) for UPS.

\textsuperscript{88} https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32
\textsuperscript{90} https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/guide-canadas-energy-efficiency-regulations/battery-chargers/21821
Table 9: Maximum allowed energy consumption for batteries dependent on products class, battery energy and battery voltage

One of the two equations shown below should be used for calculation of the UEC for a battery. If a battery charger is tested and its charge duration as determined in section 3.3.2 of the measurement method\(^91\) minus 5 hours is greater than the threshold charge time listed in table 3.3.3 of the measurement method (i.e. \((t_{cd} - 5) \times n > t_{a&n}\)), equation (ii) shall be used to calculate UEC; otherwise, a battery charger's UEC shall be calculated using equation (i).

\[
\begin{align*}
(i) \quad & \text{UEC} = 365 \left( n \left( E_{24} - 5P_m - E_{\text{batt}} \right) \frac{24}{t_{cd}} + \left( P_m \left( t_{a&n} - (t_{cd} - 5) n \right) \right) + \left( P_{ab} t_{ab} \right) + \left( P_{off} t_{off} \right) \right) \\
(ii) \quad & \text{UEC} = 365 \left( n \left( E_{24} - 5P_m - E_{\text{batt}} \right) \frac{24}{t_{cd}} + \left( P_{ab} t_{ab} \right) + \left( P_{off} t_{off} \right) \right)
\end{align*}
\]

Where:

- \( E_{\text{batt}} \) (battery energy) = Is the energy, in watt-hours, delivered by the battery under the specified discharge conditions in the test procedure.
- \( E_{24} \) = 24-hour energy as determined in measurement method
- \( P_m \) = Maintenance mode power.
- Battery maintenance mode is the mode of operation when the battery charger is connected to the main electricity supply and the battery is fully charged, but is still connected to the charger
- \( P_{ab} \) = Standby mode power as determined in the measurement method,
- \( P_{off} \) = Off mode power as determined in measurement method,
- \( t_{cd} \) = Charge test duration as determined in the measurement method, and
- \( t_{a&n}, n, t_{ab}, \text{ and } t_{off}, \text{ are constants used depending upon a device's product class and found in the test method}

The test method is described in 10 CFR Appendix Y to Subpart B of Part 430 - Uniform Test Method for Measuring the Energy Consumption of Battery Chargers.\(^91\)

\(^{91}\) https://www.law.cornell.edu/cfr/text/10/appendix-Y_to_subpart_B_of_part_430
5.4.3 Other components for mobile devices

Relevant components for mobile devices are among others:

- diodes
- processors/chipsets, storage,
- wheels
- bearings
- GPS
- apps and programming
- speakers
- integrated displays
- motors (for battery operating)
- autonomous driving
- flashlight
- cooling fans
- sensors
- actuators

A screening of relevant legislation has been carried out to identify relevant energy efficiency requirements for components, but none was found except the already mentioned requirements for EPS and battery chargers. Some programmes cover requirements for components that potentially could include requirements for the products in the above-mentioned list, but a closer look of the measures showed that none of them apply to components for mobile devices (for displays maybe to some extent). Some examples are:

Cooling fans
US (DoE and ENERGY STAR), and EU ecodesign includes requirements for fans but these are for comfort fans92 (EU), industrial fans93 (EU), and ceiling fans94 (Doe), ventilation fans95 (ENERGY STAR) and ceiling fans96 (ENERGY STAR).

Motors
For mobile devices relevant motors are DC (Direct Current) motors able to operate with power supply from batteries.

The EU ecodesign programme includes requirements for motors, but the requirements are only for AC motors and are more relevant for motors for industrial application. In general, all products for means of transport of persons and goods are not in the scope of the EU ecodesign directive. This also implies that motors for products such as e-cycles and e-scooters could not be covered within the framework of the ecodesign directive.

DoE has requirements for AC motors as part of their programme for commercial and industrial equipment97. No ENERGY STAR specifications have been identified for motors. EECA has minimum energy efficiency requirements for three phase induction electric motors with voltage rated up to 1100 V (AC)98.

92 COMMISSION REGULATION (EU) No 206/2012 for air conditioners and comfort fans
93 COMMISSION REGULATION (EU) No 327/2011 for industrial fans
95 Residential ventilations fans, https://www.energystar.gov/sites/default/files/Ventilating%20Fans%20Version%204.1%20Program%20Requirements%20_0.pdf
96 Ceiling fans, https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Ceiling%20Fans%20and%20Ceiling%20Fan%20Hi%20Light%20Kits%20Version%204.0_Program%20Requirements%20_0.pdf
No programmes have been identified for efficiency requirements of DC motors.

Displays

Various mobile devices include screens/displays. Some programmes have requirements for television sets but only the EU has requirements for electronic displays (ecodesign and energy labelling requirements) with a broader scope than televisions and monitors. The ecodesign regulation for displays will to some extent be applicable for electronic displays integrated into other products i.e. also in mobile devices. However, the regulation includes various exemptions. In general, the requirements are not applicable to means of transport of persons and goods because this is not in the scope of the Ecodesign Directive. Furthermore, the regulation does not apply to:

- displays with a with a screen area smaller than or equal to 100 cm²,
- displays that are components or subassemblies of products covered by implementing measures adopted under the EU Ecodesign Directive (2009/125/EC) which for instance are computers (laptops and tablets) and in the future also smartphones.
- medical displays

In addition, various displays are exempted from energy efficiency requirements in the ecodesign regulation and only covered by resource efficiency and information requirements:

- status displays
- control panels
- security displays

The US DoE has no energy conservation standard for televisions. The US ENERGY STAR specification for televisions covers main powered television with integrated tuner, main operated hospitality TV/HTDs and home theatre displays. The specification is not of relevance for displays in mobile devices. The US ENERGY STAR does also have a specification for monitors and signage display. Excluded products are among others displays with integrated or replaceable batteries designed to support primary operation without AC mains or external DC power, or device mobility (e.g., electronic readers, battery powered digital picture frames).

EECA has Minimum Energy Performance Standards (MEPS) and Mandatory Energy Performance Labelling (MEPL) for televisions and (computer) monitors. We consider that these do not cover displays integrated in mobile devices. The standard for televisions does only cover products supplied with a TV tuner and the standard for monitors does not cover integrated products such as integrated PCs, tablets and laptops, because these products are already subject to MEPS under other standards. A consultation is ongoing for review of the existing standards, including those for televisions and computer monitors and signage displays.

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101 More exemption is mentioned in the regulation
102 Definition: status display means a display used to show simple but changing information such as selected channel, time or power consumption. A simple light indicator is not considered a status display
103 Definition: control panel means an electronic display whose main function is to display images associated with product operational status; it may provide user interaction by touch or other means to control the product operation. It may be integrated into products or specifically designed and marketed to be used exclusively with the product
Diodes

Various programmes exist for lamps but none of them cover diodes as a component even though for instance the EU ecodesign regulation for light sources\(^{109}\) includes LED lamps. The EU ecodesign regulation for light sources does not cover LED dies, chips and packages (unless they are intended to be used directly in a luminaire). In addition, the regulation does not apply to electronic displays (e.g. televisions, computer monitors, notebooks, tablets, mobile phones, e-readers, game consoles), including displays within the scope of Commission Regulation (EU) 2019/2021 (for electronic displays), and Commission Regulation (EU) No 617/2013 (for computers and computer servers).

US DoE has no energy conservation standard for Light emitting diode (LED) lamps\(^{110}\) and the scope of the ENERGY STAR products specification for lamps\(^{111}\) does not include diodes which could be integrated in mobile devices. It is limited to lamps with integrated ballasts and drivers intended to be connected to the electric power grid with the following ANSI standard base types: E26, E26d, E17, E11, E12, G4, G9, GU10, GU24, GU5.3, and GX5.3; and rated nominal operating voltages of 120, 240 or 277 VAC, or 12 or 24 VAC or VDC.

EECA does not have standards for diodes. Regarding lighting, they only have MEPS for ballasts for fluorescent lamps, and compact and linear fluorescent lamps\(^{112}\). However minimum standards and labelling requirements for LED is under way. The standards will cover non-directional, directional, and linear LED lamps and not diodes for integration in products\(^{113}\).

5.4.4 Standby requirements

For many digital devices, standby power consumption in especially networked standby contributes largely to the total energy consumption over its lifetime because it is typically higher than traditional standby due to the need of a network interface and be ready to be rapidly woken by the network. However, manufacturers of mobile devices have a high motivation to improve their products’ energy efficiency compared to manufacturers of stationary products, because battery life directly impacts the user experience of their products.

Figure 9 shows that mobile devices compared to non-mobile devices have significantly lower networked standby power consumption despite that many of these products maintain the same functionalities during standby (e.g. voice assistants and internet connection).

