TEXTE
35/2025

Report 3

Digital sufficiency: A new perspective on digitalisation as a driver for sustainability?

Analysis report of the project "Digitalisation and sustainability at EU level: Opportunities and risks of digitalisation for the implementation of the 2030 Agenda at EU level"

by:

Frieder Schmelzle, Dr. Sabine Hielscher
Institute for Ecological Economy Research (IÖW), Berlin

publisher:

German Environment Agency

German Environment Agency

TEXTE 35/2025

REFOPLAN of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

Project No. (FKZ) 3720 41 101 0
FB001510/ENG

Report 3

Digital sufficiency: A new perspective on digitalisation as a driver for sustainability?

Analysis report of the project "Digitalisation and sustainability at EU level: Opportunities and risks of digitalisation for the implementation of the 2030 Agenda at EU level"

by

Frieder Schmelzle, Dr. Sabine Hielscher
Institute for Ecological Economy Research (IÖW), Berlin

On behalf of the German Environment Agency

Imprint

Publisher
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

Report performed by:
Institute for Ecological Economy Research (IÖW)
Potsdamer Straße 105
10785 Berlin

Report completed in:
November 2022

Edited by:
Section I 1.2 International Sustainability Strategies, Policy and Knowledge Transfer
Dr. Barbara Beckert (Fachbegleitung)

Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4804

Dessau-Roßlau, March 2025

Abstract: Digital sufficiency: A new perspective on digitalisation as a driver for sustainability?

The world is entering a digital era that changes everyday business practices and lifestyles. Digital technologies are said to support sustainable development and create untapped potentials in many areas, for instance, by reducing energy and resource consumption. However, social and ecological drawbacks have become much more apparent where digitalisation has not lived up to its ascribed potentials. Over the past years, voices have become louder advocating for a green and digital twin transition. Similarly, the European Commission has supported the twin transition by setting it as a priority in line with the European Green Deal. This report presents project findings on how to support the twin transition through a concept of digital sufficiency. A premise of sufficiency as a guiding principle for the digital transformation is that technological innovation alone cannot solve societal problems. Unsustainable practices and behaviours must be either reduced or replaced by sustainable alternatives. The aim of this report is to support the German government's position in EU debates and to formulate recommendations for priorities for action, which the government can link to the activities of the European Commission. This is done by drawing on an analysis of the role of the German Council Presidency in supporting the twin transition in Europe, both an online survey and an expert workshop on digital sufficiency as well as a literature analysis to deepen some of the expert discussions. Our analyses find that although digital sufficiency has potentials to bring new perspectives into existing debates, work on the concept is still in its infancy. Future work needs to frame the concept and link it to existing policy debates to make it relevant for policy. This report provides the first building block towards carrying out this work and outlines policy recommendations towards supporting the twin transition through digital sufficiency.

Kurzbeschreibung: Digitale Suffizienz

Die Welt befindet sich im digitalen Wandel, welcher Arbeitsabläufe von Unternehmen und alltägliche Lebensstile verändert. Digitalen Technologien wird nachgesagt, dass sie eine nachhaltige Entwicklung unterstützen und in vielen Bereichen ungenutzte Potenziale nutzbar machen können, etwa durch die Reduzierung des Energie- und Ressourcenverbrauchs. Es werden jedoch zunehmend soziale und ökologische Nachteile deutlich, wo die Digitalisierung zugeschriebenen Potenzialen nicht gerecht geworden ist. Aus diesem Grund wurden Rufe nach einer grünen und digitalen ‚doppelten Transformation' immer lauter. Die Europäische Kommission stützt diese Forderungen und stuft die doppelte Transformation im Rahmen des Europäischen Green Deals als Priorität ein. Dieser Bericht präsentiert Projektergebnisse zur Unterstützung der doppelten Transformation mit Hilfe digitaler Suffizienz. Eine Prämisse der Suffizienz als Leitprinzip für die Digitalisierung ist, dass sich gesellschaftliche Probleme nicht allein durch technologische Innovation lösen lassen. Vielmehr müssen nicht-nachhaltige Praktiken und Verhaltensweisen reduziert oder durch nachhaltige Alternativen ersetzt werden. Ziel dieses Berichts ist es, die Position der Bundesregierung in EU-Debatten zu unterstützen und Empfehlungen für Handlungsprioritäten aufzuzeigen, die die Bundesregierung mit Aktivitäten der Europäischen Kommission verknüpfen kann. Der Bericht stützt sich auf eine Analyse der Rolle der deutschen Ratspräsidentschaft bei der Unterstützung der doppelten Transformation in der EU, eine Online-Umfrage und einen Fachworkshop zum Thema digitale Suffizienz sowie eine Literaturanalyse zur Vertiefung einiger Diskussionen im Fachworkshop. Die Analyse zeigt, dass das Konzept der digitalen Suffizienz zwar Potenziale birgt, neue Perspektiven in laufende Debatten zu tragen, jedoch noch in den Anfängen steckt. Künftige Forschungsarbeiten müssen den konzeptionellen Rahmen der digitalen Suffizienz elaborieren und mit bestehenden Debatten verknüpfen, um ihn politisch relevant zu machen. Dieser Bericht liefert die ersten Grundlagen für die Durchführung dieser Arbeiten und skizziert politische Handlungsempfehlungen zur Unterstützung einer doppelten Transformation durch digitale Suffizienz.

Table of content

List of figures

List of abbreviations

Abbreviation	Explanation
AI	Artificial intelligence
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
CE	Circular economy
CO_2	Carbon dioxide
CSO	Civil society organisation
DG	Directorate-General
DMA	Digital Markets Act
EC	European Commission
EGD	European Green Deal
EU	European Union
GHG	Greenhouse gas
ICT	Information and communications technologies
IoT	Internet of Things
JRC	Joint Research Centre for the European Commission
MS	Member State
SDG	Sustainable Development Goal
UBA	German Environment Agency (Umweltbundesamt)

Summary

Digitalisation is said to offer a wide range of opportunities and risks for achieving sustainability goals. In the European Green Deal (EGD), the European Commission (EC) has described various fields of action in which digitalisation plays a key role in sustainability transformations (EC 2019). In this context, the project 'Digitalisation and Sustainability at the EU level: Opportunities and risks of digitalisation for the implementation of the 2030 Agenda at EU level', which is carried out on behalf of the German Environment Agency (UBA), and financed by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), aims to develop policy perspectives on how to make better use of digitalisation to achieve sustainability goals. To be able to strengthen the German government's position to support interlinkages between digitalisation and sustainability issues within the activities of the EC, this report provides policy recommendations on how to better support the twin transition through the concept of digital sufficiency. This is done by drawing on an analysis of the role of Germany's Presidency of the Council of the European Union (EU) – hereinafter German Council Presidency – regarding topics related to digitalisation and sustainability (REPORT 1) and an expert workshop on digital sufficiency, which was carried out in April 2022 with a following literature review that deepened some of the workshop discussions. During the expert workshop, participants discussed the dimensions and elements of digital sufficiency and possible entry points to make the concept accessible and relevant for policy makers.

Plans of the EU to achieve a twin transition are largely based on efficiency strategies to reach sustainability in green growth (EC 2019). In this report, digital sufficiency is proposed as a possible concept that incorporates sufficiency strategies into digitalisation. It addresses both the use of information and communication technologies (ICT) to move towards sustainability and the mitigation of environmental and social effects derived from ICT (see section 3). Conceptual work carried out by Santarius et al. (2022) divides digital sufficiency into four interrelated dimensions: hardware sufficiency, software sufficiency, user sufficiency, and economic sufficiency. Together, they define digital sufficiency as "any strategy aimed at directly or indirectly decreasing the absolute level of resource and energy demand from the production or application of ICT" (Santarius et al. 2022, p. 4). The concept thus addresses levels of production and consumption, including digital designs that govern the consumption of energy and resource and social impacts of ICT. It is meant to complement existing efficiency strategies towards sustainability (see section 4.1).

Following Santarius et al. (2022), this report outlines each dimension of digital sufficiency (see section 4.2). Hardware sufficiency is aimed at reducing environmental impacts of physical devices in absolute terms. This is being pursued through the production and consumption of fewer devices and via a higher relative utilisation of existing devices, e.g. through repairing, sharing, or reusing hardware. Software sufficiency covers strategies that make software less data intensive, modest in computing capacity requirements, and sufficient in energy consumption. Furthermore, software sufficiency involves software products that do not excessively utilise hardware's computational capacities to avoid premature replacement of devices. User sufficiency is strengthened if fewer ICT consumption takes place. In addition, the use of ICT that intendedly fosters sufficient lifestyles is also part of this dimension. User sufficiency thus incorporates the use of specific ICT potentials for sufficiency in technological applications such as the dematerialisation of physical processes. Economic sufficiency revolves around digital businesses and incentive structures that shape the digital economy. In contrast to currently predominant strategies of economic growth and profit maximisation, economic sufficiency is characterised by businesses that consciously address the common good and find alternative goals to growth.

Different options to support digital sufficiency exist across its four dimensions. Through consulting a diverse group of digitalisation and sustainability experts within a workshop setting, possible entry points for digital sufficiency within policy debates were sounded out in this study (see section 5.1). In addition to carrying out an online survey, workshop participants discussed several ways to make digital sufficiency relevant for policy makers and possible entry points for digital sufficiency into existing policy debates. For example, participants drew attention to the possibility of digital sufficiency providing normative directions towards achieving societal and environmental goals within digitalisation processes. Besides EU plans on designing digital devices and infrastructures as efficient as possible, digital sufficiency can put ends to the means of digitalising processes and digital lifestyles. Elements of digitalisation can be consciously replaced, avoided, or intensified with the goal of shaping future development of European societies for a more sustainable future. Systemic changes can be put at centre rather than individual user responsibilities.

Additional entry points for digital sufficiency into policy debates were identified during the expert workshop. First, as a high-ranking topic, energy security issues can potentially be tackled through the lens of digital sufficiency by decreasing the absolute energy consumption of digital products and services. Second, sufficient deployment of ICT can mitigate challenges and risks of increasingly complex digital devices and infrastructures in businesses that make it hard to manage and control them. Third, digital sufficiency draws attention to designing and using such digital applications that enable sufficient lifestyles. Users are thereby empowered to contribute to digital and sustainable transitions. Fourth, existing challenges in individual health and wellbeing resulting from excessive ICT consumption could be mitigated by following digital sufficiency principles. Digital sufficiency can therefore be taken as an opportunity for advancing a twin transition.

Two of the entry points for digital sufficiency were deepened as part of this study. The workshop participants considered two entry points to have significant potential to enable a twin transition: a) dealing with resiliency and security issues such as energy security linked to digitalisation processes and b) supportive potentials for more sustainable lifestyles. The entry points were deepened based on existing literature on these topics (see section 5.2). The first entry point draws attention to issues linked to energy supply in the EU being largely dependent on energy imports that have recently become under increasing pressure (Eurostat 2022; IEA 2022). Several researchers have highlighted the need to address energy supply challenges with reduced energy demand (e.g. Brisbois 2022), of which substantial shares are attributed to digital technologies (The Shift Project 2020). Thus, digital sufficiency such as strategies for absolute reduction in the ICT sector can play a key role in advancing energy security and thus societal resiliency. The second entry point highlights the need for in-depth explorations of deploying digital tools, products, and services to move towards sufficient production and consumption levels. These can include, for example, modal shifts in transport, increased product lifespans, and sharing practices (Sandberg 2021). Digital green apps, sharing and repairing platforms and digitally coordinated civil society initiatives are examples of ICT deployments that can assist digital (user) sufficiency. They often come not only with possibilities for individual empowerment but also increased civic engagements (Ozman and Gossart 2018) and are closely intertwined with aspects of social participation and innovation.

Policy recommendations for implementing digital sufficiency in EU policy were developed as part of this study (see section 6). They touch upon diverse levels of possible actions linked to hardware sufficiency, software sufficiency, user sufficiency, and economic sufficiency and their potential entry points. The recommendations are linked to the following themes:

- Awareness about new sufficiency-induced narratives for achieving the twin transition,

- Digital innovations for digitalisation as a public and common good,
- Voices from civil society and their role in the twin transition,
- Civil engagement in Germany for participative governance processes,
- Incentives for ICT repair and reuse in Germany and Europe,
- Experimental spaces in Germany for sufficiency-oriented data governance models,
- Digital platform cooperatives in Germany for a commons-based digital economy,
- Open standards for innovative German software developments.

Our study concludes that digital sufficiency bears considerable potential to gain a new perspective on the twin transition, which takes sustainability potentials such as social innovations linked to sufficiency experiments into account, next to technologically induced efficiency enhancements. Digital sufficiency incorporates principles of open and forward-thinking hardware and software design, sufficient digital practices, and citizen participation. These elements could form a renewed approach to digital and environmental policy designs for a digital society that facilitates sufficient production and consumption.

Zusammenfassung

Der Digitalisierung wird eine Vielzahl von Chancen und Risiken für die Erreichung von Nachhaltigkeitszielen zugeschrieben. Die Europäische Kommission hat im Europäischen Green Deal verschiedene Handlungsfelder beschrieben, in denen die Digitalisierung eine Schlüsselrolle bei der Nachhaltigkeitstransformation spielt (EC 2019). Vor diesem Hintergrund zielt das Projekt ‚Digitalisierung und Nachhaltigkeit auf EU-Ebene: Chancen und Risiken der Digitalisierung für die Umsetzung der Agenda 2030 auf EU-Ebene', das im Auftrag des Umweltbundesamtes (UBA) durchgeführt und vom Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUV) finanziert wird, auf die Entwicklung politischer Perspektiven zur besseren Nutzung der Digitalisierung zur Erreichung von Nachhaltigkeitszielen ab. Um die Position der Bundesregierung im Rahmen von Aktivitäten der Europäischen Kommission für eine stärkere und tiefere Verflechtung von Digitalisierungs- und Nachhaltigkeitsthemen zu stärken, werden in diesem Papier Politikempfehlungen gegeben, wie die doppelte Transformation durch das Konzept der digitalen Suffizienz besser unterstützt werden kann. Dabei stützt es sich auf eine Analyse der Rolle der deutschen EU-Ratspräsidentschaft (im Folgenden: deutsche Ratspräsidentschaft) in Bezug auf Themen der Digitalisierung und Nachhaltigkeit (BERICHT 1), einen Experten-Workshop zum Thema digitale Suffizienz, der im April 2022 durchgeführt wurde, und eine Literaturrecherche zur Vertiefung einiger Diskussionen aus dem Workshop. Während des Fachworkshops erörterten die Teilnehmenden die Dimensionen und Elemente digitaler Suffizienz sowie mögliche Ansatzpunkte und Möglichkeiten, digitale Suffizienz so zu gestalten, dass das Konzept für politische Entscheidungsträger*innen zugänglich und relevant ist.

