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*Sustainable software products – towards assessment criteria for  
resource and energy efficiency*

*– Supplementary material –*

# Set of criteria for sustainable software

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*We will provide updates of the set of criteria for sustainable software on:*  
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## 1 Resource efficiency

### To what extent are hardware capacities used, and therefore, to what extent are natural resources consumed indirectly, when a given function is performed?

This main criterion assumes that a given functionality can be fulfilled by a software product using different amounts of hardware capacities, which indirectly results in different amounts of natural resource consumption required for hardware provision, operation, and disposal.

The ideal is a software product that achieves a given functionality with minimum resource consumption, i.e., that maximizes resource efficiency (see glossary). Functionality is specified by standard usage scenarios (see glossary). The hardware capacities to be made available and those actually used as well as the energy consumed serve as approximations for estimating natural resource consumption.

#### 1.1 Hardware efficiency

##### Which hardware capacities must be available for operating the software product and what is the degree of capacity utilization during operation?

Hardware capacities are measured in % of the corresponding capacity of a reference system<sup>1</sup>. They can be differentiated according to two dimensions: (Table 1). On one dimension, they are differentiated in local, network and remote capacities. Here, we further distinguish in recommended (1.1.1) and minimum (1.1.2) capacities as well as capacities required in idle mode (1.1.3) and during the execution of a standard usage scenario (1.1.4). On the other dimension, we differentiate according to the type of hardware capacity: processing power, working memory, permanent storage, bandwidth, and display resolution. The matrix is open to the addition of new columns in case new categories of hardware will become relevant in the future.

**Table 1-1** Differentiation of hardware capacities in two dimensions. The numbers refer to the criteria explained in the following sections, the letters refer to the indicators.

		Processing power	Working memory	Permanent storage	Bandwidth	Display resolution
<b>Local</b>	recommended	1.1.1 a)	1.1.1 b)	1.1.1 c)	-	1.1.1 d)
	minimum	1.1.2 a)	1.1.2 b)	1.1.2 c)		1.1.2 d)
	idle	1.1.3 a)	1.1.3 b)	1.1.3 c)		
	standard usage	1.1.4 a)	1.1.4 b)	1.1.4 c)		
<b>Network</b>	recommended	-	-	-	1.1.1 e)	-
	minimum				1.1.2 e)	
	idle				1.1.3 d)	
	standard usage				1.1.4 d)	
<b>Remote</b>	recommended	1.1.1 f)	1.1.1 g)	1.1.1 h)	-	-
	minimum	1.1.2 f)	1.1.2 g)	1.1.2 h)		
	idle	1.1.3 e)	1.1.3 f)	1.1.3 g)		
	standard usage	1.1.4 e)	1.1.4 f)	1.1.4 g)		

<sup>1</sup> Application of the set of criteria requires that a reference system corresponding to current technical developments is determined periodically. The reference system serves to standardize indicators.

Each cell of the matrix in **Table 1-1** shows the associated criterion (e.g., 1.1.1) with the corresponding indicator (e.g. a)) for operationalization. The criteria and indicators will be described in the following sections, which are numbered accordingly. Not all of the criteria 1.1.1 to 1.1.4 are applicable in all the matrix cells. For this reason, some of the cells remain empty.

Criteria 1.1.5 and 1.1.6 are used for the assessment of hardware efficiency as well. They can be assessed in general terms; they do not require differentiation according to this matrix and do not show up in Table 1-1 for this reason.

When these criteria are to be aggregated later, the principal problem arises that a trade-off between different hardware capacities (local vs. remote, processing power vs. working memory, processing power for data compression vs. bandwidth, etc.) must be made. If it were possible to evaluate the hardware capacities in the form of an ecological footprint, they could be weighted and aggregated in that regard. Assessing this footprint is not part of the work reported here; we refer the reader to existing life cycle inventories for ICT hardware and electric energy as a basis for aggregation.