\(^{109}\) Commission Regulation (EU) 2019/2020 for ecodesign regulation for light sources and separate control gears


\(^{111}\) ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.1


Various measures address the energy consumption in low power modes including product specific measures for individual product groups and horizontal measures covering a wide variety of products. Examples of horizontal programs are:

- the EU horizontal ecodesign regulation, product specific requirements for computers (including requirements for low power modes)
- the US Federal Energy Management Program requiring that federal agencies purchase energy consuming products with a standby power level at 1 W or less when compliant models are available on the market\(^\text{115}\)
- the Korean e-Standby Power program (mandatory labelling)

See more details below.

5.4.4.1 EU standby regulation

The EU horizontal standby regulation\(^\text{116}\) covers devices in the following categories:

- household appliances,
- information technology equipment intended primarily for use in the household sector,
- consumer equipment,
- toys, leisure, and sports equipment.

However, the standby regulation does not apply to equipment placed on the market with a low voltage external power supply (an external power supply with a nameplate output voltage of less than 6 volts and a nameplate output current greater than or equal to 550 milliamperes) to work as intended. Therefore, various small mobile devices are not within the scope of the regulation, probably because they have a low standby consumption.

The EU ecodesign standby regulation dictates under which conditions electric appliances placed on the market in EU should automatically go to standby, off or networked standby modes and includes maximum limits for the power consumption of these low power modes. The battery maintenance mode i.e. topping up when charging level reaches a certain limit, which is very relevant for mobile devices, is not a standby mode because it is a key function and the

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\(^{114}\) Bridging the Network Standby Gap between Mobile and Mains-Powered Products. 4E Electronic Devices & Network Annex. EDNA. July 2019


standby regulation does not include power limits for this mode. However, if charging is paused when the desired charging level is reached, the appliance is considered to be in standby.

The current power limits are:

- Off mode: 0.5 W
- Standby mode: 0.5 W
- Standby mode in case the product has information or status display: 1 W
- Networked standby: 2 W (8 W for HiNA\textsuperscript{117} equipment and equipment with HiNA functionality\textsuperscript{118})

Besides power limits for power consumption in various low power modes, the regulation also includes requirement regarding availability of off mode and/or standby mode and power management. The power management requires that the equipment, when it is not providing its main function, switches automatically after the shortest possible period of time appropriate for the intended use of the equipment, into standby mode, off-mode or networked standby mode (or other mother not exceeding the power limits). For network equipment the default period of time after which the power management function, or a similar function, switches the equipment automatically into a condition providing networked standby shall not exceed 20 minutes.

For some products, the standby requirements recently have been included in the product specific regulations to better adapt the standby requirements to the functional requirements of the product regarding relevant low power modes, the power requirements for these modes and the time before the product should be switched to power-saving modes by the power management system. For standby, off mode and networked standby, the product specific regulations in most cases align with the power limits in the horizontal regulation. But especially regarding the power management requirement, often even more ambitious requirements are implemented.

The European Commission is reviewing the horizontal standby regulation. In the most recent draft of the new regulation, it is proposed to reduce the power limit for the standby mode with information and status display to 0.8 W (the current limit is 1.0 W). No changes are proposed for the other power limits. However, the review study did propose a power limit for off mode of 0.3 W (the current limit is 0.5 W).

In addition, it is proposed to extend the scope of the standby regulation to cover motor operated adjustable furniture and motor operated building elements, and parts incorporating an electric motor or an actuator and a control unit, which are designed to work with other motor-operated building elements. However, none of the products in the extended scope seem to be relevant for mobile devices.

5.4.4.2 US low standby power product purchasing requirement

Federal agencies in the US are according to the Federal Energy Management Program\textsuperscript{119} required to purchase energy consuming products with a standby power level of 1 watt or less, when compliant models are available on the market.

To assist federal buyers in complying with this low standby power product requirement, the Federal Energy Management Program (FEMP) has identified priority product categories, which include products that consume relatively large amounts of energy and are prevalent in the federal sector.

For certain products, the purchase of EPEAT-registered or ENERGY STAR-qualified models automatically satisfies the low standby power requirement. However, for other products the requirement is not fulfilled due to a variation in product category definitions or the absence of a standby power requirement in the registration or qualification process.

\textsuperscript{117} HiNA equipment means equipment with one or more of the following functionalities, but no other, as the main function(s): router, network switch, wireless network access point, hub, modem, VoIP telephone, video phone

\textsuperscript{118} Equipment with HiNA functionality means equipment with the functionality of a router, network switch, wireless network access point or combination thereof included, but not being HiNA equipment

\textsuperscript{119} https://www.energy.gov/eere/femp/low-standby-power-product-purchasing-requirements-and-compliance-resources
The US Federal guideline on how to procure products with standby power level below is shown in Figure 10.

<table>
<thead>
<tr>
<th>How To Comply</th>
<th>Purchase products on FEMP's Low Standby Power Product List.</th>
<th>Purchase products that are EPEAT-registered and ENERGY STAR-qualified.</th>
<th>Purchase products that are ENERGY STAR-qualified.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority Product Categories</td>
<td>Thin client computers and workstation computers</td>
<td>Desktop computers, integrated computers, notebook computers, tablets, portable all-in-one computers, computer displays, professional signage, and imaging equipment.</td>
<td>Audio/video equipment, televisions, uninterruptible power supplies, and corded telephones.</td>
</tr>
</tbody>
</table>

Figure 10: Purchase Guideline regarding standby buy products with standby consumption below 1 W. Gap analysis for mobile devices and related components

5.4.4.3 Korean e-Standby Power program (mandatory labelling)

According to this program, devices that are automatically switched to energy saving mode, minimize standby power and meet the standby power reduction standards are allowed to bear an energy saving label. Those that do not meet the standards must bear a warning label as shown in Figure 11.

The program targets the following products: computers, monitors, printers, facsimiles, copiers, scanners, multi-function copiers, automatic energy saving controller, audios, DVD players, microwaves, door phones, telephones and cordless telephones, radio cassette players, bidets, home gateways, servers, hand dryers, digital converters, routers and wireless routers (total 21 items)

Figure 11: The Korean e-Standby Power saving label
6 Gap analysis for mobile devices and related components

In general, there are only few policy measures for mobile devices – except for computers (notebooks and tablets). Various voluntary schemes for notebooks and tablets relate to the ENERGY STAR Programme, which seems to be the most widely used specifications for computers. Besides for the ENERGY STAR Programme itself, it is also used as a basis for TCO Certified, EPEAT, EU GPP, EU ecodesign and various ecolabels. The only identified mandatory policy measures for mobile devices are the EU ecodesign regulation (MEPS) for notebooks, the Japanese Top Runner approach for notebooks and the MEPS implemented for notebooks in Australia/New Zealand.

For components/equipment related to mobile devices there are various policy measures in place for EPS (several schemes including mandatory EU Ecodesign, AS/NZS MEPS, and US DoE), one measure for battery chargers included when embedded in products (US DoE mandatory requirements) and requirements for internal power supplies in computers. For other components no relevant measures have been identified.

In general, MEPS remove the least efficient products from the market and they are by nature not targets for the best performing products regarding energy efficiency. Therefore, mandatory or voluntary labels could be important measures to encourage energy efficiency and create market pull if relevant, and in combination with MEPS.

No mandatory labelling focused on energy efficiency in the use phase was identified for mobile devices, however a mandatory energy label is under preparation for computers and smartphones/tablets in the EU. Various voluntary labels exist, mainly environmental labels/eco labels.

It makes good sense that no product specific policy measures are in place on the energy efficiency in the use phase for those mobile devices that have a very low energy consumption in the use phase (See Figure 1).

However, some mobile devices have a relatively high annual energy consumption per unit (UEC) in the use phase especially products using energy for moving the product itself. Such products are among others drones, robot lawn mowers, e-mopeds, and robot vacuum cleaners. They are all among the products with the highest unit energy consumption in Table 1 and among the products with the highest total annual energy consumption by product (of the stock) in 2020 and in 2030.

Other mobile devices have low unit energy consumption but a high total energy consumption due to the very high number of products in the stock. Such devices are for instance smartphones, tablets, portable battery-driven tools and wireless (Bluetooth) headsets.

6.1 Identified gaps

In the previous sections, gaps have been identified both on product/component level and on horizontal level. An overview of the gaps is provided in this section.

6.1.1 Gaps for computers (portable devices)

Various programs both voluntary and mandatory exist for computers. The ENERGY STAR Program is used as basis for various measures including for instance the EU ecodesign, TCO Certified, EPEAT/ecolabel, Topten EU and the EU GPP criteria (Green Public Procurement). This program is therefore considered having a high importance and influence on the computer market worldwide.