Die Pläne der Europäischen Union (EU) zur Verwirklichung einer doppelten Transformation beruhen weitestgehend auf Effizienzstrategien, die ein nachhaltiges grünes Wachstum ermöglichen sollen (EC 2019). In diesem Bericht wird digitale Suffizienz als ein mögliches Konzept vorgeschlagen, um Suffizienzstrategien in die Digitalisierung einzubeziehen. Es befasst sich sowohl mit der Nutzung der Informations- und Kommunikationstechnik (IKT) zur Erreichung von Nachhaltigkeitszielen als auch mit der Minderung der ökologischen und sozialen Auswirkungen der IKT (siehe Kapitel 3). Die konzeptionellen Arbeiten von Santarius et al. (2022) unterteilen digitale Suffizienz in vier wechselseitig verknüpfte Dimensionen: Hardwaresuffizienz, Softwaresuffizienz, Nutzungssuffizienz und ökonomische Suffizienz. Digitale Suffizienz als Ganzes ist definiert als jegliche Strategie, die darauf abzielt, den absoluten Ressourcen- und Energiebedarf in der Produktion oder Nutzung von IKT direkt oder indirekt zu senken (Santarius et al. 2022, S. 4). Das Konzept bezieht sich also auf Produktions- und Verbrauchsmengen, einschließlich der digitalen Gestaltungsräume, die den Energieverbrauch sowie ressourcenbezogene und soziale Auswirkungen von IKT bestimmen. Es soll bestehende Effizienzstrategien in Richtung Nachhaltigkeit ergänzen (siehe Abschnitt 4.1).

In Anlehnung an Santarius et al. (2022) werden in diesem Bericht die einzelnen Dimensionen der digitalen Suffizienz beschrieben (siehe Abschnitt 4.2). Hardwaresuffizienz zielt darauf ab, die Umweltauswirkungen physischer Geräte in absoluten Zahlen zu reduzieren, indem weniger Geräte produziert und verbraucht werden und die Auslastung vorhandener Geräte erhöht wird, z. B. durch Reparatur, gemeinsame Nutzung oder Wiederverwendung von Hardware. Softwaresuffizienz umfasst Strategien, die dafür sorgen, dass Software nicht übermäßig datenintensiv ist, wenig Rechenkapazität benötigt und einen suffizienten Energiebedarf hat. Darüber hinaus umfasst die Softwaresuffizienz Softwareprodukte, die Hardwarekapazitäten nicht übermäßig beanspruchen, um dem vorzeitigen Austausch von Geräten entgegenzuwirken. Die Nutzungssuffizienz wird gestärkt, wenn weniger IKT eingesetzt werden. Darüber hinaus gehört auch die Nutzung digitaler Anwendungen, die einen suffizienten Lebensstil fördern

sollen, zu dieser Dimension. Nutzungssuffizienz umfasst somit die Nutzung spezifischer IKT-Potenziale für Suffizienz in technologischen Anwendungen wie der Dematerialisierung physischer Prozesse. Bei der ökonomischen Suffizienz geht es um digitale Unternehmen und Anreizstrukturen, die die digitale Wirtschaft prägen. Im Gegensatz zu derzeit vorherrschenden Strategien des Wirtschaftswachstums und der Gewinnmaximierung zeichnet sich ökonomische Suffizienz durch solches Unternehmertum aus, das sich bewusst mit dem Gemeinwohl auseinandersetzt und Alternativen zu Wachstumszielen findet.

Es gibt verschiedene Möglichkeiten die vier Dimensionen der digitalen Suffizienz zu unterstützen. Durch die Befragung einer heterogenen Gruppe von Digitalisierungs- und Nachhaltigkeitsfachleuten im Rahmen eines Workshops wurden in dieser Studie mögliche Ansatzpunkte für digitale Suffizienz in politischen Debatten ausgelotet (siehe Abschnitt 5.1). Neben schriftlichen Online-Umfragen diskutierten die Teilnehmenden in Gruppen Möglichkeiten, wie digitale Suffizienz für Entscheidungsträger*innen in der Politik relevant gemacht werden kann und wo sich mögliche Ansatzpunkte und Framings für digitale Suffizienz finden lassen. Die Teilnehmenden wiesen beispielsweise auf die Möglichkeit hin, dass digitale Suffizienz normative Leitlinien für die Erreichung gesellschaftlicher und ökologischer Ziele im Rahmen von Digitalisierungsprozessen liefert. Neben den Plänen der EU, digitale Geräte und Infrastrukturen so effizient wie möglich zu gestalten, kann digitale Suffizienz die Mittel zur Digitalisierung von Prozessen und digitalen Lebensstilen festlegen. Elemente der Digitalisierung können bewusst ersetzt, vermieden oder intensiviert werden, mit dem Ziel, die zukünftige Entwicklung der europäischen Gesellschaft nachhaltiger zu gestalten. Anstatt der Verantwortung einzelner Personen können systemische Veränderungen in den Mittelpunkt gestellt werden.

Im Rahmen des Experten-Workshops wurden weitere Ansatzpunkte für digitale Suffizienz in politischen Debatten identifiziert. Erstens können Fragen der Energiesicherheit durch die Brille der digitalen Suffizienz verbessert werden, indem der absolute Energieverbrauch digitaler Produkte und Dienstleistungen gesenkt wird. Zweitens kann ein ausreichender Einsatz von IKT die Herausforderungen und Risiken zunehmend komplexer digitaler Geräte und Infrastrukturen in Unternehmen mindern, die deren Verwaltung und Kontrolle erschweren. Drittens lenkt die digitale Suffizienz die Aufmerksamkeit auf die Gestaltung und Nutzung solcher digitalen Anwendungen, die suffiziente Lebensstile ermöglichen und erleichtern. Nutzer*innen werden dadurch in die Lage versetzt, zum digitalen und nachhaltigen Wandel beizutragen. Viertens könnten die bestehenden Herausforderungen für die Gesundheit und das Wohlbefinden Einzelner, die sich aus einem übermäßigen IKT-Konsum ergeben, durch die Beachtung der Grundsätze der digitalen Suffizienz gemildert werden. Digitale Suffizienz ist so als Chance für eine doppelte Transformation nutzbar.

Die Workshop-Teilnehmenden waren der Ansicht, dass zwei Ansatzpunkte ein erhebliches Potenzial für das Ermöglichen einer doppelten Transformation haben könnten: a) die Behandlung von Resilienz- und Sicherheitsfragen wie Energiesicherheit im Zusammenhang mit Digitalisierungsprozessen und b) unterstützendes Potenzial für nachhaltigere Lebensstile. Die Ansatzpunkte wurden auf der Grundlage vorhandener Literatur zu diesen Themen vertieft (siehe Abschnitt 5.2). Der erste Ansatzpunkt lenkt die Aufmerksamkeit auf Probleme im Zusammenhang mit der Energieversorgung in der EU. Diese ist weitgehend von Energieimporten abhängig und in letzter Zeit zunehmend unter Druck geraten (Eurostat 2022; IEA 2022). Mehrere Forschende heben die Notwendigkeit hervor, die Herausforderungen bei der Energieversorgung durch eine Verringerung der Energienachfrage zu bewältigen (z. B. Brisbois 2022), wovon ein erheblicher Teil auf digitale Technologien zurückzuführen ist (The Shift Project 2020). Daher könnten Strategien zur absoluten Senkung der Energienachfrage im

Digitalen eine Schlüsselrolle bei der Förderung der Energiesicherheit und somit gesamtgesellschaftlicher Resilienz spielen. Der zweite Ansatzpunkt unterstreicht die Notwendigkeit, den Einsatz digitaler Produkte und Dienstleistungen eingehend zu untersuchen, um ein suffizientes Produktions- und Verbrauchsniveau zu erreichen. Dazu können beispielsweise Verkehrsverlagerungen, längere Produktlebensspannen und Praktiken des Teilens gehören (Sandberg 2021). Digitale grüne Apps, Plattformen zum Teilen und Reparieren sowie digital koordinierte Initiativen der Zivilgesellschaft sind Beispiele für IKT-Nutzung, die digitale (Nutzungs-)Suffizienz unterstützt. Sie bieten oft nicht nur Möglichkeiten zur individuellen Befähigung, sondern auch zu bürgerschaftlichem Engagement (Ozman und Gossart 2018) und sind eng mit Aspekten sozialer Teilhabe und Innovation verwoben.

Im Rahmen dieser Studie wurden Politikempfehlungen für die Umsetzung der digitalen Suffizienz in der EU-Politik entwickelt (siehe Kapitel 6). Sie beziehen sich auf verschiedene Ebenen für mögliche Maßnahmen im Zusammenhang mit Hardwaresuffizienz, Softwaresuffizienz, Nutzungssuffizienz und ökonomischer Suffizienz sowie deren potenzielle Ansatzpunkte. Die Empfehlungen betreffen folgende Aspekte:

- Bewusstsein für neue, Suffizienz-induzierte Narrative für die doppelte Transformation,
- Digitale Innovationen für die Digitalisierung als öffentliches und Gemeingut,
- Stimmen aus der Zivilgesellschaft und ihre Rolle in der doppelten Transformation,
- Bürgerschaftliches Engagement in Deutschland für partizipative Governanceprozesse,
- Anreize für die Reparatur und Wiederverwendung von IKT in Deutschland und Europa,
- Experimentierräume in Deutschland für suffizienzorientierte Datengovernance-Modelle,
- Genossenschaftliche Plattformen für eine gemeingutbasierte deutsche Digitalwirtschaft,
- Offene Standards für innovative deutsche Softwareentwicklungen.

Unsere Studie kommt zu dem Schluss, dass digitale Suffizienz beachtliches Potenzial birgt, eine neue Perspektive auf die doppelte Transformation zu ermöglichen. Diese berücksichtigt neben technologisch bedingten Effizienzsteigerungen auch Nachhaltigkeitspotenziale aus sozialen Innovationen. Digitale Suffizienz umfasst Prinzipien offenen und zukunftsorientierten Hard- und Softwaredesigns, suffizienter digitaler Praktiken, sozialer Gerechtigkeit und breiter Bürgerbeteiligung. Diese Elemente könnten einen neuen Ansatz für die Digital- und Umweltpolitikgestaltung bilden, für eine digitale Gesellschaft, die Suffizienz in Produktion und Konsum ermöglicht.

1 Introduction

1.1 Digitalisation and sustainability for a twin transition: Is digital sufficiency a way forward?

The application of digital technologies has been ascribed large potentials to contribute to solutions of social and environmental problems such as increasing greenhouse gas (GHG) emissions, biodiversity loss, and soil erosion. Most applications of digital technologies are said to have in common that their use makes economic activities more efficient (GeSI 2020; Vinuesa et al. 2020). For instance, precision farming can reduce the number of fertilisers and pesticides needed per unit of food production. Digital tools for optimised industrial production are said to decrease energy and resource demands. Digital ICT can support transitions towards renewable and decentralised energy systems. There is a long list of actual and potential applications of digitalisation to address social and environmental issues. However, **digitalisation has not lived up to ascribed potentials** in the past. In fact, results have been mixed so far.

Cross-country studies have shown that advancing digitalisation can go along with higher levels of energy consumption (Schulte et al. 2016; Lange et al. 2020) as well as GHG emissions (Salahuddin et al. 2016). One example is the high amount of energy and resources consumed by the ICT sector itself. Freitag et al. (2021) have estimated that this accounts for between 2.1 to 3.9 % of total global GHG emissions. This is due to increasing numbers of digital devices, computationally intensive software, and the expansion of physical infrastructure such as server capacities and networks. In addition, **digitalisation often induces extra consumption** not only of digital devices and services but also of other goods and services. So-called rebound effects describe how the increased efficiency that digital technologies can achieve can also induce additional consumption of goods and services, and, therefore increasing the amount of GHG emissions produced (Coroama and Mattern 2019; Lange et al. 2020). The frequently ascribed potential of digital technologies to move towards more sustainable systems faces challenges, which require adequate political governance.

At the EU policy level, supporting the **twin transition towards a digitalised and sustainable economy** has been set as a priority, in line with the EGD (Ortega-Gras et al. 2021). In March 2020, the EC argued that Europe must leverage the potential of digital transformations, which is seen as a key enabler for reaching the EGD's objectives including sustainability goals of the New Industrial Strategy for Europe (EC 2020). Still, the European discourse on digitalisation and sustainability lacks discussions on rebound effects and on how digitalisation may increase consumption levels via fostering economic growth. The question whether a digitally driven surge in economic growth is compatible with sustainability goals necessitates considerations of **the use of digitalisation for sufficiency** including sufficient use of ICT themselves (Santarius et al. 2022). A premise of sufficiency as a guiding principle for the digital transformation is that technological innovation alone cannot solve societal problems (Lange and Santarius 2020; Spengler 2016). Unsustainable practices and behaviours must be either reduced or replaced by sustainable alternatives. The notion of digital sufficiency could provide a basis to build an understanding of how digitalisation can become part of social and environmental transformations (Santarius et al. 2022). The aim of this report is to examine this notion of digital sufficiency and its policy relevance for EU policy areas, in which it could play a role.