**Table 1-2** Basic definitions for the measurement of the criteria 1.1.3 and 1.1.4.

Identifier	Name	Definition	Comment
$FL_i$	full load	Upper limit of the capacity $i$ in the reference system.	For processing power, the FL is 100%, for working memory the sum of the installed RAM, for network bandwidth the maximum transmission speed, etc.
$BL_i$	base load	Average load of the capacity $i$ in the reference system when the software product under study is not installed	
$IL_i$	idle load	Average load of the capacity $i$ in the reference system when the software product under study is installed, but idle.	Idle load includes base load.
$NIL_i$	net idle load	$NIL_i = IL_i - BL_i$	
$t$	time	Time needed to execute the standard usage scenario on the reference system.	Begins with the start of the standard usage scenario and ends when all required actions are executed, including follow-up processes (such as releasing memory or deleting temporary files).
$GL_i$	gross load	Load of the capacity $i$ in the reference system while executing the standard usage scenario, measured as time-weighted average over $t$ .	
$NL_i$	net load	$NL_i = GL_i - BL_i$	
$AF_i$	allocation factor	$AF_i = NL_i / (FL_i - BL_i)$	Allocation factor used to assign a share of the base load $GA$ to the effective load $EL$ (defined below).

$AF_i$	allocation factor idle	$AF_i = NIL_i / (FL_i - BL_i)$	Allocation factor used to assign a share of the base load GA to the effective load idle ELI (defined below).
$EL_i$	effective load	$EL_i = NL_i + AF_i * BL_i$	
$EIL_i$	effective load idle	$EIL_i = NIL_i + AF_i * BL_i$	Used to calculate the indicators for hardware demand of criterion 1.1.3
$HD_i$	hardware demand	$HD_i = EL_i * t$	Used to calculate the indicators for hardware demand of criterion 1.1.4

For practical purposes, it is sufficient to calculate the allocation factors AF and AFI for criteria 1.1.3 and 1.1.4, in particular for processing power (indicators a. and e.) and working memory (indicators b. and f.). For all other indicators (c., d., g.) the allocation factors can be set to zero, i.e., it can be assumed that  $EL = NL$  and  $EIL = NIL$  for simplicity.

Figure 1-1 illustrates the process of measuring hardware capacity load by executing a standard usage scenario.