All regions in the assessment have requirements for computers and some of the programmes such as TCO certified and EPEAT are worldwide. The gap analysis for computers has been focused on the following programs: US ENERGY STAR, TOP Runner (Japan), AS/NZS MEPS, and EU ecodesign. The programmes based on ENERGY STAR have not been further addresses.

The identified gaps are described below.
6.1.1.1 Gaps – Scope

Slates and tablets are only to some extent covered by energy efficiency requirements. The Top Runner programme (Japan) and the AS/NZS MEPS do not include requirement for slates. The Top Runner programme does probably not include portable computers, or only to some extent.

This is also the case for the EU ecodesign regulation and the ENERGY STAR Specification. The ecodesign regulation excludes slates and tablets with idle state power consumption less than 6 W and notebooks with a viewable diagonal screen size below 22.86 cm (9 inches) and the ENERGY STAR specification excludes slates and tablets which contain cellular voice capability and notebooks with a viewable diagonal screen size smaller 6.5 inches and higher than 17.4 inches. The Top Runner Program (Japan) and AS/NZS MEPS do also exclude handheld computing devices.

In general, small handheld computer devices seem to be exempted either based on screen size or power consumption or by mentioning them as exempted products in the legislation.

In addition, mobile thin clients are not covered by the Top Runner program (Japan) and AS/NZS MEPS.

6.1.1.2 Gaps - Requirements and metrics

Even though the requirements in all the analysed measures are based on TEC, the metrics and requirements vary significantly from programme to programme and from region to region\textsuperscript{120}. This seems inappropriate for computers which to a very high extent are placed on the global marketplace. A huge gap is therefore lack of harmonisation of metrics and requirements.

Other identified gaps are:

- No regions/programmes include requirement for active modes. It is foreseen that the US and the EU will explore active mode requirements for the next revision. However, for mobile devices, especially for slates, the consumption in active mode is of less important than for desktop computers and larger notebooks.
- EU, Australia/New Zealand do not have requirements for internal power supplies at 10 % of rated output power, and Japan does not at all have requirement for internal power supply.
- The efficiency requirements for internal power supply vary from program to program
- Some region/programmes do not have limits for low power modes and power management
- US and EU refer to international IEC standards (with some modifications), while Japan and Australia/New Zealand have their own standard. These have not been compared in detail, but there might be lack of harmonisation.
- The US ENERGY STAR Program is used worldwide as a basis for various other schemes to promote energy efficiency. But still, it is a voluntary program, meaning that in the US no mandatory energy efficiency requirements exist for computers.

6.1.2 Gaps for smartphones

No energy efficiency measures were identified for smartphones besides the TCO Certified requirement for EPS delivered with the phone, a lack that can be considered as a gap.

The EU is preparing regulations with energy efficiency requirements, which are expected to be based on battery endurance. The proposed requirements will be used as inspiration for the section in this report dealing with policy recommendations.

\textsuperscript{120} But still to a large extent based on Energy Star.
6.1.3 Gaps for vacuum cleaners

No measures were identified for robots and portable (cordless) vacuum cleaners. However, the European Commission is preparing new ecodesign and energy labelling regulations for vacuum cleaners which probably will include requirements for robots and portable vacuum cleaners. The review study for vacuum cleaners\textsuperscript{121} carried out as part of the preparation of the new regulations showed that the maintenance mode consumption makes up large part of annual energy consumption for robots and cordless vacuum cleaners, especially for robots. No requirements exist for this mode either in the EU (for instance in the standby regulation) or in other regions. However, the maintenance mode is included in the equation to calculate the unit energy consumption in DoE’s energy conservation standard for battery chargers.

The lack of requirements for robot and cordless vacuum cleaners is considered as a gap in general, and the lack of requirements for the maintenance mode is deemed as a horizontal gap with relevance for various mobile devices. This will be addressed in the section with policy recommendations.

A similar gap as the one for vacuum cleaners exists for other motor operated mobile devices with a base (docking station for charging for instance lawnmowers).

6.1.4 Gaps for EPS

Various programmes include requirements for EPS supplied with a specific mobile device for instance TCO Certified. The EU, US DoE, Canada, Korea, and Australia/New Zealand all have mandatory requirements for EPS in product specific legislation. No requirements for EPS were found in Japan.

The identified gaps are described below.

6.1.4.1 Gaps – Scope

\textit{Wireless power supplies} are only mentioned in one of the addressed measures. Missing requirements for wireless power supplies is considered a huge gap because an increase in use of wireless chargers is foreseen (see Figure 6). However, the European Commission has recently initiated a review of the EPS ecodesign regulation, which should include assessment of wireless charging.

The only measure identified that mentions wireless power supplies is the TCO Certified criteria for smartphones and headsets, which require (as one of two solutions) that the product must have a built-in wireless charging capability that complies with Qi Wireless Power Transfer System, Power Class 0 Specification version 1.2.4, or future revisions. But this is not particularly dealing with energy efficiency.

\textit{Restricted application} of the requirements due to limited coverage and/or exclusions in the legislation is leading to other gaps. Examples of these are:

- The EU ecodesign requirements only apply to product types included in the Annex A of the regulation. This means for instance that power supplies for handheld tools are not covered. In addition, means of transport of persons and goods are not included in the scope of the Ecodesign Directive which excludes products such as e-bikes and e-scooters.
- EPS for motor operated products: The DoE requirements do not cover EPS that charges the battery of a product that is fully or primarily motor operated. Also, the ecodesign regulation does not cover motor operated product if they are exclusively for means of transport of persons and goods or not included in the product groups in Annex A to the regulation. This means for instance that EPS for lawnmowers, drones, vacuum cleaners and various handheld tools are not covered by the DoE requirements.

• Medical equipment is excluded from various energy efficiency requirements because of importance of reliability for equipment used on hospitals etc. EPS supplied with the equipment are also exempted. As EPS are very durable products, hence, there is no reason for exempting EPS for medical equipment from energy efficiency requirements. EPS with nameplate output above 250 W (is only covered in the US)

6.1.4.2 Gaps - Requirements and metrics

The measures for energy efficiency of EPS in both the US, EU and Australia/New Zealand all have metrics for the active mode average efficiency based on $P_o$ and requirements for no load power. While the requirements in the EU and the US are very similar for direct operation EPS with nameplate output not greater than 250 W the requirements in Australia/New Zealand are less demanding both regarding no-load power and average active efficiency. Even though there are larger similarities for EPS than for notebooks computers there is a gap regarding harmonisation of the requirements.

6.1.5 Gaps for battery chargers

Only one measure has been identified for battery chargers and this is the US DoE’s energy conservation standard. It covers batteries that are wholly embedded in another consumer product, wholly separate from another consumer product, or partially embedded in another consumer product.

As mentioned in section 5.3.3 the battery maintenance mode makes up a large part of the annual energy consumption for robots and cordless vacuum cleaners. The same could be anticipated for other similar products such as lawn movers, e-bikes, drones, motor operated tools, and other equipment charged from a docking station or base station. No power limits for this mode have been identified although the battery maintenance mode is part of the metric to calculate the unit energy consumption in the DoE energy conservation standard for battery chargers.

Lack of energy efficiency requirements for battery chargers including requirements for the battery maintenance mode is a huge gap and will be addressed in the section of this report dealing with policy recommendation.

6.1.6 Gaps for other components used in mobile devices

For components other than EPS, battery chargers, and internal power supplies, no component requirements were identified. However in general, very efficient components are used in mobile devices due to the importance of the battery operation time.

As the list of components (and products) are extensive, it is considered more appropriate to target the most relevant components (battery chargers and EPS) and horizontal issues such as networked standby and battery maintenance mode (see below) rather than various components.

One component of specific interest is the DC motor used in motor operated equipment because various of these motor operated devices are among the products with the highest energy consumption per device per year (Figure 1), as well as among the products with the highest annual energy consumption of the stock (Figure 5). An increase of the motor efficiency will have a high influence on the energy consumption of these devices (depending on the user profile). The current measures for motors do all only deal with AC motors (see section 6.4.3). When reviewing the current EU ecodesign regulation for motors\textsuperscript{122}, one of the European Commission’s tasks is to consider the extension of the scope including permanent magnet motors. The Commission shall present the result of the review to the stakeholders in the Ecodesign and Energy Labelling Consultation Forum no later than 14 November 2023.

\textsuperscript{122} Commission Regulation (EU) 2019/1781
6.1.7 Horizontal gaps

6.1.7.1 Standby and networked standby

Only two policy measures with mandatory horizontal standby requirements have been identified and they are:

- the EU ecodesign regulation regarding standby and off mode electrical power consumption\textsuperscript{123}, which also includes requirements for networked standby. This regulation covers various mobile devices, but some mobile devices are excluded.
- The Korean mandatory labelling of devices with low standby consumption and power management and a warning label if not (the Korean e-Standby power program).

