Making IT-products sustainable

Design Options for Long-lasting, Efficient and Open Hardware and Software

High energy consumption and data traffic, critical production conditions and proprietary software ensure that the production and use of digital technologies and applications have so far been environmentally and socially problematic. We present basic approaches and policy measures for a sustainable design of hardware and software.

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The production and use of digital technologies and services is associated with environmentally and socially problematic developments. These are related both to the way Information and Communications Technology (ICT) devices are produced, used and disposed of, and to the design and use of software and the associated volume of data traffic. It is therefore essential that the material (energy and resources for the production, operation and disposal of hardware) and immaterial foundation of digitalisation (e. g., software, information, knowledge, etc.) are more closely integrated. Aspects such as modular product design, repairability, transparent supply chains and the use of public and free source codes and licences play a decisive role in making hardware and software sustainable. This article outlines the basic approaches that must be considered for a sustainable design of hardware and software and illustrates the political options.

Longevity of hardware and software

Most of the environmental impacts of hardware (e. g., in the impact categories global warming, acidification, freshwater eutrophication or human toxicity) occur during its production. The production of electronic components in particular is very environmentally intensive (Hischier et al. 2015) and often takes place at locations with a high proportion of coal in the electricity mix (Manhart et al. 2016). At the same time, the absolute number of digitally networked devices is increasing worldwide with ever shorter recycling cycles of these devices. From an ecological perspective, it is always preferable to continue using existing hardware rather than buying a new notebook or smartphone. The provision of a new device in particular entails a high consumption of resources. In some cases, newer models also require more energy in the utilisation phase due to increased computing power (Prakash et al. 2017). A central adjustment factor for making hardware ecologically sustainable is to extend the service life of the devices. On the hardware side, this can for instance be supported by a modular design and the most complete repairability possible. This means taking repairability into account as early as the product design stage, ensuring access to spare parts and maintaining the warranty in the event of repairs (c. f. Voigt this issue). Recyclability must also be incorporated into the design of the equipment, e. g., to allow metals to be extracted during recycling. The use of open-source hardware means that blueprints can be viewed at any time and individual spare parts can be reproduced, which supports the repairability of devices.

Moreover, hardware is always used in conjunction with software, both elements being mutually dependent. Hardware can often no longer be used without suitable software and vice versa. Current operating systems, for example, are adapted to current hardware configurations. However the instance, the manufacturer discontinues support for this operating system, it can no longer be used safely. This means that the underlying hardware is also left without a safe operating system. A newly released operating system, however, may not be able to run on the old hardware. The lack of interoperability of software and (older) hardware in combination with the early discontinuation of software support means that functional hardware is increasingly being replaced before the end of the product's life (Manhart et al. 2016). If hardware that is still technically functional can no longer be used due to (missing) software updates or new software concepts, this is also referred to as software obsolescence (Prakash et al. 2017). The longevity of software and its availability in the future consequently also has a direct influence on the future usability of existing hardware. This also concerns the sustainable availability of the software as a resource itself. Today, many documents from previous decades can no longer be opened or the associated software can no longer be made to run, even though at the same time the hardware is becoming more and more powerful. This is usually the result of an artificially enforced shortening of the lifespan of our ICT systems through proprietary licences and vendor lock-in. A sustainable solution is the use of Free and Open Source Software

*Ökologisches*Wirtschaften *Online-Ausgabe* O1.2021 (36) | DOI 10.14512/OEWO360120

(FOSS). Free licenses grant everyone the right to use the software without restriction and for an unlimited period of time as well as access to its source code. This means that no entity can force an "end of support" for a FOSS-licensed software or prevent its availability or archiving for the future. Open interfaces also ensure interoperability. Inside and outside the FOSS ecosystem, free licensing allows full or modular integration of specific software solutions in interaction with other systems. Furthermore, the technically and legally flawless archiving and reuse of digital resources in terms of digital generational equity is guaranteed.

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Energy- and resource-saving hardware and software

Devices, digital infrastructure and applications are becoming relatively more efficient, e.g., through LED screen lighting, decreasing energy intensity per computing power and improved power management software (Koomey et al. 2011; Prakash et al. 2017). Some technical devices and applications already have legal requirements for electricity consumption or assessment criteria for environmental relevance. The EU Ecodesign Directive, for example, sets out minimum legal requirements for the energy consumption of electrical appliances. Labels such as Energy Star or Blue Angel assess electronic devices according to their energy efficiency class and therefore also provide consumers with transparent decision-making aids. For data centres, however, the assessment in efficiency classes is still in its infancy. Factors such as waste heat utilisation, type of cooling technology or server utilisation are decisive when assessing the energy efficiency of data centres (Hintemann/Hinterholzer 2018), and initial methods for calculating the energy efficiency of data centres have been developed (Schödwell et al. 2018).