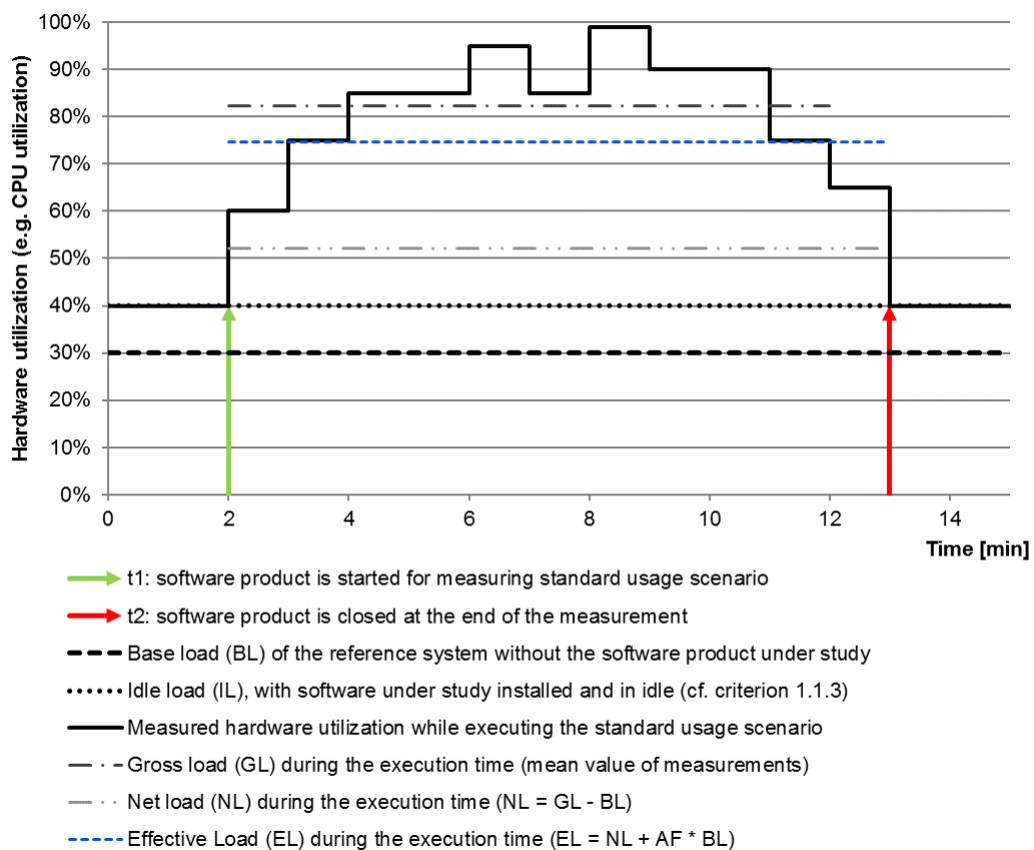


Figure 1-1 Exemplary measurement process of hardware capacity load

### **1.1.1 Recommended system requirements and resulting hardware requirements (including peripheral devices)**

**Which system requirements does the manufacturer recommend for operating the software product?**

Indicators:

- a) Recommended local processing power as specified by the manufacturer in % of the processing power of the reference system
- b) Recommended local working memory as specified by the manufacturer in % of the working memory of the reference system
- c) Recommended local permanent storage as specified by the manufacturer in % of the permanent storage of the reference system
- d) Recommended display resolution as specified by the manufacturer in % of the display resolution of the reference system
- e) Recommended network bandwidth as specified by the manufacturer in % of the network bandwidth of the reference system
- f) Recommended server processing power as specified by the manufacturer in % of the processing power of the reference system
- g) Recommended server working memory as specified by the manufacturer in % of the server working memory of the reference system
- h) Recommended server permanent storage as specified by the manufacturer in % of the server permanent storage of the reference system

### **1.1.2 *Minimum* system requirements and resulting hardware requirements (including peripheral devices)**

**What are the minimum system requirements for operating the software product?**

Indicators:

- a) Minimum local processing power as specified by the manufacturer in % of the processing power of the reference system
- b) Minimum local working memory as specified by the manufacturer in % of the working memory of the reference system
- c) Minimum local permanent storage as specified by the manufacturer in % of the permanent storage of the reference system
- d) Minimum display resolution as specified by the manufacturer in % of the display resolution of the reference system
- e) Minimum network bandwidth as specified by the manufacturer in % of the network bandwidth of the reference system
- f) Minimum server processing power as specified by the manufacturer in % of the processing power of the reference system
- g) Minimum server working memory as specified by the manufacturer in % of the server working memory of the reference system
- h) Minimum server permanent storage as specified by the manufacturer in % of the server permanent storage of the reference system

### 1.1.3 Hardware utilization in *idle mode* assuming a standard configuration

**What is the level of utilization of the available hardware capacities by the software product in idle mode?**

Indicators:

- a) Measurement of average processor utilization in idle mode under the standard configuration
- b) Measurement of average working memory utilization in idle mode under the standard configuration
- c) Measurement of average permanent storage utilization in idle mode under the standard configuration
- d) Measurement of average bandwidth utilization for network access in idle mode under the standard configuration
- e) Measurement of average server processor utilization in idle mode under the standard configuration
- f) Measurement of average server working memory utilization in idle mode under the standard configuration
- g) Measurement of average server permanent storage utilization in idle mode under the standard configuration

Average processor load (indicators a. and e.) and average working memory load (indicators b. and f.) are calculated as effective idle load EIL (see **Table 1-2**).