Requirements for mobile devices such as slates and tablets are in some regions implemented in measures dealing with energy efficiency of computers. In addition, standby requirements are also included in some public procurement guidelines.

In general, the standby consumption is low for mobile devices including when providing networked standby due to the importance of the period the device can operate on the battery between charging (see Figure 9).

The current EU ecodesign horizontal power limit for networked standby is 2 W and far beyond the power consumption in networked condition for various mobile devices for instance smartphones. However, some products might still have a high energy consumption in standby mode for instance charging/docking stations for motor operated products and probably also for various mobile audio devices.

The number of mobile devices in the stock is expected to rise steeply in the coming years and the large majority of these are foreseen to be internet connected (See Figure 3). The lack of mandatory standby requirements (especially regarding networked standby) for mobile devices is therefore considered as a huge gap.

6.1.7.2 Battery maintenance mode

Various products are placed in a docking station or base station for recharging after use. The product could by itself return to the docking station (for instance robot vacuum cleaners), or it could be placed in the dock by the user. When the battery is fully charged the charger will often stay in a mode with a relatively high power consumption, because it is monitoring the charging status of the battery. No horizontal requirements or power limits have been identified for this mode. The battery maintenance mode is for instance not covered by the EU horizontal standby regulation because the charger in this mode is performing functions beyond standby functionality (as defined in the regulation). However, the battery maintenance mode is included of the metric for calculation of the UEC in the US DoE power conservation standard for battery chargers. Lack of requirements for battery maintenance mode is considered as a huge gap which could be addressed horizontally.

6.1.7.3 Use and programming of apps and software

Apps and software have not been addressed previously in this report but there is no doubt that the use and programming/design of apps and software have a large influence on the energy consumption of various products including mobile devices.

Application software products, although being immaterial goods, can cause significant materials and energy flows. Software characteristics determine which hardware capacities are made available and how much electric energy is used by end-user devices, networks, and data centres. Recent research by the German Environment Agency has shown relevant differences in the energy consumption of different software application products with the same

\textsuperscript{123} Commission Regulation (EU) 1275/2018 and the amendment (EU) 801/2013
functionality and also discernible differences between the software products in terms of their hardware efficiency (i.e. their impact on processor utilization, working memory, permanent storage, and bandwidth for network access). A study carried out by Greenspector, reveals that mobile applications on smartphones consume 20 TWh annually in the EU, without considering upstream energy consumption of data centres and network. The study estimates that annually energy savings of 6 TWh could be achieved in the EU if the average app consumed the same amount of energy as the best-ranking app in its category.

More findings from another Greenspector study:

- On average 44% of all applications have more than 5 trackers, which have a major impact on the energy consumption of the smartphone.
- 50% of applications keep processing after the application is closed.

Various surveys have shown that the energy consumption can be reduced by better design of application. For example, one study has shown the impact of image compressions. See Figure 12.

Figure 12: Impact of gamma correction (image compression) in mobile application

No mandatory legislations have been identified dealing with energy efficiency of software related issues and programming of apps for mobile devices. However, the German ecolabel the Blue Angel has developed basis criteria for purchasing of resources and energy-efficient software products (DE-UZ 215). The intention is that consumers and public procurers by purchasing software that has been awarded the Blue Angel can be sure that the software uses hardware resources in a particularly efficient manner and saves energy. Due to lower performance requirements, the hardware

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128 Embedded software in the apps which makes it possible to track which information are search etc. (small spying programmes).

has a longer service life. In addition, the software stands out due to its high level of transparency and grants users’ greater freedom in their use of the software.

The study for preparation of the EU ecodesign and energy labelling working plan for 2020-2024 recommended to include software applications as kind of ‘energy-related product’ into the Ecodesign and Energy Labelling Working Plan 2020-2024. For product groups regulated under EU Ecodesign and/or Energy Labelling frameworks with main functionalities depending on software, it is recommended that new or revised ecodesign and energy labelling regulations should consider the following requirements with the aim of reducing the risk of software-induced hardware obsolescence:

- Availability of relevant soft-/firmware a specifies number of years after the placing on the market of the first product of a certain product model
- Availability of software-updates
- Possibility of rolling back software to previous versions
- Software compatibility
- Possibility of rolling back software to previous versions
- Possibility of rolling back software to previous versions

Most of the recently adopted EU ecodesign regulations incorporate a dedicated article dealing with software updates is included and it is expected that this article (or something rather similar) will be applied in future new or revised Ecodesign regulations. The text included in the ecodesign regulations is:

<table>
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<th>[...]</th>
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<tr>
<td>The energy consumption of the product and any of the other declared parameters shall not deteriorate after a software or firmware update when measured with the same test standard originally used for the declaration of conformity except with explicit consent of the end-user prior to the update. No performance change shall occur as result of rejecting the update.</td>
</tr>
<tr>
<td>A software update shall never have the effect of changing the product’s performance in a way that makes it non-compliant with the ecodesign requirements applicable for the declaration of conformity.</td>
</tr>
</tbody>
</table>

The above illustrates that apps and software issues are of great importance for energy consumption of various mobile devices. But still only very few measures are dealing with energy efficiency related to these aspects. If this issue is included in the next ecodesign and energy labelling working plan (mentioned above) it must be expected that the European Commission will initiate a preparatory work/study for evaluation and development of possible measures. Regulation of the energy consumption related to apps and software will be complex because it will be closely related to the functionality of apps, the consumer behaviour, the adaption between platforms, and possibilities for optimisation of flows etc.

Possibilities for improvements include among other:

- Purpose-driven adaptation of the app e.g. many users use YouTube for listening to music, but YouTube also provides video streaming. By only streaming audio, significant savings could be achieved.

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129 The study for preparation of the EU ecodesign and energy labelling working plan for 2020-2024. [https://drive.google.com/drive/folders/1cqSBxXDgQq8yQHRXrF1FUQmcUlve?usp=sharing](https://drive.google.com/drive/folders/1cqSBxXDgQq8yQHRXrF1FUQmcUlve?usp=sharing)

Adapting multimedia application streams to the platform and the connection speed of the user would reduce consumption. This technique is already partly applied to the connection for solutions like Netflix. YouTube offers the possibility to modify the definition, but the option is not visible to all users.

Web browsing is highly energy consuming and requires the application of good practices to avoid BloatWare (preinstalled software on the device, which often use memory and resources without benefit for the user). It is important to optimise images, reduce tracking tools and limit the impact of advertising to save energy.

The social network apps consume significant amounts of energy. Optimisation of the multimedia flows (images, video, gifs) is necessary, but it is also essential to offer options to the user to reduce its impacts (e.g. not to display the gifs or images). Some social media apps offer a “light” application, like Facebook, that consumes 24% less energy according to the study by Greenspector. Some social media apps offer a “light” application, like Facebook, that consumes 24% less energy according to the study by Greenspector.131

Adapt the design to the technologies. E.g. set up dark themes for AMOLED (Active Matrix Organic Light Emitting Diode) screens will save energy.

The German Federal Environment Agency has developed the methodological basis for determining the use of resources by software, comparing application software products with each other and making efficiency demands on them.132 An evaluation methodology for the resource efficiency of application software products was developed to identify the extent to which hardware resources are used and amount of energy is required (hardware efficiency, energy efficiency, and resource management). The applicability of the criteria was tested by applying it to 11 different software products: 2 word processing programs, 3 Internet browsers, 3 content management systems and 3 database systems.

The measurement results pointed out clear differences in energy consumption between the tested application software products with same functionality during their actual operation. See Figure 13.

Based on these findings, basic award criteria on resource and energy efficiency of software products (minimum system requirements, hardware utilisation and electrical power consumption in idle mode, hardware utilisation and energy demand when running a standard usage scenario, and support for the energy management system were developed for the German Blue Angel Ecolabel. In order to facilitate the application of the evaluation method, three supplementary modules are also being developed, i.e. a reference system for carrying out measurements on office software, a software for evaluating hardware utilization and energy consumption, and a recording tool for obtaining the evaluation criteria. The conclusions will provide recommendations for the application of the evaluation methodology as controlling tool for product policy.
7 Policy options to improve energy efficiency

For mobile devices with low unit energy consumption in the use phase, horizontal measures with requirements for components such as EPS (including standardised MEPS and unbundling), battery charging systems and durability of the battery seem to be the most appropriate policy measures. This should be combined with measures focusing on other phases of the life cycle with high environmental impact. Various voluntary schemes already have such requirements.

For mobile devices with higher unit energy consumption, product specific requirement should be considered possibly in combination with horizontal requirements. Relevant mobile devices with high unit energy consumptions are primarily motor operated products such as robot lawn movers, e-mopeds, battery-driven vacuum cleaners including robots, and drones, and notebooks and tablets.

Only few mobile devices will probably be targeted with product specific policies and therefore horizontal measures will be of great importance.