The environmental relevance of software results from the use of hardware and transmission capacities (computing power, working memory, networks) during its development, use and deinstallation. Although an absolute quantification of the relevance of software to the total energy consumption of ICT is still in its infancy, studies have shown that different software products that fulfil the same functional requirements can differ significantly in their electricity consumption (Gröger et al. 2018). With a view to energy and resource-saving software, it is therefore important to design it in a way that minimises the power and resource requirements during the utilisation phase. Software design principles should take this into account at the very beginning of the software life cycle. The German Federal Environment Agency has already presented initial criteria for sustainable software design (Gröger et al. 2018). Criteria such as autonomy of use, which includes FOSS licensing, offline capability and absence of advertising, are important starting points that can already help consumers and industry achieve a great deal with little effort.

Despite the development of criteria that should actually result in a decrease in the environmental relevance of digital technology, it can currently be seen that consumer electronics devices are getting bigger and bigger, and functions, performance and screen resolutions are increasing. In absolute terms, this leads to increasing energy and resource consumption (Prakash et al. 2017; Proske et al. 2020). At the same time, the absolute increase in the number of devices (e.g., in the Internet of Things) as well as rising energy consumption due to ever more efficient and thus cheaper electronic components can also be observed – a classic rebound effect. This is also reflected in the overall energy consumption of the digital sector, which for years has not been decreasing but has remained stable or even increased as the sector has grown faster than energy efficiency has increased (Lange et al. 2020). Energy- and resource-saving hardware and software is therefore distinguished not only by being relatively resource-efficient, but also by reducing the consumption of energy and resources in absolute terms. It is necessary to flank efficiency measures with consistency and sufficiency strategies (c.f. Colaço this issue). This includes questions about the appropriate size of screens as well as the intensity of use of digital technology by consumers, or the question of the design of digital applications that takes into account the principle of data frugality, i.e., the lowest possible data production and processing.

Transparent and fair product cycles

End devices, servers and networks consist of a multitude of finite resources (Hischier et al. 2015; Pilgrim et al. 2017). As the total number of devices increases, so does the need for resources for their production. In addition to plastic, glass and ceramics, digital devices consist of various metals that are classified as conflict raw materials or of concern. Tantalum, tungsten, gold, tin or cobalt are mined primarily in countries of the Global South, including Congo, South Africa, Rwanda, Peru and Chile, often under hazardous working conditions, lack of protective clothing, massive labour law violations and sometimes with the use of child labour. Furthermore, there is considerable environmental impact through river pollution, deforestation and air pollution (Pilgrim et al. 2017). Massive violations of labour and hu-