### 1.1.4 Hardware utilization during *normal use* assuming a standard configuration and a standard usage scenario

**What is the average utilization of the available hardware capacities during operation of the software product?<sup>2</sup>**

It should be noted here that utilization of hardware capacities is understood as a variable integrated over time. If, for example, program A requires twice as much processing power, working memory, or bandwidth as program B to accomplish a given standard usage scenario, but makes the processor, memory, or bandwidth available again after half the period of time required by B, then according to this criterion, A is not less efficient than B. (This is not the case for criteria 1.1.1 to 1.1.3.) Thus, the use of acceleration technologies is not penalized by this criterion.

Indicators:

- a) Measurement of average processor utilization when running the standard usage scenario under the standard configuration
- b) Measurement of average working memory utilization when running the standard usage scenario under the standard configuration
- c) Measurement of average permanent storage utilization when running the standard usage scenario under the standard configuration
- d) Measurement of average bandwidth utilization for network access when running the standard usage scenario under the standard configuration
- e) Measurement of average server processor utilization when running the standard usage scenario under the standard configuration

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<sup>2</sup> Average capacity utilization determines which free hardware capacities can be used by other software products during operation of the software product.



- f) Measurement of average server working memory utilization when running the standard usage scenario under the standard configuration
- g) Measurement of average server permanent memory utilization when running the standard usage scenario under the standard configuration

Hardware demand for processor load (indicators a. and e.) and average working memory load (indicators b. and f.) are calculated as defined in **Table 1-2**.

### **1.1.5 Economical use of hardware through adaptability and support for users when adapting the software product**

**Does the software product use only those hardware capacities required for running the functions demanded by the individual user? Does the software product provide sufficient support when users adapt it to their needs?<sup>3</sup>**

Indicators:

- a) Does the software automatically minimize the required capacities and/or are there relevant options available during installation? (Scale: yes/no)
- b) If users choose an option, can they change the decision for or against installation options at any later point in time? (Scale: yes/ no)
- c) Black box test whether hardware-intensive modules can be disabled (Scale: can permanently be disabled/can temporarily be disabled/cannot be disabled)
- d) Is it possible (without drawbacks) to disable peripheral devices that are not needed temporarily or permanently or to avoid providing them at all? (Scale: can be disabled temporarily and permanently/can be disabled only temporarily/cannot be disabled)
- e) Will files used only for installing the product be deleted after installation?

### **1.1.6 Online delivery**

**Can the software product (including all programs, data, and documentation including manuals) be purchased, installed, and operated without transporting physical storage media (including paper) or other materials goods (including packaging)?**

Indicators:

- a) Can the software be delivered and updated online?
- b) Is it supported that the user organization can store the software product and its updates on a local server, avoiding transferring them for every single user?

## **1.2 Energy efficiency**

**How much electricity does the hardware consume when the software product is used to execute a standard usage scenario?<sup>4</sup>**

The consumption of electric energy is a consequence of the utilization of hardware capacities. How to measure hardware utilization has already been described in section 1.1.4 above. In parallel to those

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<sup>3</sup> No utilization of capacities by functionality temporarily or permanently not demanded by the user.

<sup>4</sup> Use of electricity is a consequence of the use of hardware capacities already discussed in section 1.1. This implies that this criterion is redundant. However, the redundancy is desired since energy can be measured separately and not all sub criteria of hardware efficiency (1.1) are operationalizable.

measurements, the electrical power demanded by the hardware should be measured (or estimated) as well, at least for the entirety of hardware used locally, for data transmission in the network or remotely, respectively.