As most mobile devices are global devices developed for the global market place, a high degree of harmonisation of scope, definitions and measurement methods is recommended.

7.1 Policy options for products and components

7.1.1 Computers (only mobile devices slates and tablets)

Policy options to improve the energy efficiency of computers and identified gaps are described in previous sections. The addressed measures include EU ecodesign regulation for computers, US ENERGY STAR specification for computers the Australia/New Zealand MEPS and the Japanese Top Runner.

The most important identified gaps are lack of:

- harmonisation of scope and metrics for mobile computer devices
- requirements for slates, tablets and mobile thin clients in some regions
- requirements for Internal power supplies in some regions
- harmonisation of efficiency requirements for internal power supplies
- requirements for active mode

7.1.1.1 Recommended policy options - computers

As computers are products placed on the global market place, the most important recommendation is a high degree of harmonisation of the legislation dealing with efficiency of computers worldwide regarding scope, metrics, level of ambition and measurement standards. Of the mentioned issues, harmonisation of measurement standard and metrics are considered the most important. There might be reasons why some regions want to exclude some products from the scope or to implement less demanding requirements (or delay the implementation of more ambitious requirements with a few years), but it is of high importance that the basis for estimation of energy consumption and energy efficiency is the same worldwide and the results of measurement comparable from region to region.

Harmonisation of standards

It is therefore proposed that all future policy developments for computers are based on the most recent IEC standard with only few (if any) adaptions to regional demands and that development of standards in IEC is supported by relevant national and regional authorities and manufacturers.
The current IEC standard is IEC 62623:2022 that has been recently updated. It was published in April 2022.\textsuperscript{133}

Inclusion of slates and tablets

The review of the measures showed that slates and tablets were not included in all the legislation addressed and some are excluded due to screen size, containing of cellular voice capability (in the US), and idle state power consumption less than 6 W (in the EU). It is recommended to review the measures and include slates and tables in all regions, minimising the exclusions.

Metrics and active mode

All the used metrics are based on TEC/E_{TEC}, but the requirements and calculations vary from region to region. The variations concern the included modes, the assumed operation time in each mode, the allowances for functionalities beyond the base functionality, and the limits for the annual energy consumption.

It is recommended that the regions to a larger extent harmonize the requirements and the metric. Naturally, the operation time might vary from region to region but still it should be possible to agree on a common metric.

The metrics used for calculation of the annual energy consumption in the AS/NZS MEPS mention P_{work} (power consumption in active mode) and T_{work} (time in active mode). But the share of time used for T_{work} is set at 0% and thereby P_{work} has no influence on the estimated annual energy consumption. The IEC measurement standard includes methods for measuring P_{work} and T_{work}, and it should therefore be possible to include active mode in the metric. This is also considered relevant for mobile computer devices because they probably will have increased functionality in the future.

It is foreseen that the US will considerer inclusion of active mode in the next revision of the ENERGY STAR specification for computers.

It is recommended to initiate an international cooperation regarding the establishment of new metrics for notebook computers including slates and tablets. Important issues are including active mode and aligning allowances and assumptions regarding share of time in different operation modes. It could also be considered to remove P_{off} and P_{sleep} from the metric and instead include power limits for these modes in the measures.

Internal power supply (IPS)

The assessed measures include efficiency requirements for IPS with exception of the Top Runner Program. However only the US ENERGY STAR specification includes the efficiency requirement at 10 % of rated input requirements. The most demanding energy efficiency requirements for the IPS is the AS/NZS MEPS.

AS/NZS MEPS for IPS are:

Requirement for internal power supply with rated output of 500 W and below:

- 0.85 minimum efficiency at 20 % of rated output power
- 0.87 minimum efficiency at 50 % of rated output power
- 0.85 minimum efficiency at 100 % of rated output power
- Minimum power factor = 0,9 at 100 % of rated output power.

It is recommended that all regions implement requirements for internal power supplies at least in line with the ambition level in the AS/NZS MEPS.

\textsuperscript{133} https://webstore.iec.ch/publication/65120
7.1.2 Smartphones

Various voluntary schemes have requirements for smartphones and mobile phones. However, none of them have energy efficiency requirements for the use phase. The energy consumption per smartphone is low but the high number of smartphones in use, means that the total energy consumption for this product group is large, and it is increasing.

The most common requirements for smartphones are covering the EPS supplied with the phone. But the EU is preparing mandatory ecodesign an energy labelling measures for smartphones and tablets.

7.1.2.1 Recommended policy options for smartphones

The EU preparatory study proposes to use the battery endurance per cycle as a basis for energy efficiency requirements. The analysis in the study indicates relevant variations in battery endurance per full charge of smartphones. This is partly related to the battery size, but even more to how energy-efficient the smartphone operates. Given the multiple functions of smartphones, there are numerous technical aspects, including software and hardware, which have an impact on energy efficiency of the device. Battery endurance is a major indicator for this.

![Battery endurance rating smartphones](image)

**Figure 14**: Spread in battery endurance, i.e. how long a mobile phone operates on a full charge with GSMArena test procedure (endurance rating in hours for a use profile of 1 hour talk time, 1 hour web browsing, 1 hour video playback daily). (Source: EU preparatory study for smartphones)

Enhanced battery endurance per cycle has a two-fold effect of reducing energy consumption and increasing battery lifetime (as fewer charging cycles are required). Both aspects are relevant to reduce LCC (Life Cycle Costs) and environmental impacts.

Normalising the battery endurance by dividing endurance in hours by battery capacity in mAh removes the effect a larger battery (higher rated capacity) tends to have on a longer battery endurance.

Battery endurance (per cycle) can be addressed with either a specific requirement, setting a minimum endurance, or by a generic requirement, such as a mandatory information about performance against a battery endurance

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134 Ecodesign preparatory study on mobile phones, smartphones and tablets. Final Report. Fraunhofer IZM, Fraunhofer ISI, VITO. February 2021
A suitable measure is a benchmark test as used by GSMArena, which comprises a calculated battery endurance for a use scenario reflecting 1 hour of phone calls, 1 hour web browsing, 1 hour playing a video per day and inactivity the rest of the time. According to the EU preparatory study the GSMArena approach allows to make a realistic distinction in device performance, although the measured endurance times will not correspond with real life experience in terms of battery endurance per full charge. There are other benchmark approaches, such as going through a defined cycle of operations repeatedly until the battery shuts off, but the overall test philosophy is the same. In that sense, the GSMArena approach is only one option of how to measure and benchmark battery endurance per cycle.

GSMArena data is considered a good benchmark, but the basic use scenario leads to the conclusion that the lowest rated devices must be fully charged once a day and above-average smartphones every 3 to 5 days, which does not fully correspond with the analysis of consumer behaviour in Task 3 of the EU preparatory study for smartphone, which indicates a more frequent charging.

It is recommended to:

- as a first step to follow the EU preparatory work and base further work on the outcome of this
- investigate further the possibilities for using the battery endurance as a basis for policy development for smartphones
- investigate further which tests and user profiles should be used for estimation of the battery endurance, but the above mentioned GSMArena is considered a good basis for this.
- in the first place to consider consumer information based on battery endurance for instance a label, but in the longer term also minimum requirements could be considered.

It is important to use an aggregated and normalised battery endurance score to outweigh the influence of larger batteries.

The endurance score proposed in the preparatory study is an aggregated and normalised value in hours, as a calculated value derived from the four types of battery endurance tests (talk, web browsing, video playback, and inactive/standby). The endurance score can be translated into an energy efficiency index as shown in Figure 15.

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135 A modified formula is used in the recent published draft working document on Have your Say: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12797-Designing-mobile-phones-and-tablets-to-be-sustainable-ecodesign_en
7.1.3 Vacuum cleaners

7.1.3.1 Policy recommendations for vacuum cleaners

It is recommended to develop policy measures for robots and portable (cordless) vacuum cleaners.

The measure should include requirements regarding:

- the Annual Energy Consumption (AE) for cordless and robot vacuum cleaners which includes the power consumption in battery maintenance mode (formula specifically targeted robots and cordless vacuum cleaner (see section 6.3.3).
- the maintenance mode (see section 8.2.2)
- the run time of the battery (from full load) at max. power consumption correlated to cleaning performance
- other low power modes

The disadvantage of setting requirement regarding the runtime of the battery is the risk that manufacturers will oversize the battery and thus increase resource consumption. However, the runtime could also be optimized be ensuring energy efficient operation of the device (efficient motor etc.).