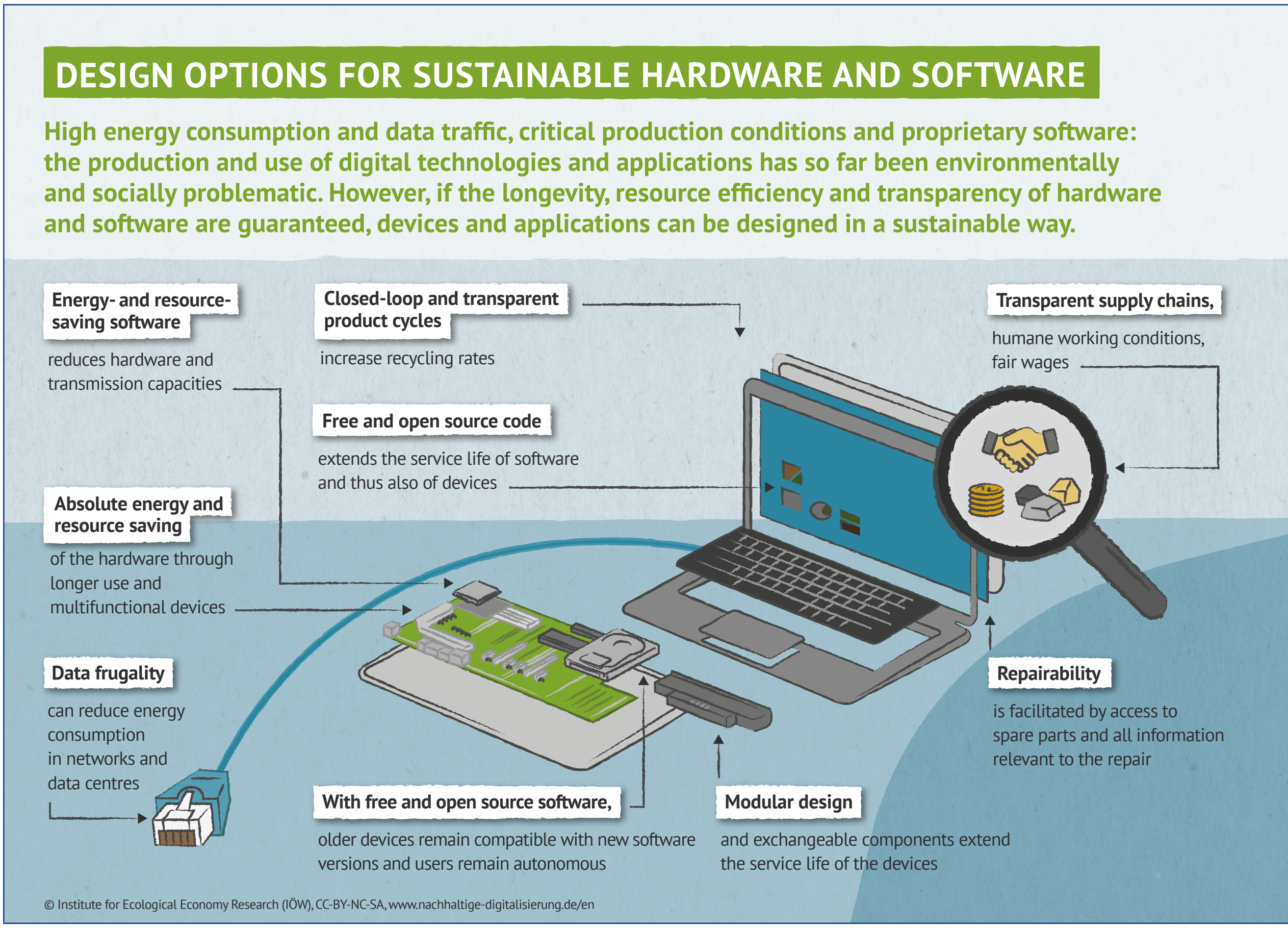

Figure 1: Design options for sustainable hardware and software

man rights are also known to occur in the production of digital devices, e. g., in Chinese factories (Chan 2019). The product life cycle of many devices in the Global South ends as it began, such as in Agbogbloshie in Ghana, on the largest landfill site on the African continent. There too, people live and work under inhumane conditions and face health hazards in order to recover recyclable raw materials from electronic waste (Höfner/Frick 2019). The recycling potential for e-waste is currently largely untapped: Only 20 % of the e-waste generated in Europe is recycled at all. The majority either ends up in residual waste, where it is later incinerated, or is exported illegally, mostly to countries in the Global South (Baldé et al. 2017). The production process is also characterised by a great lack of transparency and it is often not possible to determine which components were produced or disposed of where and under what conditions.

The production and programming of software is also often characterised by a great lack of transparency. Proprietary software development delivers fully compiled and locked code to users. This means they have no way of checking whether the software is doing what it claims to be doing. Companies keep their knowledge of the software secret, so new versions can be published, and old versions can be declared obsolete. This creates dependencies which not only impair the autonomy of the users, but can also affect the lifespan of hardware, as already described above as “software obsolescence”. These knowledge monopolies mean that the bankruptcy of a private-sector enterprise could not only result in an enormous loss of knowledge but could even lead to the breakdown of entire infrastructures.

In order to safeguard sustainability in all dimensions, it is therefore essential that hardware and software are fully transparent and traceable throughout the entire manufacturing process. For hardware this means transparent supply chains as well as humane working conditions and fair wages throughout the entire supply chain, for which the manufacturing companies are responsible. The prerequisite for the reuse of valuable components of ICT equipment is a functioning recycling system. Transparent software development means that the original source code with all subsequent changes is publicly accessible. Freely licensing the source code allows it to be used by all, even for business purposes. This prevents the monopolisation of knowledge and at the same time the monopoly position of individual (private-sector) actors. Free licenses allow knowledge to be archived and reused. As in the model of a circular economy, already developed programs or versions can be revived or further developed. Transparent production cycles, in which every single code contribution is traceable, also ensure responsible and independent users (c. f. Voigt this issue).

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Policy options for sustainable hardware and software

It is possible to achieve a sustainable design of digital devices and applications by safeguarding the frugal use of energy and resources, longevity as well as transparency and respect for human and labour rights along the life cycles of hardware and software (Fig. 1). The following section outlines how these sustainability goals can be incorporated into policy-making.