Indicators:

- a) Measurement of the energy consumed on the local device for running the standard usage scenario under the standard configuration
- b) Estimation of the energy consumed in the network for the data traffic caused by running the standard usage scenario under the standard configuration (a current estimate of network energy intensity in kWh/GB from literature may be used, if necessary differentiated among types of access network)
- c) Measurement of the energy consumed by servers for the remote processing and storage for running the standard usage scenario under the standard configuration (if measurement not possible, an estimate based on factors for average energy intensity of data center services from literature may be used)

The electric energy consumed is the integral of electric power over the time needed for the execution of the standard usage scenario. Departing from the specifications provided to measure hardware load (section 1.1.4), only net indicators will be used for the energy measurements (indicators a. and c.), i.e., only the quantity that exceeds the level of the electric base load. This is done to increase practicability (calculating an allocation factor for electricity may be difficult because a true upper limit for electric power is sometimes not known). It also adds to the clarity of the results of the energy measurements if base load energy is not included when comparing software products.

### 1.3 Resource management

#### **To what extent does the software product contribute to efficient management of the resources it uses during operation?**

Since the extent to which a given software product is used may vary, adaptive demand for hardware capacities that is supported by the software product contributes to resource conservation. Hardware capacities not in use can potentially be used by other processes or reduce their energy consumption. Both options contribute indirectly to natural resource conservation.

In contrast to criteria 1.1 and 1.2, this criterion refers to adapting the demand for hardware capacities at the program's runtime, in particular the transition to less energy-consuming modes, dependent on the current user requirements or the available hardware capacities or energy. In other words, while resource efficiency in the various modes was addressed by criteria 1.1 and 1.2, the focus here is on the ability to switch between modes depending on context.

### **1.3.1 Adaptation of hardware capacities used to current demand**

**Does the software product have the feature to release hardware capacities (and reduce energy consumption as a consequence) when it doesn't temporarily use these capacities?**

Indicators:

- a) Does the software product have different modes which have a measurable effect on energy consumption?
- b) Does the software product dynamically change to a more energy saving mode when possible (e.g. sleep mode)?
- c) In case the user has to make energy-relevant settings, are these settings concentrated in one place and easily understandable for the user?<sup>5</sup>

### **1.3.2 Adaptation of hardware capacities used to current supply**

**Is the software product able to dynamically adapt its demand for hardware capacities and energy when the supply is changing? (e.g., when the available bandwidth is decreasing or battery is low)**

Indicators:

- a) Does the software product switch to a more economical mode when less hardware capacity or energy is available, avoiding errors or loss of data? (no restrictions, slower execution, error during execution)
- b) Is the full software functionality available in if the energy management of lower system layers or connected client systems is activated?<sup>6</sup>

### **1.3.3 Default settings supporting resource conservation**

**Are the default settings of the software product selected in such a way that they also take the goal of resource conservation into account?<sup>7</sup>**

Indicators:

- a) Reviewer's assessment whether the default settings of the software product are selected in such a way that they also take the goal of resource conservation into account

### **1.3.4 Feedback on use of hardware capacities and energy**

**Can the local and remote hardware capacities used by the software product and their resulting energy consumption be monitored, and are the displayed values correct?**

Indicators:

- a) Are the hardware capacities in use, data flow, and energy consumption displayed? (Scale: yes/to some extent/no)
- b) Assessment by the reviewer whether the display is correct

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<sup>5</sup> Examples: Background/sleep settings, animations, computing-intensive processes such as indexing etc., cache sizes, ability to select the time at which processes are executed to take advantage of ecologically more beneficial energy (demand shaping).

<sup>6</sup> In particular server-based software should avoid that activating the energy management on client side hampers the functionality. For example, no session information should be lost if the client computer enters sleep mode.

<sup>7</sup> Example: Default setting for printing: Double-sided printing if the printer has this capability?

## 2 Potential hardware operating life

### To what extent are hardware replacement cycles decoupled from software replacement cycles?<sup>8</sup>

Software imposes requirements on the hardware on which it is executed. The faster these requirements increase as the software product is developed further, and the more specific they are, the more they limit the use of hardware products already in existence. If existing hardware products cannot be used, or can no longer be used, to execute the given software product, then this shortens the operating life of the hardware.

The ideal is a software product whose development dynamics permit operators to manage their hardware products independently of these dynamics, i.e., decouple hardware management from software management.