1.2 Purpose and outline of the study

This report presents project findings and policy recommendations on how to achieve a European digital and sustainable twin transition. An analysis of the concept of digital sufficiency is carried out to examine its potential in enabling such a transition. The aim is to introduce digital sufficiency into EU's policy and to formulate policy recommendations that can be taken up by policy makers within the EC. This is done by drawing on an analysis of the course set by the German Council Presidency and its role in supporting the twin transition (REPORT 1), an online survey and expert workshop on digital sufficiency, and a literature review that deepened selected expert discussions from the workshop. During the workshop, participants discussed the dimensions and elements of digital sufficiency as well as possible entry points for making digital sufficiency relevant for policy makers.

The remainder of the paper is structured as follows: Section 2 describes the methodology used for the data collection and analysis. Section 3 puts digital sufficiency into the context of existing EU debates on digitalisation and sustainability to show its potential. Section 4 presents the concept of digital sufficiency by drawing on its different dimensions. Section 5 outlines results from the online survey, the expert workshop, and a literature review on possible entry points for digital sufficiency as a policy-relevant concept. Section 6 presents summarised policy recommendations on how to develop and implement digital sufficiency strategies to support the twin transition.

2 Methodology

The aim of the report is to deepen the understanding of digital sufficiency and its interlinkages with digitalisation and sustainability debates. To this end, this report is based on 1) a document analysis of press releases, articles and speeches, 2) an online survey and a half-day workshop with digitalisation and sustainability experts such as policy makers, NGOs, think tanks, and academic researchers, and 3) a follow-up literature review to deepen the understanding of digital sufficiency and selected points raised during the workshop.

The **document analysis** of press releases, articles and speeches published during the German Council Presidency highlighted three thematic nexuses in debates surrounding the issues of sustainability and digitalisation: 1) sustainable digitalisation, 2) digitalisation for sustainability and 3) digitalisation and sustainability in silos (for more details on future priority areas refer to REPORT 1). Priority areas included the role of digitalisation within a circular economy (CE) (see REPORT 2) and the introduction of sufficiency to digitalisation i.e. by noting digital sufficiency as a response to social and environmental risks. Based on these findings, the project team in collaboration with the German Environment Agency (UBA) and Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) decided to deepen the work on digital sufficiency. Existing work linked to digital sufficiency was considered to have high, yet untapped potentials for strengthening environmental and climate protection. For example, the use of digitalisation for sufficiency could reduce numbers of digital devices, reduce data intensity of digital applications, and increase hardware longevity. Moreover, digitalisation could enable sufficient lifestyles and systemic changes for sufficient production and consumption.

In preparation for the online survey and expert workshop, an extended short characterisation in the form of a paper was produced on digital sufficiency and sent to the participants. The paper included 1) an overview of the four dimensions of digital sufficiency: hardware sufficiency, software sufficiency, user sufficiency, and economic sufficiency (Santarius et al. 2022), and 2) an outline of implications for EU policy at the interface of digitalisation and sustainability. Participants were invited to respond to the extended short characterisation online to be able to shape the questions and discussions of the workshop and its agenda. However, participation in the online survey was low.

The invitation to the **expert workshop** was widely distributed through the project partners' social media and newsletter channels. Some of the participants were directly contacted because of their expertise on the topic of digitalisation, sustainability, sufficiency, etc. Due to the COVID-19 pandemic the expert workshop was conducted online, which allowed for a wide group of experts from all over Europe to participate. In total, twenty participants from NGOs and think tanks, policy makers, and academic researchers joined the half-day workshop (including the project team). The event took place on the 26th of April 2022. It kicked off with a welcome and introduction to the topic. Afterwards the participants could choose from two break out groups: 1) "Dimensions and elements of digital sufficiency: What are the dimensions and elements of digital sufficiency?", and 2) "Entry points for digital sufficiency: How can we link digital sufficiency to existing policy debates to make it policy relevant?". A planned third group ("How to introduce digital sufficiency into concrete policy frameworks?") was cancelled due to lacking participants. Results were synthesised afterwards. A subsequent plenary discussion concluded the workshop. During the event, recordings and notes were taken to form the basis for the analysis of this report. Two weeks later, a written summary was sent to the participants to gain feedback and additional insights. No additional response from the experts could be gained.

To deepen some of the points raised during the expert workshop, **a follow-up literature analysis** was carried out. Considering that work on digital sufficiency still is in its infancies in policy and academic circles, the literature review picked up themes that workshop participants mentioned during the workshop that were broadly linked to digital sufficiency such as energy security, sustainable lifestyles, and digital wellbeing. Literature searches were carried out in academic and more generic search engines to find additional work on digitalisation, sustainability, and sufficiency. In addition, a list of references derived from publications on digital sufficiency (The Shift Project 2020; Colaço 2021; Santarius et al. 2022) was followed up for the literature review.

There are several potential limitations to the findings of this study. First, literature on digital sufficiency has been mainly advanced by a small group of academic researchers and is at its beginnings, making it challenging to develop a comprehensive understanding of the concept. Therefore, most of the literature reviewed for this report did not directly discuss digital sufficiency, but rather issues surrounding it, in order to place work on the concept in a broader context of existing work on digitalisation and sustainability. Second, an inherent potential for selection bias lies in the perspectives that were brought together in the expert workshop. Invitations were sent to a diverse group of possible participants to address and minimise this potential shortcoming. Finally, due to the novelty of the concept of digital sufficiency, participants partly had different understandings of it, which set some limitations to the workshop discussions. A subsequent literature review helped to deepen some of the themes mentioned at the workshop. They were mainly chosen based on their potential to contribute to policy discussions on the twin transition.

The next section puts digital sufficiency into the context of existing EU debates on digitalisation and sustainability to outline its potential for policy makers.

3 Digitalisation and sustainability debates at the EU level

Building on findings from this project, the following section outlines discussions on digitalisation and sustainability at the EU level and links them to the concept of digital sufficiency.

The EC has announced to **align policies with the twin digital and green transition** to achieve the benefits outlined in the course of the EGD. Digitalisation is said to be an enabler to achieve sustainability ambitions by, for instance, increasing efficiency and/or dematerialising certain products and services. There are considerable agreements that digital and environmental transitions need to be integrated more strongly to support transformations towards climate neutrality. However, the use of digital tools often goes along with additionally induced production and consumption. Empirical evidence shows that digitalisation is so far hardly the game-changer for sustainability that it is often promised to be (Lange et al. 2020; Clausen et al. 2022). Many existing efforts focus on implementing and promoting efficiency measures, and at increasing the share of renewable energy and recycling rates, with some impacts, but potentially not enough to meet the social and environmental goals outlined in the EGD (EC 2019).

The notion of sufficiency goes beyond efficiency potentials, as it addresses **absolute demands of energy and natural resources** by drawing attention to questions such as the extent to which unsustainable practices can be reduced without decreasing quality of life (Spengler 2016; Lange et al. 2019; Sandberg 2021). For example, digital technologies may entail various opportunities to facilitate more sufficient behaviours. Moreover, digital sufficiency draws attention to rebound effects, which are a frequent downside of technological efficiency improvements (Börjesson Rivera et al. 2014; Itten et al. 2020). Moreover, drawing on the notion of digital sufficiency can help to problematise how a ‘business as usual’ digitalisation may foster an economic growth paradigm that still relies on rising energy consumption and resource extraction (Lange et al. 2020). Some sufficiency measures are already part of existing policy debates within the EC. For example, product longevity and repairability issues are discussed to reduce the environmental footprint of digital devices (Smith 2022; Tagesschau 2022).

Introducing a sufficiency perspective into debates on digitalisation and sustainability can bring additional opportunities to harness the potential of digital technologies whilst keeping environmental costs at bay. Following the interlinkages between digital sufficiency and the twin transition (The Shift Project 2019; Colaço 2021; IPCC 2022), digital sufficiency needs to be explored further to meaningfully combine digital and environmental developments and to support the changes required for transformations towards sustainability. The following section elaborates on the dimensions and elements of digital sufficiency.

4 Digital sufficiency as a complementary strategy to sustainability and digitalisation approaches

The following section presents some of the project results and makes a case for digital sufficiency by outlining existing work on the concept and its relevance for a twin transition. First, it presents arguments for the need to go beyond efficiency approaches and the need to include sufficiency approaches and, second, it draws on the work by Santarius et al. (2022) on digital sufficiency to outline four dimensions that provide a differentiated understanding of the concept.

4.1 Going beyond efficiency: The need for sufficiency within the twin transition

Several studies have identified the potential of digitalisation i.e. the increasing and pervasive application of ICT throughout societies to reduce energy and resource consumption, achieved through **technology-enabled *efficiency* improvements**. Similarly, the EGD is first and foremost a "growth strategy" (EC 2019, p. 2) that primarily aims to achieve sustainability goals based on making economies more efficient. Efficiency strategies are frequently aimed at "doing more with less" (Santarius et al. 2022, p. 2) i.e. reducing resource and energy inputs per unit of product or service. Thus, it marks a relative concept of not consuming more than necessary to produce necessary goods while maintaining decent quality of life. For example, digital data gathering and processing technologies such as sensors within the Internet of Things (IoT) can affect the amount of energy used in people's homes or industrial processes through autonomously optimising for energy efficiency. Such studies often neglect that efficiency improvements can cause rebound effects that countervail some or all the initially generated savings (Hilty et al. 2006a; Santarius 2017; Coroama and Mattern 2019). The extent of a rebound effect is often considered to be the offset between the percentage of increased consumption and improved energy efficiency (Greening et al. 2000). Energy efficiency improvements derived from smart homes have been argued to bring about several types of rebound effects, for example, the increased purchase of lighting bulbs following an increase in their efficiency (Hong et al. 2006; Sorrell and Dimitropoulos 2008). As pointed out by the The Shift Project (2020, p. 2) "[a]t this point, our digital growth is unsustainable: there is a 9% annual increase in energy consumption due to digitalisation".

Drawing on existing literature, Santarius et al. (2022, p. 3) have highlighted several phenomena that "inhibit the realisation of positive effects and build the basis for devoting greater attention to sufficiency". Although energy and resource efficiencies in data processing and transmission are constantly being realised, the overall volume of data storage, processing and transmission is increasing and **often outweighing efficiency gains** (Malmodin and Lundén 2018). Similarly, cost efficiencies, energy efficiencies, time efficiencies etc. have been gained through ICT in industrial production and consumption processes, whereby rebound effects often countervail them (Hilty et al. 2006a; Gossart 2015). To be able to achieve absolute savings, several authors have argued that a combination of efficiency and sufficiency strategies needs to be considered in the development and diffusion of ICT (Sachs et al. 1998; Princen 2003; Sachs 2015). There is no hierarchy among efficiency and sufficiency strategies, as they can and should complement each other. Nonetheless, existing efforts from industry actors and politicians to reduce emissions are frequently based on hopes in finding technology-based solutions to create efficiency gains, often neglecting sufficiency strategies (Alfredsson et al. 2018; Bengtsson et al. 2018). Hilty et al. (2011) have argued that sufficiency strategies are key when trying to address rebound effects from digitalisation. In contrast to efficiency, sufficiency aims at qualities and scales of demands instead of fulfilling them with lower resource input and emission output.

Ideas of **sufficiency within sustainability** debates have started to be worked on from the 1980s onwards, alongside notions of efficiency. Subsequently, Princen (2005) has written a book on the 'The Logic of Sufficiency' in which sufficiency is understood as avoiding over- and underconsumption through reducing consumption levels (in particular material ones) in affluent societies. Over time, different meanings and strategies have been attached to this notion. These have included, for example, strategies of reducing the environmental footprint of societies including the promotion of sharing practices, i.e. digital peer-to-peer platforms that facilitate sharing of products across several participants and keeping products for longer (Curtis and Mont 2020; Mont et al. 2020), ideas of the 'Good Life', notions of downshifting materialistic requirements or voluntary simplicity (Schneidewind et al. 2013), and alternative economic systems such as degrowth and post-growth approaches (Petschow et al. 2018).

Today, it is not a marginal position in sustainability sciences that policy must **address overall production and consumption levels** in order to achieve existing sustainability goals (Alfredsson et al. 2018). At the same time, hopes on future developments and scalable innovations largely rely on a desired "technology push" (EC 2019, p. 18), whereby strategic exnovation does not seem to play too much of a role. The 12th Sustainable Development Goal (SDG) aims at an "efficient use of natural resources" (UN 2015) to make production and consumption sustainable, whereby absolute reduction is not mentioned. More recently, sufficiency principles have gained renewed attention (Niessen and Bocken 2021; Sandberg 2021; Schreiber et al. 2021). They are closely intertwined with digitalisation for a twin transition. A premise of sufficiency as a guiding principle for the digital transformation is that **technological innovation alone cannot solve societal problems** (Spengler 2016; Lange and Santarius 2020). Unsustainable practices and behaviours must be either reduced or replaced by sustainable alternatives. This can mean, for instance, sharing products with other users. Against the background of existing environmental and climate crisis and the digitalisation of all economic sectors, an application of sufficiency principles to the digital world has become more necessary over the past years.

The need to strengthen **sufficiency principles within digitalisation and sustainability** is underlined by the fact that empirical evidence has shown ICT's adverse net environmental impacts (Hintemann 2018). Works by the Shift Project (The Shift Project 2020) and Lange and Santarius (2020) have advanced these arguments for paying attention to sufficiency in the digital world. The Shift Project (2020, p. 2) has defined digital sufficiency as "moving from an instinctive or compulsive use of digital systems to a more controlled use of technologies, constructed by measuring both associated risks and opportunities". The authors link this understanding to 'sober' digital transitions, thus referred to as digital sobriety. They explicitly call on governments and businesses to take actions whilst taking sufficiency-oriented principles on board. The call for actions includes, for instance, 1) the inclusion of environmental impacts as decision-making criteria, 2) the empowerment of organisations to manage digital transitions, and 3) the implementation of carbon audits for digital projects (The Shift Project 2019, 2020).