Conservation of resources

In order to contribute to absolute resource frugality in the sector and to prevent rebound effects, efficiency measures of digital technology must be flanked by consistency and sufficiency strategies that encompass all areas of the product life cycle. Modularisation and standardisation of hardware contributes to reducing electronic waste and thus to saving resources. At EU level, this can be achieved by means of mandatory specifications for the standardisation of electronic accessories (including charging cables) and electronic components. Another requirement is a functioning recycling system that fully utilises its potential through efficient collection (e. g., a deposit system for equipment or a low-threshold return system in shops) and the further development of recycling technologies so that the valuable contents of digital equipment can be reused (Handke et al. 2019). Mandatory requirements to design software in a way that minimises electricity and resource consumption during the utilisation phase must continue to be introduced. The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety has already presented starting points for this with the Blue Angel for software. There are also criteria for assessing energy efficiency in data centres. This label should be extended to include criteria that assess environmentally sound planning, operation and disposal. The implementation of the requirements should become mandatory in public procurement procedures. Furthermore, compulsory info-labels for resource-saving products and applications can help consumers to make informed choices. In the case of digital services such as video streaming, platform operators should ensure that the standard resolution of videos is always adapted to the size of the terminal equipment and that automatic playback is deactivated ("Sufficiency by default").

Longevity

The longest possible service life of the devices and applications also contributes to the absolute conservation of resources, and this means that the repair and update capability of hardware and software must be ensured. This includes several aspects that can be implemented at EU level, for example by extending the Ecodesign Directive, as has long been demanded: The "right to repair" of appliances must be enshrined in law and includes the mandatory publication of all information relevant to the repair as well as non-discriminatory and permanent access for all (commercial) repairers and end-users to all means and tools relevant to the repair. Full rights of use as well as warranty must be maintained, even if the repair is carried out by independent certified repair companies and alternative software or operating systems are used. This includes designing equipment in such a way that it can be repaired ("Design for Repair & Upgrade"). Free licensing of hardware and software after the end of production also contributes to the longest possible service life. For hardware, this means that the rights of use or ownership for building instructions and spare parts after the end of production are made available to the general public under a free licence so that users and workshops can reproduce spare parts themselves. With regard to software, this means introducing a mandatory publication of the source code under a free licence once a software or electrical device is no longer supported ("Upcycling of software"). This, together with the unrestricted right to install alternative software and operating systems, provides a powerful instrument against planned software obsolescence.

Transparency

The sustainable production of hardware requires transparent supply chains as well as humane working conditions and fair wages throughout the entire manufacturing process. Companies must be legally obliged to ensure transparency in supply chains and to exercise due diligence on both human rights and environmental issues, as currently demanded by various civil society organisations in the "Initiative Lieferkettengesetz" (Supply Chain Law Initiative). Failure to comply with these so-called due diligence obligations must result in sanctions under public law such as fines or exclusion from public procurement procedures. Businesses must also be held accountable for human rights violations resulting from failure to comply with due diligence obligations, including internationally (Initiative Lieferkettengesetz 2019). Electronic waste must not, as it is currently the case, be disposed of in an obscure way and, in case of doubt, be exported to the countries of the Global South. The export ban must be enforced more strongly here (Handke et al. 2019).

Transparency is also crucial in the development of software. In order to promote public and sustainable digital infrastructures (c. f. Frick et al. this issue), a legal obligation is required that hardware and software developed with public money should be published under an open-source licence ("Public Money Public Code" or "Public Money Public Hardware"), because developments paid for by all should also be available to all. It remains essential to create long-term structures that promote the development of sustainable and open hardware and software and contribute to digital sovereignty, such as the establishment of a European Open Technology Fund.

Sustainable public procurement

The public sector has a prominent role to play in implementing the policy recommendations for sustainable hardware and software: Tendering and procurement criteria for public authorities should be structured in a way that ensures that comprehensive environmental criteria are taken into account. This means that it gives preference to free and open-source software and devices as well as to those that provide open interfaces and modular designs. The production processes should take place under fair conditions, be transparent and traceable. Second-hand equipment should be used wherever possible. The use of environmental criteria and open standards must become mandatory in all public services and outstanding regulations and standardisation processes must be supported by public authorities. A paradigm shift towards free and open-source software is particularly important in the area of critical infrastructure. At EU level, for example, it is necessary to derive and implement concrete measures from the EU Commission's open-source strategy. For European projects such as the creation of a trustworthy cloud environment (GAIA-X), it is also imperative to include binding sustainability criteria (an example here is the Blue Angel for data centres) in the call for tenders, thereby setting technological standards at European level that give high priority to environmental protection.

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