#### 2.1 Backward compatibility

### Does the manufacturer of the software product guarantee that the current release can be executed on a reference system that is $n$ years old?<sup>9</sup>

Indicators:

- a) Initially use the specification by the manufacturer (hardware, older operating systems, older frameworks), since no standard configurations have been defined for previous years.
- b) When this criterion has been applied for a long enough time period, so that the standard usage scenario can also be executed on earlier standard configurations as well: Can the standard usage scenario still be executed with the current release of the software product on a configuration that was the standard configurations  $n$  years ago ( $n$  still needs to be specified)?

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<sup>8</sup> Decoupling software and hardware replacement cycles amounts to long potential hardware operating life. Basic assumption: Every software product requires a system environment as the platform on which it is executed. The system environment is defined as the sum of the hardware and software components of the ICT system that are required for executing the software product. The software product itself can be part of the system environment of other software products. Example: A web browser requires an operating system, additional system software, and hardware as a system environment, and at the same time it constitutes the system environment for a web application. From the perspective of a given software product, the following question is crucial to understand its influence on hardware operating life: when the software product is replaced by a newer version, which requirements to the lowest level—the hardware—does this generate via the intermediate levels of the system environment?

<sup>9</sup> Thus, the software product can be executed on a standard hardware configuration that has already been in operation for  $n$  years.

## 2.2 Platform independence and portability

**Can the software product be executed on different currently prevalent productive system environments (hardware and software), and can users switch between them without disadvantages?<sup>10</sup>**

Indicators:

- a) Manufacturer specifications (compatible with various operating systems, runtime environments).
- b) Execute standard usage scenario on various currently prevalent productive system environments and check for portability of data and software settings.

## 2.3 Hardware sufficiency

**Does the amount of hardware capacity used remain constant over time as the software product is developed further and additional functions are added?**

This criterion rewards software manufacturers who make it easy for their customers to continue to use their existing hardware. It intentionally does not take into account whether functionality is expanded. Sufficiency means that the amount of resources required will *not* increase even if the utility they provide increases (which is possible, after all, because of increasing efficiency).

The ideal is a software product that fulfills more and more requirements from one version to the next, but nonetheless does not increase its hardware requirements.

This criterion can be applied only when products have already been assessed several times, i.e., when at least one previous result is available.

Indicators:

- a) intertemporal comparisons with the following imaginable results:
  1. “very good”: To date, new versions have resulted in a decrease in the hardware capacities required.
  2. “good”: To date, new versions have resulted in no increase in the amount of hardware capacities required.
  3. “sufficient”: Although to date, new versions have increased the amount of hardware capacities required, the increases have not overcompensated for the efficiency improvements due to technical factors as exhibited by the succession of reference systems over time.
  4. “insufficient”: Because of new versions, the required hardware capacities have increased faster than technical efficiency.

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<sup>10</sup> We recommend that this criterion should not be considered one of the minimum requirements because in principle, there could be very resource-efficient software that runs on just one platform. Nonetheless, platform independence is to be considered beneficial since it gives users more freedom when optimizing procurement of hardware and system software.

### 3 User autonomy

#### **Does the manufacturer of the software product respect user autonomy in dealing with the purchased product?**

This main criterion assumes that a relevant number of users is interested in using software in a resource-efficient way. If they can do so without functional disadvantages, they will try to work with a small amount of hardware capacity (which they generally pay for) and keep energy consumption low (which is also financially relevant or at least impacts the battery life of mobile devices). However, users can do so only if they are not forced to consume unnecessary amounts of resources and if they understand how they can avoid unnecessary resource consumption.

The ideal is a software product that respects the freedom of users to decide about utilizing hardware capacities (and thus indirectly about using resources) when using the product, as far as possible.

The following criteria are to be evaluated from the perspective of target groups that are not technical specialists; in other words, they will generally not be fulfilled simply by the fact that an expert can fulfill them. Criterion 3.1.2 is an exception in this regard.