The concrete term '**digital sufficiency**' was first put forward by Lange and Santarius (2020). Similar to the concept of 'digital sobriety' (The Shift Project 2019), digital sufficiency aims at fulfilling needs for decent lives whilst at the same time avoiding unnecessary deployment of resource-intensive ICT. Digital sufficiency has been called to be a critical perspective on digital technologies that draws attention to novel approaches linked to technology design, usage patterns and their political governance. In addition to direct ecological impacts, this concept aims to not only address individual users and producers but also wider social and economic developments such as rebound effects and workings of digital economies. It thus contrasts the view that „[t]he decision as to who needs what lies with consumers themselves. And sufficiency, in other words the voluntary decision to forego unnecessary digital consumption, makes an important contribution to reducing the ecological footprint of digitalisation" (BMU 2020, p. 12). This formulation risks the misunderstanding that individual consumers were responsible for and capable of shouldering the twin transition. However, not only efficiency improvements but deep structural adjustments are needed to achieve it.

An initiative by the international research and innovation network Future Earth stresses that currently predominating efforts to decrease emissions by economic sectors "is not sufficient […] because, while research indicates that deep decarbonisation is technically possible, we have not yet figured out how to steer society onto a decarbonization path" (SDA 2020a, p. 4). This analysis indicates a strategic gap, which cannot be countered by technological fixes (only). The initiative sees potentials in the role of "digital disruptors to drive changes in existing economic, governance, and cognitive systems" (ibid., p. 14) and thus addresses **socially determined aspects** of mindsets, cultures, and power relations rather than efficiency-enhanced technical artifacts. A demand for "a new social contract for the digital age, which addresses individual rights, justice and equity, inclusive access, and environmental sustainability" (SDA 2020b) underlies this approach.

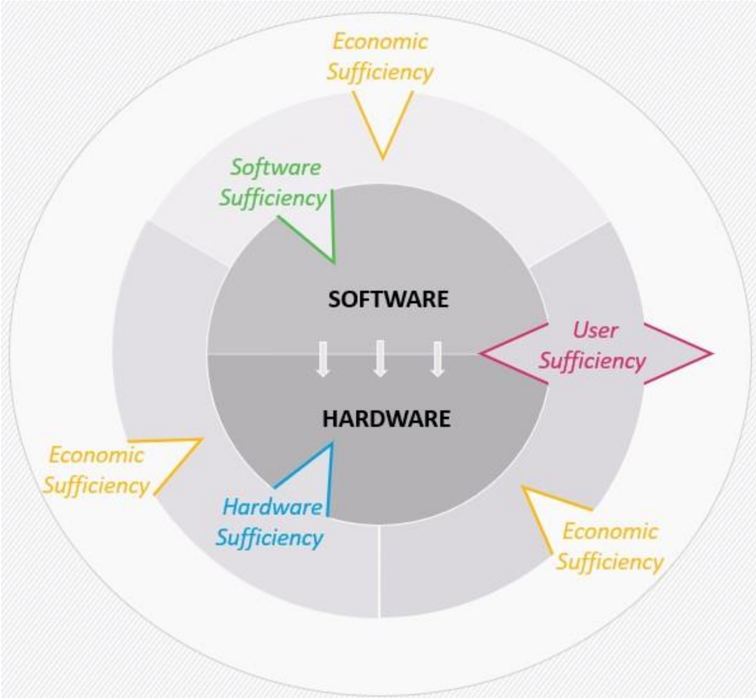
Despite similarities among the sufficiency-related works laid out above (Lange et al. 2019; The Shift Project 2019, 2020; SDA 2020a, 2020b), it stands out that bridges to concrete policy areas and courses of action are rare. Santarius et al. (2022) try to build such bridges by **breaking down sufficiency into policy-oriented dimensions**. Moreover, their concept seems adequate to sketch out paths towards a twin transition that supports a European "positive and human-centric vision of the digital economy and society" (EC 2021, p. 18). In this regard, also the German government holds up the involvement of civil society actors to effectively develop human-centric digital technologies (Federal Government of Germany 2022). As the realisation of this intention still leaves room for improvement, e.g. in the development of artificial intelligence (AI) (Jones 2022), also in other EU Member States (MS) civil society organisations (CSOs) do often not feel listened to by political decision makers (Beining et al. 2020).

Due to the mentioned focus of digital sufficiency by Santarius et al. (2022), its political tangibility and its connectiveness to the role of underrepresented groups in the present digital economy, the present study focuses on their four-dimensional view. Different dimensions of digital sufficiency are presented in the next section.

4.2 Four dimensions of digital sufficiency

The term digital sufficiency is still rather new in academic and policy debates. In contrast to techno-optimistic narratives, digital sufficiency perspectives take a **critical perspective on digital technologies and their role in sustainability transformations.** With their contributions to an emerging debate, Santarius et al. (2022) have attempted to address the current lack of strategies against rebound effects as well as insufficient policy options. A sufficiency concept is sketched out specifically suited to the digital world. Four interrelated dimensions of digital sufficiency form the core of the concept (see Figure 1). Hardware sufficiency revolves around the (steadily growing) material base of digitalisation, namely hardware devices. Software sufficiency concerns energy-consuming digital applications that run on these devices and process digital data to fulfil tasks for users. User sufficiency addresses the (non-)use of digital technologies for purposes that can serve or hamper economic sufficiency. Economic sufficiency is an image of socio-economic political conditions, embedded economic practices, digital business models, and digital market actors that are built on reducing absolute energy and resource consumption.

Figure 1: The four dimensions of digital sufficiency



Source: own illustration, Institute for Ecological Economy Research (simplified based on Santarius et al. 2022, p. 12).

Software and hardware create an inseparable interplay. As indicated with grey arrows in Figure 1, software strongly influences sustainability effects of hardware. This interrelationship is not delimited to hardware's operational energy consumption (moderated e.g. by the computational intensity of a software's functions) but can also affect premature wear of devices (caused e.g. by hardware requirements that end devices' use phases before they are physically broken). Among other principles, software sufficiency therefore covers the frugal use of hardware capacities and the imperative of processing only data that is absolutely necessary (cf. green arrow). On the hardware side, sufficiency manifests mainly in designs that allow long lifetimes of devices to reduce absolute consumption of natural resources as well as in minimised deployment of devices and appropriate disposal and recycling of incorporated materials (cf. blue arrow). The (non-)utilisation of software and hardware strongly depends on social factors, which are reflected in the user sufficiency dimension. First, ICT can be used sufficiently if non-essential applications with negative sustainability effects are omitted (e.g. modular services, cf. inward red arrow). Second, ICT applications can be instruments to promote sufficient practices with aggregate economic impacts (e.g. digital sharing platforms, cf. outward red arrow). Establishing such can fertilise the fourth dimension, which is economic sufficiency. It constitutes a sufficiency-oriented environment to provide appropriate framework conditions for digital sufficiency such as the structure of dominant business models and their political governance (cf. yellow arrows). Economic incentives are shifted from a growth paradigm to a strengthened focus on public and common good, so that digital businesses can evolve on less concentrated markets and with cooperative models such as worker-owned businesses and platform cooperatives. The four dimensions of digital sufficiency and their interlinkages are outlined in more depth throughout the following sub-sections.

4.2.1 Hardware sufficiency: using fewer devices and for longer

Digital applications run on physical devices, even if they appear to be virtual. They depend on processing units and often on diverse transmission infrastructures such as routers or even large-scale submarine cables (TeleGeography 2022). These contain natural resources just like the numerous hardware devices that receive, store, and output digital data. End devices such as notebooks and smartphones are obvious examples for resource-consuming hardware. However, also background tasks of data centres, web servers and embedded systems such as control units rely on material structures. Consequently, there are always direct environmental impacts from "the physical existence of ICT" (Hilty et al. 2006b, p. 1619). They are often classified as so-called "primary" (Hilty et al. 2006b, p. 1619) or "lifecycle" impacts (Hilty and Aebischer 2015, p. 26). All material equipment, components, and peripheral devices that are required to deploy digital applications constitute the hardware part of digitalisation.

Hardware sufficiency is the dimension of digital sufficiency that is aimed at reducing the absolute environmental impact of the devices that form the material basis for ICT usage and societal digitalisation (Santarius et al. 2022). It includes "being able to produce fewer devices […] [as well as] ensuring that their complexity and resource use do not surpass the purpose they are designed for" (Santarius et al. 2022, p. 4). To achieve this, different opportunities open up. From a circular economy (CE) perspective, the optimal solution for sustainable hardware is to use regenerative resources in production. Achieving this would mean that natural resources are not consumed but are part of a closed material cycle. This would mitigate several problems, for example, mining practices for the critical natural resources that are essential for digital hardware could be minimised. Mining conditions are often inhumane and harmful to ecological and social systems in the Global South (Coderre-Proulx et al. 2016; WEED 2017; Manhart et al. 2019). Globally, electronic waste disposal takes place illegally in most cases (UNEP 2015). Hardware recycling is in many cases challenging and expensive (Marschneider-Weidemann et al. 2016). There are no foreseeable options to produce hardware from regenerative resources such as organic materials in the near future.

Against this background, hardware sufficiency appears to be a strategy to both mitigate the outlined challenges in the manufacturing and recycling of devices as well as to reduce problematic mining practices in the Global South. Sufficiency draws attention to the need of deploying **less carbon-intensive physical hardware units** and extending their use phases so that the carbon intensity of individual devices decreases, considering that the largest share of carbon emissions originates from their production. For example, in the case of smartphones, manufacturing accounts for more than three times of carbon emissions than from the use phase (Benton et al. 2015, p. 29). Due to the absence of regenerative natural resources, significant efforts should be put into longer hardware lifespans to increase hardware sufficiency. Producers have a strong influence on the product quality of devices. Design choices can raise or reduce the probability of hardware breaking at an early stage of its usage phase. From a consumption perspective, lifetimes can be lengthened through repairing and reusing devices or components. Providing services that enable the transfer of initially discarded hardware devices to users with lower expectations for the use of the same device, could significantly extend the device's lifetime. In addition, it potentially reduces the need for additional production of the same device model. Such services that allow for the sharing and transfer of devices already exist (Hardware for Future 2022).

Hardware sufficiency can therefore also lead to reduced production quantities. Fewer people can also use certain hardware devices or specific applications are deliberately avoided. Moreover, people can use non-digital alternatives that are more environmentally friendly. The quantitative reduction of hardware devices does not necessarily mean that people have to stop using them. People can **share devices instead of using several single units**, seeing that the aggregate effect still means a reduced hardware deployment. If shared usage can be sufficiently coordinated, capacity utilisation rises while resource demand decreases. An effective approach to stretching use periods of hardware would certainly be to design and construct them in ways that **promote durability**. The European Environmental Bureau expects that extending the average lifetime of notebooks and smartphones by one year would abate carbon dioxide (CO_2) emissions as equivalent to 2 million cars (Zuloaga et al. 2019). Even though product design and repairability is crucial to make progress in this regard, the lifetime of hardware is not detachable from the perceived obsolescence of devices. For example, lots of smartphones are replaced after 2 years, although they are still functioning,

Another factor that moderates hardware durability lies in software (cf. Figure 1). Central impacts are outlined in section 4.2.2. Principles of **open design and open source** are important conditions for a CE (BMBF 2018) and can encourage more people into product repair practices. Products that link to open design principles are not only easier to repair, but also to upgrade, reuse, and recycle (Bonvoisin 2017). If the **possibility of modifying** products is guaranteed by producers, users or third parties are able to develop designs further in order to make it easier to repair and make it more durable. However, such open design principles are often in conflict with particular business interests in shielding intellectual property (Voigt 2022). Today, portable hardware devices are increasingly difficult to repair due to, for example, permanently installed batteries (López Dávila et al. 2021) or other components, effectively hindering the lengthening of product lifetimes by design. The use of permanently installed batteries is suspected to be one of the reasons why Germany is – despite existing e-waste policies – one of the most e-waste-intensive countries worldwide (Forti et al. 2020).

To sum up, hardware sufficiency revolves around two aspects. Devices should 1) be reduced numerically to a sufficient level, and 2) designed in a way that allows people to use them for longer. This involves addressing issues connected to, for example, durability, open designs, and repairability.

4.2.2 Software sufficiency: using leaner programs to disburden hardware

As highlighted by Hilty and Aebischer (2015, p. 27), there always are “physical actions needed” to run an ICT system. The often less visible part of digital systems is the software involved. However, as Mahaux et al. (2011, p. 19) have put it, “at the heart of IT lies software”. It is indispensable for making hardware operate as intended. Software does not only create the interface between users and devices but also influences the intensity of sustainability impacts. Software design can determine forms, frequencies, and durations of digital ICT use as well as respective external impacts (Duboc et al. 2020). Even though software is not as tangible as hardware, its potency can barely be underestimated since it is “central to the operation of most sectors of industrial societies” (Penzenstadler et al. 2014, p. 40). It thus marks another important building block of digitalisation, which does not only cause energy consumption but can steer concrete physical effects of socio-economic developments.

Software sufficiency is the dimension of digital sufficiency that foremost accounts for a possibly frugal hardware utilisation of digital applications and services (Santarius et al. 2022, p. 6). It includes software development practices that “reduce data volume and traffic and demand for computing power and that increase the service life of ICT hardware” (ibid., p. 6). While hardware sufficiency is mainly concerned with reducing the production of physical devices and infrastructures, software sufficiency focuses on decreasing their impact in terms of minimising data processing and transmission. In this regard, software sufficiency can be seen as both a parallel and a subordinated dimension to hardware sufficiency. From a technical perspective, computers and programs are barely separable. Still, there are several advantages when treating them as different dimensions not only from an analytical perspective but also when developing recommendations for two very different industries i.e. hardware and software sectors.

In **programming**, the most direct operational level in software development, determining factors for data and processing requirements of software can already lie in the selection of an appropriate programming language. It has been empirically shown that for solving one and the same problem, energy demand can vary by factors of up to 80, depending on which programming language is used (Pereira et al. 2017). Adopting data-efficient techniques through respective cache policy and minimised data exchange can help to realise features with lower energy and resource demand (Murugesan 2022). Even though these measures mark efficiency gains, they can strengthen software sufficiency (at this point, software sufficiency as defined above seems to lack coherence with the overall term digital *sufficiency* to some degree). Still, choices in superordinate software design strongly influence the hardware requirements of software applications. There usually are **differently power-intense features**, for example, locally processed and web-based programme modules. The latter comes with online traffic, thus requiring energy for permanent up- and downloading of a web document instead of editing it offline. Precautious software development can increase control over features that are either particularly energy-intensive or expected to be used particularly frequently. Eco-efficient software reduces both energy consumption and hardware requirements (Blue Angel 2020) and thus serve software sufficiency. Users' preferences for less resource demanding devices, whilst accepting a reduced performance can be addressed by, for example, allowing software applications to adjust their behaviour to the power mode of a given device or operating system (Murugesan 2022) i.e. lowering performance or user options in favour of reduced computing capacity requirements.