7.1.4 EPSs

Various regions have mandatory requirements for EPS and in addition several voluntary schemes include requirements for EPS supplied with products including some mobile devices. However, still there is room for improvement of existing and development of new policy measures.
7.1.4.1 Policy recommendations for EPS

**Wireless power supply**

More and more products will in the future be charged via a wireless power supply instead of an EPS. A wireless power supply is per definition 136 not a class A EPS 137 because such an EPS should be connected to the end-use product via a removable or hard-wired male/female electrical connection, cable, cord, or other wiring, even though it provides the same function. Examples of wireless power supplies are shown in Figure 16.

![Figure 16: Examples of wireless power supplies replacing EPS](image)

It is considered very important to develop energy efficiency standards for wireless power supplies. The only wireless power supplies subject to the current DoE energy conservation standards for battery chargers are those used in a “wet environment,” such as electric toothbrushes and water picks charging 139.

Wireless charging technologies are becoming increasingly popular among consumer product manufacturers, and DOE has indicated interest in potentially treating these in a request for information (RFI). The Department also suggests that such products would be considered “non-Class A” EPSs because they are not connected to the end-use product using a removable or hard-wired electrical connection which, are currently subject to an energy conservation standard but may be in the future.

Development of policy options for wireless power supplies will require more knowledge regarding the product and development of a test procedure. A test procedure should also consider the consumer behaviour which might be different for wireless power supplies than for EPS. In the EU, wireless power supplies will be taken up in the ongoing work on the revision of the existing ecodesign regulation for EPS. The review will also include common chargers 140.

The maintenance mode (the battery charger mode in which the battery is fully charged but still interfacing with the charger), addressed in the section dealing with battery chargers could also constitute a large portion of the energy impact of wireless charging. In a study of the Swiss Federal Office of Energy 141, the authors found that the maintenance mode energy use of a smartphone over the course of 24 hours could be greater than the energy required to provide a

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136 An EPS is connected to the end-use product via a removable or hard-wired male/female electrical connection, cable, cord, or other wiring.

137 A Class A EPS is a device that is designed to convert line voltage AC input into lower voltage AC or DC output; is able to convert to only 1 AC or DC output voltage at a time; is sold with, or intended to be used with, a separate end-use product that constitutes the primary load; is contained in a separate physical enclosure from the end-use product; is connected to the end-use product via a removable or hard-wired male/female electrical connection, cable, cord, or other wiring; and has nameplate output power that is less than or equal to 250 watts.


full charge. As wireless charging stations become prevalent in public places and households, the amount of time that devices spend fully charged on wireless charging pads may grow and this should be taken into by establishment of user profiles.

It is therefore recommended to consider requirements for the battery maintenance mode for both wireless power supplies/chargers and other battery chargers.

Other policy recommendations

- Harmonization of requirements worldwide and measurement standards
- Implementation of requirements in regions without energy efficiency measures for EPS
- Extension of the scope to products yet not covered by requirements especially EPS for motor operated products, handheld tools, and medical equipment (coverage vary from region to region but should be the same).
- Consider the relevance of requirements for EPS with nameplate output above 250 W

7.1.5 Battery chargers

7.1.5.1 Policy recommendations for battery chargers

It is recommended that all regions develop requirements for battery chargers (including when embedded in other products) based on the method used by the US DoE. The potential for more demanding requirements should also be investigated. Harmonisation of the requirements between regions is strongly recommended.

The DoE method used for calculation of the energy consumption of chargers, includes the power consumption in active mode, maintenance mode, off-mode, and standby mode, as well as assumptions regarding the period the charger is in these modes (user profile).

The measurement method\textsuperscript{142} describes the user profiles for different product classes of battery chargers. The user profile varies a lot from product class to product class. The user profiles do not estimate the time spent in maintenance mode alone but a combined number of daily hours for active mode and maintenance mode together. The applied user profiles appear from Table 10.

As the assumptions regarding user profiles will have a large influence on the calculated unit energy consumption, it is proposed/recommended to supplement the current requirements based on user profiles with power limits requirements for the low power modes including for the maintenance mode, to ensure that all battery chargers have low consumptions in these modes. The power limits could be similar to the ones suggested for vacuum cleaners in the EU review study or potentially even lower (see more below).

\textsuperscript{142} https://www.law.cornell.edu/cfr/text/10/appendix-Y_to_subpart_B_of_part_430
Table 10: User profiles applied in the DoE test method for battery chargers

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Rated battery energy (Wh)</th>
<th>Special characteristic or battery voltage</th>
<th>Active + maintenance (W)</th>
<th>Standby (W)</th>
<th>Off (W)</th>
<th>Number per day</th>
<th>Hours per day</th>
<th>Hours threshold charge time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low-Energy</td>
<td>≤5 Wh</td>
<td><strong>Inductive Connection</strong> ****</td>
<td>20.64</td>
<td>0.10</td>
<td>0.00</td>
<td>0.15</td>
<td>137.73</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Low-Energy,Low-Voltage</td>
<td>≤100 Wh</td>
<td>&lt;4 V</td>
<td>7.82</td>
<td>0.29</td>
<td>0.00</td>
<td>0.25</td>
<td>14.49</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Low-Energy,Medium-Voltage</td>
<td>≤50 Wh</td>
<td>10-10 V</td>
<td>6.42</td>
<td>0.30</td>
<td>0.00</td>
<td>0.10</td>
<td>64.20</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Low-Energy,High-Voltage</td>
<td>≤50 Wh</td>
<td>10-10 V</td>
<td>16.84</td>
<td>0.91</td>
<td>0.00</td>
<td>0.50</td>
<td>33.60</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Medium-Energy,Low-Voltage</td>
<td>≤100-3000 Wh</td>
<td>&lt;20 V</td>
<td>6.52</td>
<td>1.16</td>
<td>0.00</td>
<td>0.11</td>
<td>59.37</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Medium-Energy,High-Voltage</td>
<td>≤100-3000 Wh</td>
<td>220 V</td>
<td>17.15</td>
<td>6.85</td>
<td>0.00</td>
<td>0.34</td>
<td>50.44</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>High-Energy</td>
<td>≤3000 Wh</td>
<td><strong>Inductive Connection and designed for use in a wet environment (e.g. electric toothbrushes).</strong></td>
<td>8.14</td>
<td>7.30</td>
<td>0.00</td>
<td>0.32</td>
<td>25.44</td>
<td></td>
</tr>
</tbody>
</table>

* If the duration of the charge test (minus 5 hours) as determined in section 3.2 of appendix Y to part B of this part exceeds the threshold charge time, use equation (9) to calculate UIC otherwise use equation (7).

** Wh = Rated battery energy as determined in 10 CFR part 420.3(a).

**** Inductive connection and designed for use in a wet environment (e.g. electric toothbrushes).

The EU review study for vacuum cleaners indicates on the basis of information from European consumer association (ANEC/BEUC) that the power consumption in maintenance mode (for trickle charge) is considerable and that the consumption varies between 0.5 and 8 W for models on the market. This means that the yearly ‘maintenance mode’ energy use could be as high as 60 kWh, which is higher than the total yearly energy use of EU regulated canister vacuum cleaners. The estimated market average in the EU for the maintenance mode of cordless vacuum cleaners is 2.6 W and 3.7 W for robots.

The EU review study for vacuum cleaners (see Section 6.3.3) suggests for the maintenance mode requirements for cordless and robots to follow that of the 2019 requirements in the EU standby regulation, but even lower limits should be possible. The suggested power limits for maintenance mode are:

- For cordless vacuum cleaners: 0.5 to 1.0 W
- For robot vacuum cleaners: 2.0 W.

The requirements for the maintenance mode could be included in legislation dealing with battery chargers (in line with the DoE standard) or in a horizontal regulation for maintenance mode, which in addition could include requirements for other low power modes for mobile device of which requirement for networked standby is of especially high importance.

### 7.2 Horizontal policy measures

#### 7.2.1 Policy recommendations for standby power

For many mobile devices, standby power consumption, especially networked standby, contributes largely to the total energy consumption over its lifetime because the power consumption in networked standby condition is typically higher than traditional standby, due to the need of a network interface and the need to be quickly awakened by the network. Some mobile devices such as smartphones have a low power consumption in networked standby (see Figure 9) while others such as robot vacuum cleaners have a higher consumption.

The gap analysis showed that only the EU has horizontal mandatory power limits for consumption in standby modes and power management requirements for broader groups of electrical appliances. The EU requirements cover various mobile devices, but even in the EU there is a lack of standby requirements for several products.
Even though the standby and networked standby consumption is low for mobile devices, some products might still have a high energy consumption in standby for instance charging/docking stations for motor operated products and probably also for various mobile audio devices. Furthermore, when the number of mobile devices with a large share being internet connected is foreseen to rise steeply in the coming years, it is needed to establish mandatory power limits for consumption in standby and network standby modes and power management requirements for broader groups of electrical appliances.