#### 3.1 Transparency and interoperability

##### **Can users understand resource-relevant aspects of the software product with a reasonable amount of time and effort? Are they free to re-use data they produced with this software product with other software products?**

###### 3.1.1 Transparency of data formats and data portability

##### **Is sufficient documentation provided for the data formats (file or data stream formats) used by the software product to enable interoperability? Do the data formats comply with open standards enabling further use of the data with another software product?<sup>11</sup>**

To apply this criterion, it must first be defined which standards are considered open standards at the time of awarding a label.

Indicators:

- a) Review of manuals and technical data sheets, comparison with known open standards
- b) Check of compliance with known and open standards.

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<sup>11</sup> This is decisive to prevent customer lock-in (dependence on the software product), which may force unnecessary resource consumption, both in the case of retaining an inefficient product and in the case of switching to a different product, which may require resources as well.

### 3.1.2 Transparency and interoperability of the programs

**Are application programming interfaces (APIs) clearly documented, and are dissemination and further development of the program supported? Do the interfaces comply to open standards to enable interoperability?**

Weighting of indicators may be highly dependent on context. The effects of open source code and licensing models on resource use cannot be assessed in terms of a general rule.

Indicators:

- a) If APIs exist: Review of the documentation of the interfaces on the basis of the documentation of the software product and its APIs
- b) Is the source code open?
- c) Is the software released under a license that allows it to further develop it?

### 3.1.3 Continuity of the software product

**Can the software product be used for longer periods of time without serious negatives (in particular IT security problems) occurring, and does the user have the option to avoid unnecessary updates?<sup>12</sup>**

Indicators:

- a) How long is the time period for which the supplier guarantees future support for the product, including security updates?
- b) Does the manufacturer respond promptly when security gaps (vulnerabilities) become known?
- c) Can the user influence the frequency of updates by configuring the software product and when doing so differentiate between security updates and other updates?
- d) Is it possible to receive differential updates only?<sup>13</sup>

### 3.1.4 Transparency of task management

**Does the software product inform users that it is automatically launching or running tasks in the background that are possibly not being used?**

Indicators:

- a) On the basis of the installation and the execution of standard usage patterns, test which processes are automatically launched by the software product and whether it informs users of this (Scale: informs users of all such processes/informs users of some such processes/does not inform users)
- b) If the software product is automatically launched at system start ("autostart"): does it inform users that this is the case?
- c) If the user carries out an action that can be understood as ending the program, but at least one of the tasks remains active: does the software product inform the user that this is the case?

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<sup>12</sup> A high frequency of updates causes resource consumption and makes it more difficult to maintain transparency. It is difficult to define the "necessity" of updates objectively; however, it makes at least sense to differentiate between security-relevant (and thus doubtless necessary) updates and other updates; this is addressed by indicator b).

<sup>13</sup> This avoids replacing the entire program, which can cause significant resource consumption if performed frequently.

## 3.2 Uninstallability

**Can the software product be uninstalled easily, without leaving traces, and without avoidable disadvantages?**

### 3.2.1 Uninstallability of programs

**Does the user receive sufficient support to uninstall the program without leaving traces?**

Indicators:

- a) Uninstallation of the software and comparison with the condition prior to installation, which must be identical.

### 3.2.2 Capability to erase data

**Does the user receive sufficient support when erasing data generated during operation of the software product as desired?**

This criterion is intended specially to avoid the case that compliance with high IT security standards following uninstallation of the software product can be guaranteed only by physically destroying hardware.

Indicators:

- a) After erasing of the data explicitly stored by the user and comparison with the condition prior to installation, are the two states identical in relevant respects?
- b) Does the software product provide transparency about the places where it stores data?
- c) Is the user supported in erasing data stored on remote storage devices without leaving traces?

## 3.3 Maintenance functions

**Does the software product provide easy-to-use functions permitting users to repair damage to data and programs?**

### 3.3.1 Recoverability of data

**Can the data be recovered in its last condition following an abnormal termination?**

Indicators:

- a) Does the manufacturer provide specifications and can they be validated by means of a test?
- b) Can the user set the periodicity at which changes are automatically saved?