In addition to programming, software can also be viewed from a **software system engineering perspective**. Here, software is treated in its context of hardware, users, and the system environment. Respective interactions between these elements have more or less direct software-governed sustainability impacts (Duboc et al. 2020). Decisions on software sufficiency are not made by coders but rather by software designers (Becker et al. 2016). Developers determine, for example, which functions are integrated, and which are omitted, how they are designed, and how much power users have to adjust them. Even graphical interfaces are part of the sufficiency toolset in specifying and implementing software requirements. Depending on their design, they can, for instance, serve to nudge people towards certain usage patterns (Gossen et al. 2022), which may be geared towards sufficiency in software engineering.

Not only technically necessary requirements have an influence on software sufficiency. Software providers can deliberately decide to delimit **authorised device models** depending on software performance outcomes. There have been cases of blocking installations of operating systems on computers with older processors and therefore preventing device neutrality. Here, older hardware is not seen as suitable because "performance or experience could be below par" (Parmar 2021). What becomes apparent is that software developers can decide which performance level should be acceptable for users. Taking into account that a specific computer operating system runs on billions of devices, and many of them within the EU (Krempl 2017), accumulated effects of such top-down decisions are not to underestimate. For this reason, it can be assumed that achieving sustainability goals does not only lie with hardware "but rather above all with the software" (Blue Angel 2020, p. 5).

Furthermore, software is comprised of "programs and associated documentation" (Sommerville 2007, p. 6). **Software documentation** should as well be examined from a software sufficiency perspective. Absolute data volumes and processing demands depend on coded specifications that are not always available to software users, administrators, and developers. If adjustments on the software side can increase the service life of devices, such opportunities should be made more transparent. This includes easily accessible information on user interfaces, software manuals, and code documentation for developers.

Another practice that can counteract sustainability in ICT is the application of **bloatware** i.e. irreversibly pre-installed software that is not necessary to run the system. Embedded firmware usually does not even provide a user interface, meaning that users "may not even be aware that there is any software involved at all" (Endres and Rombach 2003, p. 151). Software sufficiency is a good reminder to only make use of software to deliberately fulfil users' actual needs. In addition, it has become evident that many ex-works devices (hardware as originally delivered by producers or resellers) collect and transmit sensible data without asking for consent. For example, security researchers, who studied smartphones of more than 200 smartphone manufacturers have found this to be the case (Gamba et al. 2020). Pre-installed bloatware does not only consume energy; it is often incompatible with privacy rights and a potential security risk. Most users do not notice when a smartphone transmits, for example, lists of installed apps to hardware manufacturers (Hurtz 2019). Other actors that receive such data are, for example, network operators, advertisers, social network companies, and tracking service operators (Gamba et al. 2020). Considering that especially cheap devices are said to be impacted by such built-in data breaches adds justice implications to the use of ICT.

So-called software bloat i.e. a process whereby successive versions of a computer program becomes slower denotes a phenomenon that has been seen as a software-specific rebound effect. As argued by Kern et al. (2013, p. 8) the "availability of more powerful hardware in the near future relaxes software developers' efforts to produce highly efficient code." A typical result is software that is not optimised for saving computing capacities. Software development resources are rather invested into the provision of more features, faster delivery, etc. Consequently, increasing efficiency gains from hardware technologies can be reduced through software developments, thus offsetting possible absolute savings. In addition, software developments have an influence on hardware replacement rates so called **software induced hardware obsolescence** (Gröger and Herterich 2019; Albers 2021). For instance, the most frequent reason for replacing a smartphone in Germany is that owners become unsatisfied with the battery performance (Haas 2021, p. 6). According to a consumer survey, this experience triggers new purchases twice as often as the desire to own the newest model on the market (ibid.). It is very likely that in most cases replacements do not result from aged batteries but rather from increased energy demand of installed smartphone applications.

To sum up, software sufficiency can be addressed by several actors, for example, coders, software engineers, system engineers, and product owners. Various aspects such as deploying lean programming languages, making decisions on the design of individual features and documentations, and making use of sufficiency-oriented user settings can impact software sufficiency outcomes. Many relate directly to hardware sufficiency as software can influence requirements of devices and digital infrastructures.

4.2.3 User sufficiency: using digital technologies less and with a purpose

Digitally networked societies always come with far-reaching changes where "the opportunities and risks of ICT for sustainable consumption [are] … very closely interlinked" (BMUB 2018, p. 17). As described above, the social and environmental impacts of hardware, software, and their interplay in production and consumption processes are highlighted by partially 'hidden' physical processes (e.g. mining of rare resources and high energy consumption patterns). These processes are often not directly experienced by ICT users. Other impacts are more tangible, especially if they are linked to an intended function of a digital system or service. These functions can be changed to serve sufficiency.

User sufficiency is the dimension of digital sufficiency that draws attention to the use of digital products and services. According to Santarius et al. (2022, p. 8), user sufficiency enables users "to reduce their consumption needs while maintaining a decent quality of life". Hereby, special characteristics of ICT are harnessed to use digital applications as tools to facilitate sustainable lifestyles both online and offline. Although most online platforms for sufficiency-oriented business models and lifestyles are not well-known (Lange and Santarius 2020), there are examples, which facilitate user sufficiency by showing user options for on how to live a sustainable life. In addition, digital communication and coordination can reduce transaction costs between users and help them to compare sufficient lifestyle practices (Kenney and Zysman 2016). The global rise of digital platforms is largely attributable to this factor. Moreover, the coordination of sharing goods, delivering of spare parts, and gaining repair expertise can thus be coordinated much more effectively than in the analogue world. Supportive digital knowledge networks cross seemingly unlimited distances and make information available in real-time.

User sufficiency also covers frugal practices i.e. **reduced use of digital devices and services** where they do *not* promote sufficiency. Some digital applications are known for being especially energy intensive. One example is video streaming, which is used for entertainment purposes but also increasingly for remote work and education. Turning off webcams in video calls can save up to 96 % of CO_2 emissions and opting for lower rather than high-definition video streaming up to 86 % (Obringer et al. 2021). While choosing sufficient options (such as turning off webcams) can reduce the quality of user experience, savings are so significant that governing incentives should be considered. Users can be informed about, for example, the environmental impacts of opting for high-definition online videos. Providers of digital services can make users aware of the respective options and make these visible and understandable. In the light of existing systems that characterise most of today's digital economy, individual users require substantial empowerment to be *able* to use ICT more sufficiently.

The role of **marketing and advertising** is often controversially discussed in sufficiency debates. General stimulation of consumption through marketing and advertising can counter efforts for a reduction of absolute levels of demand. However, content marketing does not hamper sustainability per se. It can be actively used for both environmentally friendly products and sufficiency-promoting services. Providers may, for example, implement nudging mechanisms to influence short-term consumer decisions towards more sufficient aggregated outcomes (Gossen et al. 2022). While simple but effective measures such as graphical 'dark patterns' are often used against consumers (Bogenstahl 2019), they could just as well suggest sufficient alternatives to customers. Dark patterns are user interfaces, consciously designed to 'trick' users into behaviours that tend not to be in their own interest (ibid.). To use them for user sufficiency, online retailers could, for example, ask for a confirmation if orders appear to be redundant (such as one garment of several sizes) or if articles really need to be shipped as fast as technically possible.

Many modern software applications bear significant potential for progress in environmental and climate protection (Rolnick et al. 2019; Vinuesa et al. 2020; Kaack et al. 2021). Hopes of this kind usually build on the premise that the intended function of a software system directly serves a sustainability objective, say the pursuit of a Sustainable Development Goal (UN 2015). A software system can entail positive immediate sustainability impacts (Duboc et al. 2020). Sufficiency-promoting digital products and services are special cases of such applications and systems. The intensification of deploying, e.g. digital applications that enable sharing practices, reduce dispensable data traffic or facilitate repair work, marks a constituting aspect of user sufficiency.

To sum up, user sufficiency can influence both hardware and software sufficiency outcomes. It covers two main aspects: 1) digital ICT can be used for sufficiency in energy and resource consumption and 2) ICT is frugally used more generally. The latter aims at reducing environmental footprints and negative social impacts. The former addresses sufficiency potentials that are directly enabled by digital tools and products.

4.2.4 Economic sufficiency: shaping digital businesses for public good

Many of the currently prevailing digital business models make commercial use of mostly personal data by selling them to other businesses in the market and using it for individualised online advertisement (Christl 2017; Zuboff 2019). According to this logic, for example, a search engine that appears to be free to its users is paid indirectly through buying products at another point in time from another party than the search engine provider. The link between them is not directly visible to consumers but central to the business model the search engine provider relies on. Moreover, many of the most digital businesses strive for economic growth that can inherently oppose sufficiency principles.

Economic sufficiency relates to digitalisation through drawing attention to potential transformative changes of economies towards sufficient production and consumption systems (Santarius et al. 2022, p. 10). Such economic systems would foster desired business models towards sustainable production and consumption systems rather than mainly focus on economic growth. Business models in a sufficient digital economy are mainly dedicated to maintaining and creating public and common goods, whereby concentration of capital and market power would be subject to democratic regulation. Economic sufficiency is not directly linked to ICT, but rather the economies surrounding them. Considering that seven of the ten largest companies by market capitalisation primarily produce or provide digital consumer technologies based on soft- and hardware (Johnston 2022), the relevance of this dimension becomes apparent. Economic sufficiency draws attention to the surrounding conditions for competing economic activities in digitalisation. As illustrated in Figure 1, it can be interpreted as an overarching dimension that frames and influences the other three dimensions.

The digital economy is characterised by the **extraction and commercialisation of data sets and streams**. Most social networks, smartphone apps, games, news portals, email providers, etc. use personalised advertising technologies to make profits with apparently 'free' offers. In this sector, a small number of big-tech corporations hold enormous shares of market power, which allows them to use practices that can potentially be against their users' interests (Christl 2017; Zuboff 2019). In some cases, there are just no real alternatives. At the same time, they have evolved into some of the most engaged lobbying groups at the European level over the last years (Bank et al. 2021). In addition, media and research sectors have the risk of being dependent on large digital tech companies, which can be observed in different settings such as targeted funding, lobbying, and deplatforming (Köver and Dachwitz 2019; netzpolitik.org 2020; Kayser-Bril 2021). It is evident that the digital economy has not only driven innovation, growth, and perceived convenience in several fields. It has also produced winners and losers along the way.

A high prevalence of venture capital financing nurtures **growth-based business models**, which inherently put a strain on natural ecosystems. As a result, "many new digital services are primarily tailored to deliver high return on investments" (Santarius et al. 2022, p. 10). This logic tends to drive competition between short-term maximisation of dividends and long-term common interests. To change existing economic structures as inherent drivers of these dynamics, alternative business models that focus on quality of life rather than on market power, profit maximisation, and economic growth must catch on. Central actors in this endeavour include businesses, policy makers, civil society, and educators (Sandberg 2021). Business models based on economic sufficiency can be, for instance, cooperative and commons-based platforms, which are owned and governed by several actors and can therefore pursue alternative goals rather than mainly economic growth (Lange and Santarius 2020). Often through democratic and less profit-oriented structures, cooperatives are considered to bring further economic and social return, for example, as they can empower women, marginalised groups, and lower income classes (Schwettmann 2014).

It is a political governance task to create incentives and **support for sufficiency-oriented business** models. In addition to nurturing cooperation and the common good, economic boundary conditions that serve economic sufficiency must be linked to ICT-related rebound effects. Effective market-based instruments are, for example, the taxation of GHG emissions or respective certificate trading schemes to tackle emissions where most of them arise (European Council 2022). Such instruments could indirectly address the risk of producing and consuming even greater numbers of digital technologies. Moreover, economic sufficiency can draw attention to the deployment of ICT that does not exceed its purpose without consent. Consumer and privacy rights in the data economy must be strong enough to effectively limit data extraction, processing, and transmission.

To sum up, economic sufficiency frames and shapes hardware sufficiency, software sufficiency, and user sufficiency. It is aimed at designing economic activities in ways that deliberately prioritise sustainability goals towards the public and common good. As described by Santarius et al. (2022), digital sufficiency in its four dimensions can manifest in product design, business models, user behaviour, and economic structures with a common overarching goal of lowering absolute consumption of energy and resources. It thus includes an integrated view and a governance perspective on digitalisation.

5 Ways forward for digital sufficiency to foster a twin transition

The following section presents the results derived from the expert workshop and elaborates on some of its discussions. First, entry points for digital sufficiency into existing policy debates raised in workshop discussions are presented. Second, two entry points are deepened based on a subsequent literature review to further explore some of the interlinkages between the entry points and the concept of digital sufficiency.

5.1 Suggested entry points for digital sufficiency into policy debates

During the expert workshop, a representative of the EC argued that digital sufficiency could be a concept, which resonates with policy makers. Still, its relevance needs to be highlighted to make it appeal to a wide range of policy makers. This is deemed necessary to diffuse ideas linked to digital sufficiency more widely. Throughout the expert workshop, two overall arguments were made on how digital sufficiency can support a twin transition. In addition, different suggestions emerged on how entry points for digital sufficiency could be identified. Entry points are meant to link digital sufficiency to existing policy debates and highlight its relevance by demonstrating how it can support the EU's twin transition.