**Ambitious requirements for networked standby**

It is recommended for mobile devices to consider ambitious requirements for power consumption in networked standby to prevent a huge increase in energy consumption due to a large number of mobile devices with internet connection. It is proposed to go for a networked standby power limit below 0.5 W, which is more than twice as much as for smart phones. Requirements should also include power management to be ensure that products switch from active mode to networked standby.

It is proposed that the power limit is implemented in a horizontal legislation for mobile devices. In the EU it could also be implemented in the current horizontal standby regulation, which is under review. A horizontal regulation for mobile devices could advantageously also include power limits for the battery maintenance mode. The regulation should cover all mobile devices with as few exemptions as possible.

An example of proposed networks standby requirements for cordless phones is shown in Figure 17. The proposal is from the EU preparatory study for smartphones, mobile phones, and tablets.

![Figure 17: Examples of potentials requirement for networked standby.](image)

Standards for measurement of the power consumption in networked standby condition already exist and are (with some modifications) used for the EU standby regulation.

A mandatory label in line with the Korean e-Standby Power label could be considered as an alternative. In case of a label, it will be important to have a warning label for products with high standby consumption and without power management.

**7.2.2 Battery maintenance mode**

No horizontal requirements or power limits have been identified for this mode (see Section 6.1.3) and it is therefore recommended to consider horizontal requirements for this mode. Inspiration can be sought in the metric for calculation of the UEC in the US DoE power conservation standard for battery chargers.

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143 The EU regulation refers to EN 50564:2011 based on IEC 62301:2011 (with some modifications)
7.2.3 Use and programming of apps

The way apps are designed and used heavily influence the energy consumption of mobile devices such as smartphones, tablet, and smart watches, see Section 6.1.7.3. Poorly optimized software can deplete a device's battery much faster than necessary and lead to a huge increase of energy consumption in datacentres. Mobile applications have become part of the daily life and are used for every small time e.g. browsing the internet, check emails etc.

Several improvement options exist as described in Section 6.1.7.3. However, development of energy efficiency policies in this area is very complex because the energy consumption depends on hardware, software, design and functionality of applications and the consumer behaviour (at least).

For use and programming of apps the first steps in a policy development process could be to establish an overview of the problems and possible solutions. Next steps could be to create awareness among developers of hardware, software and apps and users, and develop practical guidelines and tools for developers and recommendation for users on how to use their devices and applications more efficiently. Practical guidelines could in a later step be implemented as policy measures/design standards around the world for development of software and applications.
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   https://www.lifewire.com/what-is-a-mobile-device-2373355
   https://en.wikipedia.org/wiki/Mobile_device
   https://www.definitions.net/definition/mobiledevice


19. New ecodesign- and energy labelling regulations are under preparation. These are expected to cover cordless and robot vac-uum cleaners (but probably not handheld vacuum cleaners)


22. Achievements of Energy Efficiency Appliance and Equipment Standards and Labelling Programmes 2021. 4E for the IEA

23. Commission Regulation (EC) No 1275/2008 with regard to ecodesign requirements for standby and off mode, and networked standby, electric power consumption of electrical and electronic household and office equipment.


25. COMMISSION REGULATION (EU) 2019/1782

26. COMMISSION REGULATION (EU) No 617/2013


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131. Ecodesign preparatory study on mobile phones, smartphones and tablets. Final Report. Fraunhofer IZM, Fraunhofer ISI, VITO. February 2021
9 Appendix A: Method description of stock and energy consumption

In this section, assumptions, sources and calculations behind the estimated stock and energy consumption, are described. Figure 18 shows the principle used to calculate the total annual energy consumption.

\[
\text{STOCK} \times \text{Unit Energy Consumption (UEC)} = \text{Total Annual Energy Consumption (AEC)}
\]

*Figure 18: Principle of total annual energy consumption calculation*

9.1 Stock

The stock is estimated based on multiple sources. The stock of some products has been derived based on statistics reporting world-wide sales, while the stock of other product groups is based on stock information from e.g. EU Ecodesign studies, which have been scaled to estimate a stock worldwide. This section covers the methods used to estimate stock and the development. All sources are shown in Table 16 in the end of this section.

Scaling method

The stock of the following product groups has been scaled from studies conducted for Europe or United States:

- GPS, handheld
- Wearables
- Wireless/Bluetooth headset
- Unmanned Aircraft Systems (drones)
- Battery driven power tools
- Cordless vacuum cleaners
- Vacuum cleaners (robot)
- E-Scooters
- E-Bikes
- E-Mopeds
- Portable speakers
- Industrial smart sensors

The number of devices per person has been calculated in either the United States or Europe, depending on the used studies, by dividing stock with the population in the area. The device per person ration have afterwards been multiplied with the total population in the world to estimate a total number of products in the world.

The distribution of products in Western countries is typically much higher than the rest of the world, due to the high GDP level. A material reduction factor provided by UN stats, have therefore been used to reduce the device per person ratio to better reflect a world average. The data used and sources are shown in Table 11 and Table 12.
<table>
<thead>
<tr>
<th>Geographic region</th>
<th>Population size</th>
</tr>
</thead>
<tbody>
<tr>
<td>World population, total</td>
<td>7,753,000,000</td>
</tr>
<tr>
<td>Population Euro area, total</td>
<td>342,949,773</td>
</tr>
<tr>
<td>Population USA, total</td>
<td>328,329,953</td>
</tr>
</tbody>
</table>

Table 11: Population size of different regions
Source: The World Bank\(^{144}\)

<table>
<thead>
<tr>
<th>Material footprint per capita (2017)</th>
<th>Metric ton per person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low income</td>
<td>2</td>
</tr>
<tr>
<td>Lower middle income</td>
<td>4.7</td>
</tr>
<tr>
<td>Upper middle income</td>
<td>16.9</td>
</tr>
<tr>
<td>High income</td>
<td>26.3</td>
</tr>
<tr>
<td>World average</td>
<td>12.2</td>
</tr>
<tr>
<td>Reduction factor high income consumption (USA/EU) compared to world average</td>
<td>46%</td>
</tr>
</tbody>
</table>

Table 12: Material consumption of different income levels and world average
Source: UNstats\(^{145}\)

Stock based on sales and other assumptions

This section presents assumptions used to estimate the stock for those products where stock data, by accessible sources, were unavailable. See related sources of sales and stock in Table 16Table 13.

<table>
<thead>
<tr>
<th>Product</th>
<th>Other assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robot lawnmowers</td>
<td>Sale of 7 million per year is assumed to be static for the last 5 years. Lifetime is estimated to be 5 years(^{146}).</td>
</tr>
<tr>
<td>Wireless/Bluetooth headsets</td>
<td>745 million units is the expected stock in 2017 worldwide. Multiplied with CARG 12.2 to adjust to 2020(^{147}).</td>
</tr>
<tr>
<td>Handheld gaming devices</td>
<td>According to an American statistic 14.6%(^{148}) of all adults own a handheld gaming device. It is assumed that 14.6% of all people in the world owns a handheld gaming device and afterwards reduced by the material reduction factor between rich countries and the world average. Zero development of the stock towards 2030 is assumed, because of the adaptation of the smartphone and tablets.</td>
</tr>
<tr>
<td>GPS Handheld</td>
<td>745 million units is the stock in 2017 worldwide, assumed to be the same in 2020.</td>
</tr>
</tbody>
</table>

\(^{144}\)https://data.worldbank.org/indicator/SP.POP.1564.TO
Wearables | Based on total shipments of wearables the last 3 years. Based on an assumed lifetime of 3 years.
---|---
Personal care products (hair style, beauty care and grooming products) | Global sales in 2020 was 27.1 billion dollars. An average purchase price of a personal care product of 100 dollars is assumed. It is assumed that half of the personal care products are battery driven. A lifetime of 3 years as static sales for the last 3 years has been used to estimate stock.
E-reader | Data from USA, shows that 19% of adults own an e-reader, but it is assumed that the owning share is far less in other parts of the world and the newest available data is from 2015 and sales have probably decreased since then, due to the adaptation of smartphone and tablet.

Table 13: Assumptions made to estimate stock, where stock data were unavailable

Method used to project development of stock

The 2030 stock data have mainly been forecasted by using CAGRs (Compounded Annual Growth Rate), provided by market research companies, who analyse the market of the different product groups (see principle in Figure 19). The sources and links to the CAGRs are available in Table 16. The sources did not always estimate a CAGR to 2030, but e.g. to 2026 or 2028. To get an indication of the total stock in 2030, the estimated CAGRs have been assumed to be reasonable all the way to 2030. However, the extended use of CAGR provides a significant risk of overestimating the stock in 2030.

![Figure 19: Principle of stock projection](image)

The used CAGR and other assumptions used for stock projections can be found in Table 14.