### 3.3.2 Self-recoverability

**Can the installed instance of the software product be recovered following the occurrence of an inconsistent state?**

Indicators:

- a) Manufacturer specifications and review by means of a test

## 3.4 Independence of outside resources

**Can the software product be operated as independently as possible of resources not subject to the users' control?**

### 3.4.1 Offline capability

**To what extent does the software product avoid forced connectivity that is not necessary for providing the functionality?<sup>14</sup>**

Indicators:

- a) Testing on the basis of the standard usage scenario (Scale: offline operation possible/possible with limitations/impossible)

## 3.5 Quality of product information

**Does the information provided about the software product support its resource-efficient use?**

### 3.5.1 Comprehensibility and manageability of product documentation, licensing conditions, and terms of use

**Is all the information easy for users to understand?**

Indicators:

- a) Inspection by reviewers; test with actual users

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<sup>14</sup> Examples of unnecessarily forced connectivity: establishing a connection to the license server, repeated download of fonts required.

### 3.5.2 Resource relevance of product information

**Does the product information include everything that users need to minimize resource consumption by the software product in a structured form, and is the information correct?**

The long-term goal is to develop standardized product descriptions for resource-relevant product information. As soon as a satisfactory standard exists in this regard, compliance with it can be included as an indicator.

Indicators:

- a) Qualitative assessment of completeness and comprehensibility
- b) Does the product information refer to the current version of the product?
- c) Inspection whether the information is correct (information is conclusive / partially conclusive / non-conclusive)

## Glossary

*Energy efficiency:* Generally, the amount of “useful work” divided by the amount of energy it requires. In the context of this document, “useful work” is operationalized as the successful execution of standard usage scenarios.

*Hardware:* The material goods required to run programs or to store or transport data.

*Hardware capacity:* Quantifiable characteristic of a hardware system which represents its performance limit on a given dimension of performance (e.g., working memory capacity, computing power, bandwidth).

*Hardware system:* Delimitable unit of hardware that performs defined functions.

*Indicator:* An empirically determinable quantity that provides insight into a matter that cannot be measured directly. The indicators proposed in this document have different levels of measurement. In some cases, researchers will have to settle for an ordinal scale (e.g., “insufficient”, “sufficient”, “good”, “very good”, or even merely “fulfilled”, “not fulfilled”) to avoid giving the false impression of non-existent precision arising from a cardinal scale.

*Reference system:* A hardware system that is defined as generally customary in terms of its most important capacities (e.g., working memory, processor performance) during a defined period of time (e.g., one year). The purpose of the reference system is to be able to express indicators such as “minimum local memory” in relation to a reference value (currently “customary” memory).

*Resource:* In the context of this document, a natural resource, in particular a raw material, a form of energy, or also the capacity of an environmental medium to absorb emissions. To differentiate natural resources from technical ones, especially hardware resources, the more precise term “hardware capacities” is used here for the latter. Since using hardware capacities always results in using natural resources, this distinction (which ultimately amounts to a definitionally difficult differentiation between the ecosphere and the technosphere) is not of decisive importance here.

*Resource efficiency:* Generally, the amount of “useful work” divided by the amount of resources it requires. In the context of this document, “useful work” is operationalized as the successful execution of standard usage scenarios.

*Software:* Programs and data in digital form.

*Software product:* A delimitable unit of programs and data for which a license is available.

*Standard configuration:* A set of conditions, defined as a reference, under which a given software product is run; it includes the parameter settings selected during installation or operation, the system software provided, potentially additional software products required for operation, as well as the reference system at the hardware level.

*Standard usage scenario:* A usage scenario that is used for testing a software product and is supposed to be as representative as possible for the customary use case.

*Usage pattern:* Abstracted form of a sequence of interactions with a given software product.

*Usage scenario:* Description of a usage pattern which is generally machine executable.

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