During the workshop, the participants created two overall arguments about how digital sufficiency supports digital and sustainability transformations: 1) digital sufficiency provides normative directions towards achieving societal and environmental goals and 2) digital sufficiency points to the need for system changes rather than individual responsibility. To point 1, workshop participants referred to different arguments that are being made linked to the twin transition. On the one hand, digitalisation is seen as supporting sustainability transformations where the support is mainly based on technological innovations and efficiency measures. On the other hand, digitalisation is considered to hamper steps towards sustainability, seeing, for example, how much energy and resources are being consumed. The participants argued that, within these perspectives, normative social and environmental goals linked to the twin transition are often missing. The EU's twin transition lacks clear societal visions or targets to be achieved. Even though the EC (2022b, p. 68) points out that green and digital transitions will bring about "radical changes" that are affecting "its citizens, its economy and its environment" (ibid.), ideas rarely discussed and envisioned on how a future digital world should look like, what should be achieved, and who should benefit from it. Here, digital sufficiency can provide new questions and answers about changing existing production and consumption practices and normative directions of the twin transition. Digital sufficiency has the potential to help **describing desired ends to the means 'digitalisation'**.

To point 2, workshop participants pointed out that in contrast to efficiency measures, digital sufficiency draws attention to not only optimisation but also replacement, avoidance, or intensification of practices. Digitalisation processes and their governance through the lens of digital sufficiency are guided by the overarching question of what is appropriate and necessary in order to reduce social and environmental impacts (or avoid them in the first place). During the workshop, participants emphasised that these questions cannot be answered by each person individually but must rather **take place at the systems level** based on rules and boundaries for digitalisation. Several participants pointed to digital business models that follow global market logics rather than adhering to the creation and maintenance of public and common goods. Digital sufficiency draws attention to the need of changing existing production and consumption systems and ways to shift economic activities away from growth paradigms. Policy instruments that facilitate the twin transition must be implemented together with images and visions that make such changes tangible. Digital sufficiency was seen as a concept that allows for developing targeted visions linked to a twin transition. Workshop participants widely agreed that the challenge the EU faces in light of digitalisation and sustainability nexuses cannot be addressed by lots of individuals (i.e. the responsibility of individuals) but require system changes. At the same time, the urgency and necessity of changing citizens' lifestyles was said to be something that needed to be addressed but also something that is extraordinarily challenging to achieve.

In addition to arguments of how digital sufficiency can support the EU's twin transition, participants suggested several entry points that could help digital sufficiency to enter existing policy debates. Digital sufficiency can assist in 1) dealing with energy security issues; 2) dealing with complex IT structures within businesses, 3) supporting more sustainable lifestyles, 4) increasing people's health and digital wellbeing, and 5) empowering European citizens. In the next paragraphs, each entry point is briefly introduced as discussed during the workshop.

Dealing with energy security as linked to digitalisation processes – As a currently high-ranking topic in Europe, energy security, i.e. the uninterrupted availability of energy sources at an affordable price, was suggested to be a relevant entry point for digital sufficiency in existing policy debates. The digital world is inseparable from electrical energy supply, considering its reliance on energy consuming facilities and processes. This reliance is strongly expected to increase (Andrae 2019; Freitag et al. 2021). The recent Ukraine crisis has drawn attention to energy security issues, including the EU countries' reliance on often unreliable energy imports and a changing energy mix. Increasing energy consumption due to digitalisation processes can therefore aggravate these energy security issues. Digital sufficiency draws attention to the need to reduce energy and resource consumption linked to digitalisation and therefore could potentially tackle some of the energy security issues, making it a possible entry point.

Dealing with complex IT structures within businesses – Some of the workshop participants mentioned that some businesses have major issues with what they experience to be complex IT systems in their organisations. Participants felt that this can be an additional entry point. Widening and deepening the digital infrastructure within organisations can create a connectivity that becomes challenging to manage and keep secure. Special skills become necessary to manage digital infrastructures. While ICT can increase efficiency gains, digital infrastructures often introduce additional maintenance and security requirements to businesses. It is not always clear if, for example, increased networking and automation is worth their outcome. Digital sufficiency and, here, decreasing the use of ICT could counter some of these existing challenges. In addition, advanced digitalisation within businesses typically produces potential targets for cyberattacks because digital services are networked and often online. Unbalanced trade-offs between digital upgrading and its manageability can turn into risks and consequently emerging costs that can become challenging to control. Digital sufficiency principles draw attention to the deployment of ICT where it is needed instead of where its introduction delimits hidden costs of rising complexity. Simple software applications and the frugal use of devices are the elements of digital sufficiency that take this into account.

Supporting more sustainable lifestyles – Deploying fewer digital devices, applications and infrastructures tends to minimise possible hardware redundancies and respective consumption of energy and resources. This entry point created some discussions between the participants during the workshop. On the one hand, some of the participants argued that using fewer digital technologies and applications can lower absolute negative social and environmental impacts linked to digitalisation. On the other hand, special fields of application such as critical supply chains and infrastructures, including servers and power systems depend on redundant system elements to ensure their resiliency. The discussion had no conclusion. Still, it was also argued that digital technologies can be deliberately used to foster sufficiency in consumption. As described in section 4.3, the need to address high consumption lifestyles is already discussed in political debates. For example, while four out of five German smartphone users state that sustainability would be a very important criterion for the acquisition of their next device (Haas 2021, p. 8), only 8 % use their smartphones for more than two years (ibid., p. 4). Mainstream digital devices do not often allow for longer use periods. In addition, the expected product lifetime as a criterion is often not available to people at the point of purchase. Digital sufficiency options can be addressed by policy makers by, for example, bringing in more stringent repair regulations, changing labels on products, for instance, introducing a product lifetime label, etc. Some of the measures have already been introduced by the EC but more stringent rules and regulations could still be developed and implemented. During the workshop, it was also acknowledged that the concept of digital sufficiency can be taken further than just reducing consumption levels, which still denotes a frequent understanding of the concept (see section 4.1). Sufficiency can also manifest in refusing or rethinking (Bocken et al. 2022).

Increasing people's health and digital wellbeing – Research studies have shown that people's relations with their digital devices such as smartphones in everyday life can be ambivalent and complex. Often dichotomous positions are being created, either heralding the value of digital devices, for example, creating more convenience in daily life, or stressing the dangers linked to their use (Ytre-Arne et al. 2020). Still, research has found that they can cause addictions, depression, anxieties, and various health concerns. Such debates can be used as an entry point for digital sufficiency. Digital sufficiency and, here, the conscious and reduced use of digital devices can therefore potentially increase people's health and wellbeing. Indeed, it has been shown that sufficiency measures have considerable positive impacts in this regard (Creutzig et al. 2022). Some of the workshop participants argued that digital sufficiency can also mean digital wellbeing. Here, digital sufficiency ideas are not centred around the design of digital technologies but rather linked to ideas of human wellbeing in the digital world.

Digital sufficiency can potentially empower European citizens – During the workshop, some of the participants argued that if people are surrounded by an appropriate (lower) number of digital devices and infrastructures, individual self-determination in the digital world could be increased. In addition, it was argued that there is a need for platform regulations, strengthened consumer rights, transparency of ICT system, and a greater participation of diverse actors in deciding on digitalisation processes. Moreover, it was pointed out that effective antitrust regulations (e.g. for breaking up firms that abuse market dominance) could dissolve existing power asymmetries in the digital sector and lead not only to more democratic and fairer markets but also to more sustainable and user-centric digital devices and services. Implementations of digital sufficiency principles could be a way to set clearer visions and goals to empower citizens in digital developments. For example, digital sufficiency draws attention to open software strategies and the publication of hardware manuals that make the design and functioning of digital applications and devices more transparent. User groups and developers thus can trace hardware and software designs and identify possible points to strengthen consumer rights.

In addition to the presented entry points, workshop participants argued that it is crucial to not only examine how much digitalisation is necessary or appropriate through the lens of digital sufficiency but also what kind of digital society people want to be part of within the EU. Sufficiency is often framed as the need or even compulsion to renounce consumption. Even though this is an aspect of digital sufficiency (see section 4), there is far more to it than the reduction of consumption. As highlighted by some of the participants, alternative practices exist, which cause lower sustainability impacts but maintain or improve people's quality of life.

5.2 Exploring selected thematic entry points for digital sufficiency

In the following two subsections, two entry points are explored in greater depth, based on a subsequent literature review, to further explore some of the interlinkages between the two entry points and the concept of digital sufficiency. The project team and workshop participants indicated what they felt were the two most promising entry points. These are: 1) dealing with energy security issues linked to digitalisation processes and 2) supporting more sustainable, digitally enabled lifestyles. Both entry points for digital sufficiency relate to aspects of societal resiliency and security on the one hand and social innovation, participation, and inclusion on the other hand.

5.2.1 Digital sufficiency as an opportunity to address energy security issues?

Energy security denotes the continuous supply of energy relative to overall energy demand (Winzer 2012). As a key policy issue, it demarks the supply of a basic public service that is meant to guarantee decent livelihoods for citizens and industries. Over the past months, due to the Ukraine crisis and the decision to become independent from Russian energy supplies until around 2030 (EC 2022a), calls to **address increasing energy security issues** have become more pressing in Europe. European energy mixes have been signified by import dependencies over time. From 1990 to 2019, the ratio of net imports to gross available amounts of energy developed from 50 % to 60.5 % (Eurostat 2022) with Russian imports accounting for 24.4 % of the total EU's energy demand (ibid.). In 2021, Russia delivered 15 billion m^3 of natural gas to the EU, which accounted for almost half of overall gas imports (IEA 2022).

Although the clash of interests between meeting the EU's energy demand and being less reliant on energy imports has been already discussed before the Ukraine crisis (Acevedo and Lorca-Susino 2021), the imperative to act has become much more urgent. As energy demand is a determining factor for energy consumption, answers do not have to lie exclusively in the energy sector. Hence, digital sufficiency is not the means to solve all existing energy security issues, still, it can play a role in **making Europe less reliant on energy imports** and advancing sustainable energy transitions across the EU (Colaço 2021). Possible means to address energy security issues are either reducing absolute demand or increasing absolute supply. The latter depends on domestic energy production and imports. As potentials for renewable energy production capacities in the EU are only slowly being accelerated, strategies for energy imports but also demand side measures should be considered. The ICT sector plays an increasing role in absolute energy consumption and thus can hardly be foregone. The dimensions of digital sufficiency show different options to (re)design it accordingly.

While creating new strategic partnerships could contribute to coping with possible energy security issues in the near and medium-term future, energy import dependencies do not decrease in that case but might rather shift to different types of coalitions that can turn out to be not less problematic than previous ones. Such partnerships highlight the need to consider **sufficiency measures, which can be aided by elements of digital sufficiency**. Measures consist of, for example, reduced energy consumption in manufacturing, subsidies for energy savings, and a rollout out of prepaid metering. Discussed policy instruments to reduce energy consumption are, for instance, the elimination of tax reliefs for manufacturing companies and energy savings through feed-in tariffs (Best et al. 2022). Respective measures can address also the digital sector. Maximum levels of energy consumption have started to be discussed as well since empirical evidence shows that there is no continuously stable correlation between energy consumption and wellbeing (Burke 2020). Still, regulatory instruments to reduce energy demand are rare (Zell-Ziegler et al. 2021).

Direct power consumption of ICT rose by 37 % between 2010 and 2019 (The Shift Project 2019), thus increasing energy security issues. Annually, 9 % of increases in total energy demand are attributable to digitalisation (The Shift Project 2020). Against this background, a stabilisation of current digital transitions towards a rather "unregulated and environmentally unaudited digital world" (Obringer et al. 2021, p. 1) with increasing ICT usage may aggravate both the global climate crisis and potentially upcoming energy crisis, stressing the need for sufficiency strategies, including digital sufficiency. Economic sufficiency measures can be suitable to address also increasing energy consumption because many dominant digital business models are currently based on continuous growth of data production, transmission, and processing (The Shift Project 2020), whereas digital sufficiency points to alternative business models and appropriate production and consumption of data. The decisive difference sufficiency perspectives are making here is that they question existing structures of consumption instead of incrementally optimising them for efficiency. **Sufficiency measures within energy, including digital sufficiency** could therefore become a concept that plays a role in dealing with Europe's energy security issues.

Energy security is an issue of increasing interest. Against the background of ICT's demand for energy, digital sufficiency can play a role in addressing potential scarcity. All digital sufficiency is linked to energy demand, i.e. energy consumption of software and hardware devices, user choices on what to consume and how much, and the economic framework that governs (digital) businesses. Reduced overall energy consumption of ICT increases energy security and thus serves a basic societal need. Implemented in practice, digital sufficiency can contribute to meaningful change that aims at the long-term objective of protecting livelihoods. It could highlight transition paths towards urgently needed absolute reduction of energy consumption and GHG emissions while enhancing energy security and strategic resiliency.

5.2.2 Digital sufficiency as a way to strengthen more sustainable consumption patterns?

Sustainable living has become an increasingly significant issue in our society. Over the last twenty years, a wide variety of research from the social and natural science has drawn attention to the consequences of high-consuming lifestyles on the environment (WCED 1987). In March 2022, the EC adopted a proposal for a directive on 'Empowering Consumers for the Green Transition' that is aimed at changing consumer practices to achieve the EGD's social and environmental goals. Similarly, in Germany, the 2030 Agenda for Sustainable Development was translated into the German Sustainability Strategy in 2016 and then concretised by the National Programme for Sustainable Consumption. The programme states that "technological solutions – concerning resources and energy efficiency, for example – play a role in sustainable consumption, as do sufficiency strategies and sustainable lifestyles" (BMUB 2018, p. 34). Sufficiency approaches to sustainable consumption aim to **target high-consuming lifestyles** by changing consumption patterns or reducing the consumption levels (Lorek and Fuchs 2013). A maximum level of consumption is set that is considered to be environmentally sustainable (Spangenberg 2014; Spengler 2016). The level might vary based on cultural and historical contexts. In addition, it has been pointed out that it does not include all groups of people and needs to be re-evaluated over time.