<table>
<thead>
<tr>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smartphones</td>
</tr>
<tr>
<td>Tablets</td>
</tr>
<tr>
<td>Notebooks</td>
</tr>
<tr>
<td>E-mopeds</td>
</tr>
<tr>
<td>Portable battery-driven tools</td>
</tr>
<tr>
<td>Battery-driven vacuum cleaners (handstick)</td>
</tr>
<tr>
<td>Wireless/bluetooth headsets</td>
</tr>
<tr>
<td>Battery-driven vacuum cleaners (Robot)</td>
</tr>
<tr>
<td>Unmanned Aircraft Systems (drones)</td>
</tr>
<tr>
<td>Robot lawn mowers</td>
</tr>
</tbody>
</table>

STOCK 2020 x CAGR = STOCK 2030
<table>
<thead>
<tr>
<th>Product</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobilephones/featurephones</td>
<td>Forecasted by source to 644 mio. in 2026, forecasted by VM to reach 200 in 2030.</td>
</tr>
<tr>
<td>Robot wet floor</td>
<td>Stock and sales are assumed to be equal to vacuum cleaners.</td>
</tr>
<tr>
<td>E-bikes/pedelecs</td>
<td>Expected CAGR at 12.27% until 2026, assumed growth rate until 2030.</td>
</tr>
<tr>
<td>Handheld gaming devices</td>
<td>Growth assumed to be stagnant because the market has not experience growth since 2009.</td>
</tr>
<tr>
<td>Mobile routers</td>
<td>Forecasted by source to 445 mio. in 2026, forecasted by VM to reach 550 in 2030.</td>
</tr>
<tr>
<td>GPS Handheld</td>
<td>Expected CAGR at 12.2% until 2028, stock assumed to stagnate after 2028.</td>
</tr>
<tr>
<td>Wearables</td>
<td>Expected CAGR at 14.7% until 2030, growth rate assumed until 2030.</td>
</tr>
<tr>
<td>Industrial smart sensors</td>
<td>Development based on WP Task 3 Industrial smart sensors 2025.</td>
</tr>
<tr>
<td>Personal care products (hair</td>
<td>Forecasted retail sales development by source.</td>
</tr>
<tr>
<td>style, beauty care and grooming</td>
<td></td>
</tr>
<tr>
<td>products)</td>
<td></td>
</tr>
<tr>
<td>E-scooters</td>
<td>Expected CAGR at 9.0% until 2031, assumed growth rate until 2030.</td>
</tr>
<tr>
<td>E-readers</td>
<td>Stock in 2020 is assumed to be 0, because of replacement with smartphone and tablet.</td>
</tr>
<tr>
<td>Portable speakers</td>
<td>Stock forecast based on Ecodesign working plan study.</td>
</tr>
</tbody>
</table>

Table 14: CAGRs and assumptions used for stock projections.

9.2 Energy consumption

Method used to estimate the energy consumption

The total annual energy consumption (AEC) is based on the stock and an estimated Unit Energy Consumption (UEC). The UEC is based on energy consumption of the device and the use pattern. The UEC is found in available sources, and if sources were unavailable assumptions have been made to estimate the UEC. Assumptions are listed in Table 15 and sources for energy consumption can be found in Table 16.

<table>
<thead>
<tr>
<th>Product</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable battery driven power</td>
<td>No source found. It is estimated that a power tool run in average 15 hours per year and uses 1000 W.</td>
</tr>
<tr>
<td>tools</td>
<td>List of power tools and energy consumption: <a href="https://generatorist.com/power-tools-contractors-appliances-wattage-requirements">https://generatorist.com/power-tools-contractors-appliances-wattage-requirements</a></td>
</tr>
<tr>
<td>Robot Lawn Mowers</td>
<td>Assuming 15 kWh per month, in 8 month per year.</td>
</tr>
<tr>
<td></td>
<td><a href="https://lawnstory.com/robot-lawn-mower-price/">https://lawnstory.com/robot-lawn-mower-price/</a></td>
</tr>
<tr>
<td>Robot Wet floor</td>
<td>Assumed to be equal to the energy use of a robotic vacuum cleaner.</td>
</tr>
</tbody>
</table>

Table 15: Energy consumption assumptions for products where UEC were unavailable in sources
Sources used to estimate stock, development and energy consumption

<table>
<thead>
<tr>
<th>Products</th>
<th>Source Stock</th>
<th>Publish date stock</th>
<th>Source stock link</th>
<th>Source development link</th>
<th>Source energy consumption link</th>
</tr>
</thead>
<tbody>
<tr>
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<td>---------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Category</td>
<td>Source</td>
<td>Year</td>
<td>URL</td>
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<td>----------------------------------------------------------------------</td>
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<tr>
<td>Device</td>
<td>Source</td>
<td>Year</td>
<td>URL</td>
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<td>------------------------</td>
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<td>----------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Portable speakers</td>
<td>EC Ecodesign working plan 2020-2024 Task 3</td>
<td>2020</td>
<td>Calculated in &quot;background calc assumptions&quot;</td>
<td>Calculated in &quot;background calc assumptions&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interconnected home audio and video</td>
<td></td>
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</tr>
</tbody>
</table>

Table 16: Sources used for stock, development of stock and energy consumption
10 Appendix B: Table of horizontally similar component or functions

<p>|                      | Motor/actuator | Sensors | Processor unit (advanced) | Processor unit (simple)/control unit | Cooling fans | External power adapter - wire | External power adapter - wireless | Display Coloured/advanced | Display LCD/simple | Battery Lithium-ion | Battery management system | Storage / harddrive | Memory | Flash Light | Diode | Wheels (powered) | Speaker | Bearings | GPS | Functions | Connected - wireless (any kind of connection) | Standby mode | Networked standby | APPs | Autonomous driving |
|----------------------|----------------|---------|----------------------------|---------------------------------------|--------------|-------------------------------|-------------------------------|-------------------------------|-------------------|----------------------|---------------------|----------------------------|-------------------|--------|--------------|-------|------------------|---------|----------|-----|-----------|----------------------------------------|------------|------------------|------|------------------|
| Smartphones          | x              | x       | x                          | x                                     | x            | x                             | x                             | x                             | x                 | x                    | x                   | x                                           | x                | x      | x            | x      | x                | x       | x       | x   | x         | x                                      | x          | x                 |      | x                |
| Tablets              | x              | x       | x                          | x                                     | x            | x                             | x                             | x                             | x                 | x                    | x                   | x                                           | x                | x      | x            | x      | x                | x       | x       | x   | x         | x                                      | x          | x                 |      | x                |
| Notebooks            | x              | x       | x                          | x                                     | x            | x                             | x                             | x                             | x                 | x                    | x                   | x                                           | (x)              | x      | x            | x      | x                | x       | x       | x   | x         | x                                      | x          | x                 |      | x                |
| E-mopeds             | x (x)          | x       | x                          | x                                     | x            | x                             | x                             | x                             | x                 | x                    | x                   | x                                           | x                | x      | x            | x      | x                | x       | x       | x   | x         | x                                      | x          | x                 |      | x                |
| Portable battery-driven tools | x (x)          | x       | (x)                        | x                                     | x            | (x)                           | x                             | (x)                           | x                 | x                    | x                   | x                                           | x                | x      | x            | x      | x                | x       | x       | x   | x         | x                                      | x          | x                 |      | x                |
| Battery-driven vacuum cleaners (handstick) | x              | x       | x                          | (x)                                   | x            | x                             | (x)                           | x                             | x                 | x                    | x                   | x                                           | x                | x      | x            | x      | x                | x       | x       | x   | x         | x                                      | x          | x                 |      | x                |
| Wireless/bluetooth headsets | (x)            | x       | x                          | (x)                                   | x            | x                             | (x)                           | x                             | x                 | x                    | x                   | x                                           | x                | x      | x            | x      | x                | x       | x       | x   | x         | x                                      | x          | x                 |      | x                |
| Battery-driven vacuum cleaners (Robot) | x              | x       | (x)                        | x                                     | x            | x                             | x                             | (x)                           | x                 | x                    | x                   | x                                           | x                | x      | x            | x      | x                | x       | x       | x   | x         | x                                      | x          | x                 |      | x                |
| Unmanned Aircraft Systems (drones) | x              | x       | x                          | (x)                                   | x            | x                             | x                             | (x)                           | x                 | x                    | x                   | x                                           | x                | x      | x            | x      | x                | x       | x       | x   | x         | x                                      | x          | x                 |      | x                |</p>
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<th>Component</th>
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<tbody>
<tr>
<td>Robot lawn mowers</td>
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<td>Mobile phones/feature phones</td>
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<td>Robot wet floor</td>
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<td>Personal care products (hair style, beauty care and grooming products)</td>
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<td>E-scooters</td>
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<td>E-readers</td>
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<td>Portable speakers</td>
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</tbody>
</table>

Table 17: Horizontally similar components and functions. X: Component included in the devise. (X): Component is possibly included in device.