Digital economies and cultures can be targets of sufficiency strategies. Thinking about ways to support the twin transition through digital sufficiency might be a useful way forward in policy debates on sustainable consumption. **Digital technologies can support changes** in consumption patterns based on sufficiency approaches and vice versa. Such interlinkages between digital technologies and changes in consumption patterns can be enabled by both collaboration (e.g. Do-It-Together initiatives) and individualism (e.g. the use of digital technologies and tools to engage consumers to practice more sustainable consumption patterns) towards sustainable lifestyles (Jaeger-Erben et al. 2015; Fauchart et al. 2022). Sandberg (2021) developed a typology of consumption changes based on sufficiency approaches, identifying the following types: 1) absolute reductions (i.e. reduction in the quantity linked to how often and how long something is done such as driving a car – reduction of car journeys and their length); 2) modal shifts (i.e. changes of mode of consumption to consumption patterns with a lower environmental impact such as from driving to cycling); 3) product longevity (i.e. delaying the purchase of a replacement product such as a car or bicycle); and 4) sharing practices (i.e. sharing products where less resources are needed to less products being purchased and their efficient use such as car sharing practices).

Some digital technologies are designed to enable sustainable consumption through **sufficiency-orientated digital marketing** and sustainable consumption applications. Interviewing several sufficiency-orientated clothing companies, Gossen and Heinrich (2021) have found that digital technologies can allow for reaching a wider audience for such sufficiency campaigns and being able to effectively target consumers. This way, sufficient lifestyles can be facilitated for an increased number of sustainability-oriented lifestyles. In addition, the examined digital marketing practices by Gossen and Heinrich (2021) make it possible to have varying engagements with consumers from allowing for feedback on existing sufficiency ideas to spontaneous and personal communication about changing consumption patterns. Still, Frick et al. (2021, p. 15) have argued that "sufficiency norms, as well as sufficiency-promoting online contents, are currently too rare to play a role for consumption levels. It seems that refraining from consumption triggering material aspirations is more effective at fostering sufficiency than is the boosting of sufficiency-promoting online content".

In addition to sufficiency-orientated digital marketing, **mobile applications for sustainable consumption** are another form to enable sufficiency approaches towards sustainable consumption. Brauer et al. (2016) have identified 260 so called 'green' apps in several application stores. The most widespread application functions are the ones that provide knowledge and information, e.g. through footprint calculators or guides and manuals. In addition, they have found application functions for networking and collaboration (e.g. to organise food waste recycling) and interactive feedback systems (e.g. gamification of household energy consumption to make reductions). Applications often offer the advantage of being directly used in consumption situations via a barcode scan. They can therefore enable direct comparisons between participants and act as regular prompts for users. First and foremost, digital information is especially easy and fast to retrieve as long as it is provided in an adequate format. Feedback applications for energy consumption at home, such as smart metering, function in a similar way. However, it has been questioned whether these applications contribute to significant and long-term energy savings (Schultz et al. 2015; Malmodin and Coroama 2016). For overall outcomes it is crucial to consider what users do with the information derived from the applications, how they respond to it (or not), and for how long. Actual ICT usage patterns thus play a significant role for sufficiency and must be carefully taken into account to evaluate the impact of a digital product or service. More research is needed to understand these dynamics in order to support digital sufficiency.

Next to the use of digital technologies for sufficient lifestyles, **Do-It-Together initiatives and digital social innovation initiatives** have made use of digital technologies and tools – including collaborative online platforms, digital fabrication – to empower citizens to collaborate and tackle social and environmental challenges in fields ranging from health, energy and food to housing, manufacturing, mobility and more (Bria et al. 2015). Examples are digitally mediated groups such as *KoKonsum* in Germany, i.e. sharing communities, which share flats, cars, power tools, etc. via an online platform, and *BUND-Repair Café* in Germany, i.e. a Do-It-Together initiative, which offers a space and tools for people to repair their broken products with the help of amateur repairers so that they can keep and use their products for longer. Here, ICT is used to “facilitate the efficient mediation or exchange between users and providers” (Curtis and Lehner 2019, p. 8). Without digital tools, communication and transaction costs between participants could rise drastically. Digital technologies thus help individual citizens to pursue sufficiency-oriented practices and digital social innovation initiatives to replicate and diffuse more easily. Hardware devices and software can be made accessible to more individuals and groups from local neighbourhoods up to specialised CSOs engaged in digital and/or environmental domains.

Characteristics of Do-It-Together initiatives and digital social innovation initiatives are **distributed networks of things, people, and digital technologies** that mediate and maintain such networks and access, whereas ownership of products plays a minor role (Botsman and Rogers 2010). Still more recently, work has been carried out on the so called ‘dark side’ of some Do-It-Together initiatives and sharing communities that derives from socially and environmentally undesirable impacts of introducing ICT into sharing and doing together (e.g. Buhalis et al. 2020). For example, Frenken and Schor, (2019, p. 126) have found that “the alleged sustainability benefits of the sharing economy are, however, much more complex than initially assumed”. Sharing is considered to influence lessening the demand for new products, however, besides from car sharing there is no empirical evidence for this assumption. Light and Miskelly (2019) have argued that to be able to draw out the social and environmental benefits of such initiatives and communities, it is key to not only stress and work on the ‘how’, i.e. the facilitation of networks and platforms through digital means, but also the ‘why’, i.e. local social and environmental practices that are enabled through networking and sharing. In sum, Do-It-Together and digital social innovation approaches rely on factors of inclusion, participation and cooperation, which are not necessarily determined only by the degree of digital ICT employment but by social processes, conditions, and norms.

Digital technologies, applications and platforms have the potential to support sharing practices, keeping products for longer, and engage people in absolute consumption reduction practices, including ways to change their consumption patterns. Still, such ICT are not the panacea for sustainable consumption, seeing that notions of sustainability are not inherent in these technologies and communities. Digital sufficiency might therefore aid the process of enabling a twin transition that aids the process of moving towards more sustainable consumption patterns, seeing that it is not only about deploying digital technologies but also drawing attention to absolute reductions of consumption and reflecting on normative goals.

6 Policy recommendations for implementing digital sufficiency

The EC considers digitalisation as a precondition for reaching climate targets and enabling sustainable production and consumption patterns. The EGD has introduced several policy changes to enable a twin digital and green transition. Still, such twin transition is mainly advanced by developing technological innovation to maintain and decouple economic growth from energy and resource consumption. Digital sufficiency can broaden existing approaches whilst providing new perspectives on how to facilitate social and environmental benefits. The following policy recommendations are intended to draw attention to supporting steps towards including the concept of digital sufficiency in policy thinking across all four dimensions, hardware sufficiency, software sufficiency, user sufficiency, and economic sufficiency. The following two subsections present initial recommendations on how to start introducing digital sufficiency in the European and German twin transition.

6.1 Recommendations to EU policy makers

- **Raising awareness among policy makers at all levels about the significance of sufficiency-induced narratives in digitalisation to move towards a twin transition**

As part of the EGD, the EC considers digital technologies as a key enabler for achieving the sustainability goals, for example, through improving energy efficiency. However, much research finds that technology is only one factor in moving towards a twin transition in addition to reflecting upon how they are intertwined with practices of production and consumption. Digital sufficiency highlights that technologies alone cannot overcome sustainability challenges and directly addresses the need to decrease absolute levels of resource and energy demand from production and consumption. EU policy makers therefore benefit from engaging with existing literature on digital sufficiency and raising awareness of the concept in policy circles and beyond. A first step towards integrating these narratives could be the realisation of workshops at responsible Directorates-General (DG) such as 'Environment' (ENV) and 'Communications Networks, Content and Technology '(CNECT).

- **Supporting the development of digital innovations towards digitalisation as a public and common good**

Digital sufficiency draws attention to digital innovations that aim to nurture a public and common good beyond business models that first and foremost strive for growing market shares and capital accumulation. An example of such innovations are digital social innovations that seek to address sustainability issues, actively orienting technology towards social ends and focus on improving well-being. They can change the speed and scale of overcoming barriers to accessing resources, information, and support and improve networking between initiatives. In addition, digital social innovations can change the impact and perception of citizen participation by making ways to participate easier and less time consuming. Although the EC has recognised the key role of social innovation in sustainability transformations and has supported research on digital social innovation through its Horizon programmes, more could be done to design policies that support the diffusion and acceleration of digital social innovations.

- **Strengthening voices from civil society in the governance of the twin transition to be able to address diverse societal needs and sustainability challenges**

Diverse civil society groups and organisations can help make voices heard and promote more inclusive digital policies whilst working on issues linked to the twin transition. Moreover, they can advance the ethical use of digital technologies that often are still poorly understood. Such groups and organisations often experiment with ideas derived from digital sufficiency (such as repairing platforms and networks to lengthen product lifetimes). The important role of civil society within digitalisation has been recognised by a wide range of state and non-state actors, e.g. in the German 2021 coalition agreement (German Federal Government 2021). Although extensive EU digital policies have been recently developed, e.g. the Digital Markets Act (DMA), civil society involvements beyond policy consultation processes are rare. Future legislative procedures and implementation processes can be enhanced by creating more meaningful formats to take up and strengthen the voices of civil society in digital policy developments. As an initial step such formats could be discussed with civil society groups and organisations as part of a wider consultation process and focus groups (potentially carried by the EC's Joint Research Centre (JRC)).

6.2 Recommendations to German policy makers

The concept of digital sufficiency and its dimensions point to a set of key topics and issues that need to be further strengthened with policies for digitalisation. These are the role of civil society, repairability of products, data governance towards data volume reductions, new ways of organising and governing, and open standards for digital ecosystems. The following recommendations address some of these themes and show how German policy makers could advance them nationally with a view to influence European developments.

► **Widening the role of civil society within the German Digital Strategy, whilst finding formats to greater enable citizen participation in governance processes**

The German Digital Strategy (German Federal Government 2022) and coalition agreement have stressed the important role of civil society in shaping a digital society. Initiatives such as *Civic Coding* or *KI-Ideenwerkstatt für Umweltschutz* (i.e. AI workshop for environmental protection), where citizens can come together to develop ICT applications and other types of innovations for the public and common good are a great starting point to strengthen the voice of civil society within digitalisation. Such initiatives could be widened beyond AI, whilst including important issues of justice, solidarity, and access. In addition to creating additional research programmes and projects, UBA could pioneer initiatives such as workshops with diverse civil society groups to discuss and identify current challenges that impede an increasing role of civil society in existing governance process surrounding digitalisation. This could also help to improve the recognition of issues of justice, solidarity, and access in German and EU policy making around the twin transition.

► **Learning from the introduction of the repair bonus and index, whilst aiming to implement a national repair bonus system**

Repair bonuses and indexes have been introduced in the German region of Thuringia and nationally in Austria and France in 2022. The initial response to the bonus was high, with the potential result that broken products were repaired rather than discarded, extending their lifetime. To be able to learn from current experiences, the BMUV could launch research calls, aiming to better understand the potential impacts of such schemes and their governance. Such learning can then contribute to the national implementation of repair bonuses and indexes in Germany, while also incorporating considerations of obsolescence prevention, repairability, and reuse options for ICT products into the German Waste Prevention Programme. Such efforts could create a role for German policy makers to advocate for similar schemes in the EU alongside existing right-to-repair developments.

- **Accelerating and strengthening the significance of sufficiency criteria in European ecodesign labelling and regulation**

To expand environmental and climate protection by the existing EU Ecodesign Directive, the 2022 proposal for a new Ecodesign for Sustainable Products Regulation aims to provide a new framework for ecodesign requirements for most physical products in the EU single market. Next to energy and resource efficiency, it incorporates sufficiency-oriented product properties such as durability, reusability, repairability, maintainability, and possibilities of remanufacturing and recycling. In this context, the EC's Ecodesign and Energy Labelling Working Plan 2022-2024 aims to revise energy labels, introduce rules for smartphones and tablets, and explore options for a European repair score for these products. These initiatives in ICT product design and transparency are positive developments to hardware sufficiency and user empowerment that recognise more sustainability aspects than energy and resource efficiency. The BMUV could advise and accompany this process wherever possible in order to promote these efforts. With UBA's experience from the *Blue Angel* labelling of smartphones and tablets (considering e.g. disassembly, repair, component durability, and recycling requirements), active knowledge sharing and exchange with the JRC and relevant DGs could bring significant advance the EC's current engagement.

- **Promoting open standards for software products and platforms to tap the full potential of engaged software engineers and developers**

Software impacts on the sustainability of ICT must be deliberately governed towards social and environmental goals. This can include socially inclusive digital applications that enable sufficient practices or the use of software development principles that lower energy consumption and increase hardware obsolescence. However, software often faces technical and legal barriers to implementing innovative solutions into digital ecosystems that are dominated by restrictive competitors. With the DMA, the EU has recently granted users a right to remove pre-installed applications from their systems to strengthen individual freedom of choice and to give way to alternative options. As a next step, requirements of open standards (i.e. agreed technical specifications) would broaden access for developers and enable the provision of alternative applications. The 2022 German Digital Strategy pursues an obligation to use open standards within public administration, which can increase interoperability among digital applications and fair competition for their development. To improve market access for actors that prioritise sufficiency aspects, this demand needs a broader range of application than public administration. In order to achieve this, the BMUV, the Federal Ministry for Digital and Transport and the Ministry for Economic Affairs and Climate Action could first seek a common understanding and agreement on additional areas of application (e.g. government-funded development projects).

- **Setting up development of data governance models towards public and common good and climate protection in deeper consideration of data volume and traffic**

The European Data Governance Act is concerned with the governance of, for instance, data processing infrastructures, data sharing tools, and cloud infrastructures. Among other things, it aims to enable the idea of data altruism i.e. voluntary provision of data for the purpose of public good (see also the EU GreenData4All initiative). Such ideas should be supported, but are currently criticised for being to vaguely defined and overly regulated. Setting up real life laboratories led by civil society groups in Germany and financed by the German ministries that experiment with differing data governance business models might be a first step to better understand potentials of data altruism and its governance and creating definitions for its implementation. Findings derived from these labs could then be able to enhance future developments of the Data Governance Act within the EU. Currently, issues of the reduction of data volume and traffic demands are not part of the Data Governance Act. Experiments could therefore additionally look at ways to incorporate such reduction potentials in the future governance of data.

- **Supporting and recognising the role of digital platform cooperatives to move towards commons-based digitalisation and value-based platform economies**

Although platform cooperatives (e.g. *Supercoop* and *SMart*) have gained some national financial support, they are currently not recognised by the EU Observatory on the Online Platform Economy, the EU Digital Services Act, and the German Digital Strategy. Still, considering that platform cooperatives are employee-owned, democratically governed, and often pursue commons-based digitalisation goals, a recognition of these activities can support the German government's ambitions to create inclusive digital spaces for a more democratic and just society. Still, several barriers exist for platform cooperatives, including, for instance, creating financially sustainable business models and scaling up existing activities. Several European countries have created incubation and funding programmes specifically for platform cooperatives. German ministries could set up a similar programme to provide initial support for platform cooperatives that help to address existing sustainability challenges.

In conclusion of this study, digital sufficiency bears considerable potential to gain a new perspective on the twin transition that distributes efforts more broadly, namely rather on expedient corporate practices and social innovation than on technological innovation. Its implementation would incorporate principles of open and forward-thinking hardware and software design, sufficient digital practices, social justice, and wide citizen participation. Carrying them into EU policy could start off a renewed approach to digital and environmental policy design. For the goal of a digital economy and society that facilitates sufficient production and consumption as a complement to the many efficiency improvements that digital technologies can enable, the steps outlined above could promote sustainability both through and within digital transformation.

7 List of references

Acevedo, RA.; Lorca-Susino, M. (2021): The European Union oil dependency: a threat to economic growth and diplomatic freedom. International Journal of Energy Sector Management, Vol. 15 No. 5; pp. 987–1006. DOI: 10.1108/IJESM-10-2020-0010.

Albers, E. (2021): On the Sustainability of Free Software. Free Software Foundation Europe. https://fsfe.org/freesoftware/sustainability/sustainability.en.html. Viewed: 02.04.2022.

Alfredsson, E.; Bengtsson, M.; Brown, H. S.; Isenhour, C.; Lorek, S.; Stevis, D.; Vergragt, P. (2018): 'Why achieving the Paris Agreement requires reduced overall consumption and production'; Sustainability: Science, Practice and Policy, 14(1); pp. 1–5. DOI: 10.1080/15487733.2018.1458815.

Andrae, A. (2019): Comparison of Several Simplistic High-Level Approaches for Estimating the Global Energy and Electricity Use of ICT Networks and Data Centers. International Journal of Green Technology, 5(1); pp. 50–63. DOI: 10.30624/2414-2077.2019.05.06.

Bank, M.; Duffy, F.; Leyendecker, V.; Silva, M. (2021): Die Lobbymacht von Big Tech: Wie Google & Co die EU beeinflussen. LobbyControl. https://www.lobbycontrol.de/wp-content/uploads/Studie_de_Lobbymacht-Big-Tech_31.8.21.pdf

Becker, C.; Betz, S.; Chitchyan, R.; Duboc, L.; Easterbrook, SM.; Penzenstadler, B.; Seyff, N.; Venters, CC. (2015): Requirements: The Key to Sustainability. IEEE Software, 33(1); pp. 56–65. DOI: 10.1109/MS.2015.158.

Beining, L.; Bihr, P.; Heumann, S. (2020): Towards a European AI & Society Ecosystem. Stiftung Neue Verantwortung. https://www.stiftung-nv.de/de/publikation/towards-european-ai-society-ecosystem

Bengtsson, M.; Alfredsson, E.; Cohen, M.; Lorek, S.; Schroeder, P. (2018): Transforming systems of consumption and production for achieving the sustainable development goals: moving beyond efficiency. Sustainability Science, 13(6); pp. 1533–1547. DOI: 10.1007/s11625-018-0582-1.

Benton, D.; Coats, E.; Hazell, J. (2015): A circular economy for smart devices - Opportunities in the US, UK and India. Green Alliance. https://green-alliance.org.uk/wp-content/uploads/2021/11/A-circular-economy-for-smart-devices.pdf

Best, B.; Thema, J.; Zell-Ziegler, C.; Wiese, F.; Barth, J.; Breidenbach, S.; Nascimento, L.; Wilke, H. (2022): Building a database for energy sufficiency policies. F1000 Research, 11, 229. DOI: 10.12688/f1000research.108822.2.

Blue Angel (2020): Resource and Energy-Efficient Software Products: Basic Award Criteria. DE-UZ 215. Bonn: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Federal Environmental Agency, Environmental Label Jury, RAL gGmbH. https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ 215-202001-en-Criteria-2020-02-13.pdf

BMBF – Bundesministerium für Bildung und Forschung (German Federal Ministry of Education and Research) (2018): Ressourceneffiziente Kreislaufwirtschaft. Bonn: Bundesministerium für Bildung und Forschung (BMBF). https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/pdf/ressourceneffiziente-kreislaufwirtschaft.html

BMU – Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection) (2020): Digital Policy Agenda for the Environment. http://www.bmu.de/DL2444-1.

BMUB – Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety) (2018): National Programme on Sustainable Consumption - From Sustainable Lifestyles towards Social Change. Bonn: German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). https://www.bmu.de/en/publication/national-programme-on-sustainable-consumption/

Bocken, NMP.; Niessen, L.; Short, S. W. (2022): The Sufficiency-Based Circular Economy - An Analysis of 150 Companies. Frontiers in Sustainability, 3; 899289. DOI: 10.3389/frsus.2022.899298.

Bogenstahl, C. (2019): Dark Patterns – Mechanismen (be)trügerischen Internetdesigns. Institut für Technikfolgenabschätzung und Systemanalyse (ITAS). https://publikationen.bibliothek.kit.edu/1000133932

Bonvoisin, J. (2017): Limits of ecodesign: the case for open source product development. International Journal of Sustainable Engineering, 10(4–5); pp. 198–206. DOI: 10.1080/19397038.2017.1317875.

Börjesson Rivera, M.; Håkansson, C.; Svenfelt, Å.; Finnveden, G. (2014): Including second order effects in environmental assessments of ICT. Environmental Modelling and Software, 56; pp. 105-115. DOI: 10.1016/j.envsoft.2014.02.005.

Botsman, R.; Rogers, R. (2010): What's Mine Is Yours: The Rise of Collaborative Consumption. New York: Harper Business.

Brauer, B.; Ebermann, C.; Hildebrandt, B.; Remane, G.; Kolbe, L. (2016): Green by App: The Contribution of Mobile Applications to Environmental Sustainability. In. PACIS 2016 Proceedings. https://aisel.aisnet.org/pacis2016/220.

Bria, F.; European Commission; Directorate General for the Information Society and Media; Digital Social Innovation; Nesta; The Waag Society; ESADE; IRI; FutureEverything (2015): Growing a digital social innovation ecosystem for Europe: DSI final report. Luxembourg: Publications Office. https://ec.europa.eu/futurium/en/system/files/ged/50-nesta-dsireport-growing_a_digital_social_innovation_ecosystem_for_europe.pdf

Brisbois, MC. (2022): Climate change won't wait for future innovation - we need action now. Nature, 603(7899); pp. 9. DOI: 10.1038/d41586-022-00560-2.

Buhalis, D.; Andreu, L.; Gnoth, J. (2020): The dark side of the sharing economy: Balancing value co-creation and value co-destruction. Psychology & Marketing, 37(5); pp. 689–704. DOI: 10.1002/mar.21344.

Burke, MJ. (2020): Energy-Sufficiency for a Just Transition: A Systematic Review. Energies, 13(10); 2444. DOI: 10.3390/en13102444.

Christl, W. (2017): Corporate Surveillance in Everyday Life - How Companies collect, combine, analyze, trade and use Personal Data on Billions. Cracked Labs. https://crackedlabs.org/dl/CrackedLabs_Christl_CorporateSurveillance.pdf.

Clausen, J.; Niebel, T.; Hintemann, R.; Schramm, S.; Axenbeck, J.; Iffländer, S. (2022): Klimaschutz durch digitale Transformation: Realistische Perspektive oder Mythos? CliDiTrans Endbericht. Berlin: Borderstep Institut. https://www.borderstep.de/wp-content/uploads/2022/01/AP4_CliDiTrans_Endbericht_20220202.pdf.

Coderre-Proulx, M.; Campbell, B.; Mandé, I. (2016): International Migrant Workers in the Mining Sector. Genf: International Labour Office (ILO), p. 83. https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---migrant/documents/publication/wcms_538488.pdf.

Colaço, I. (2021): Digital Sufficiency as a Principle for Energy Transition Policies. Ökologisches Wirtschaften - Fachzeitschrift, 36(O1); pp. 33–35. DOI: 10.14512/OEWO360133.

Coroama, V.; Mattern, F. (2019): Digital Rebound – Why Digitalization Will Not Redeem Us Our Environmental Sins. in Proceedings of the 6th international conference on ICT for Sustainability (ICT4S 2019). Lappeenranta, Finland: CEUR Workshop Proceedings. http://ceur-ws.org/Vol-2382/

Creutzig, F.; Niamir, L.; Bai, X.; Callaghan, M.; Cullen, J.; Díaz-José, J.; Figueroa, M.; Grubler, A.; Lamb, WF.; Leip, A.; Masanet, E.; Mata, É.; Mattauch, L.; Minx, JC.; Mirasgedis, S.; Mulugetta, Y.; Nugroho, SB.; Pathak, M.; Perkins, P.; Roy, J.; de la Rue du Can, S.; Saheb, Y.; Some, S.; Steg, L.; Steinberger, J.; Ürge-Vorsatz, D. (2022):

Demand-side solutions to climate change mitigation consistent with high levels of well-being. Nature Climate Change, 12(1); pp. 36–46. DOI: 10.1038/s41558-021-01219-y.

Curtis, S. K.; Lehner, M. (2019): Defining the Sharing Economy for Sustainability. Sustainability, 11(3); 567. DOI: 10.3390/su11030567.

Curtis, S. K.; Mont, O. (2020): Sharing economy business models for sustainability. Journal of Cleaner Production, 266; 121519. DOI: 10.1016/j.jclepro.2020.121519.

Duboc, L.; Penzenstadler, B.; Porras, J.; Koçak, SA.; Betz, S.; Chitchyan, R.; Leifler, O.; Seyff, N.; Venters, CC.; Akinli Kocak, S.; Betz, S.; Chitchyan, R.; Leifler, O.; Seyff, N.; Venters, CC. (2020): Requirements engineering for sustainability: an awareness framework for designing software systems for a better tomorrow. Requirements Engineering, 25(4); pp. 469–492. DOI: 10.1007/s00766-020-00336-y.

EC – European Commission (2019): The European Green Deal. European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2019:640:FIN.

EC – European Commission (2020): Making Europe’s businesses future-ready: A new Industrial Strategy for a globally competitive, green and digital Europe. Press release, 10 March. https://ec.europa.eu/commission/presscorner/detail/en/ip_20_416. Viewed: 29.06.2022.

EC – European Commission (2021): 2030 Digital Compass: the European way for the Digital Decade. European Commission. https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52021DC0118.

EC – European Commission (2022a): REPowerEU – Joint European Action for more affordable, secure and sustainable energy. Strasbourg. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2022:108:FIN.

EC – European Commission (2022b): Transitions Performance Index 2021- Towards fair and prosperous sustainability. Luxembourg: European Union. https://op.europa.eu/en/publication-detail/-/publication/50fff167-a34e-11ec-83e1-01aa75ed71a1/language-en

Endres, A.; Rombach, D. (2003): A Handbook of Software and Systems Engineering - Empirical Observations, Laws and Theories. Harlow: Pearson Education Limited.

European Council (2022): Fit for 55: how the EU plans to revise energy taxation. https://www.consilium.europa.eu/en/infographics/fit-for-55-energy-taxation/.

Eurostat (2022): EU energy mix and import dependency. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_energy_mix_and_import_dependency#EU_energy_dependency_on_Russia.

Fauchart, E.; Bacache-Beauvallet, M.; Bourreau, M.; Moreau, F. (2022): Do-It-Yourself or Do-It-Together: How digital technologies affect creating alone or with others?. Technovation, 112; 102412. DOI: 10.1016/j.technovation.2021.102412.

Federal Government of Germany (2022): Digital Strategy - Creating Digital Values Together (Translation). https://www.bmdv.bund.de/SharedDocs/EN/Documents/Press/pm-063-en-long-version.pdf.

Forti, V.; Baldé, CP.; Kuehr, R.; Gel, B. (2020): The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. Bonn/Geneva/Rotterdam: United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA). https://ewastemonitor.info/gem-2020/. Viewed: 04.07.2022.

Freitag, C.; Berners-Lee, M.; Widdicks, K.; Knowles, B.; Blair, GS.; Friday, A. (2021): The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations. Patterns, 2(9); 100340. DOI: 10.1016/j.patter.2021.100340.

Frenken, K.; Schor, J. (2019): Putting the sharing economy into perspective. In: A research agenda for sustainable consumption governance. Edward Elgar Publishing.

Frick, V.; Matthies, E.; Thøgersen, J.; Santarius, T. (2021): Do online environments promote sufficiency or overconsumption? Online advertisement and social media effects on clothing, digital devices, and air travel consumption. Journal of Consumer Behaviour, 20(2); pp. 288–308. DOI: 10.1002/cb.1855.

Gamba, J.; Rashed, M.; Razaghpanah, A.; Tapiador, J.; Vallina-Rodriguez, N. (2020): An Analysis of Pre-installed Android Software. In: The 41st IEEE Symposium on Security and Privacy. San Francisco: IMDEA Networks Institute. http://eprints.networks.imdea.org/1959/.

German Federal Government (2021): Koalitionsvertrag 2021 (German 2021 coalition agreement). https://www.bundesregierung.de/breg-de/aktuelles/koalitionsvertrag-2021-1990800.

German Federal Government (2022): Digital Strategie der Bundesregierung (German Digital Strategy). https://digitalstrategie-deutschland.de/. Viewed: 17.10.2023.

GeSI – Global Enabling Sustainability Initiative (2020): Digital Solutions for Climate Action. Brussels: Global Enabling Sustainability Initiative. https://gesi.org/research/download/52.

Gossart, C. (2015): Rebound Effects and ICT: A Review of the Literature. In: Hilty, LM. and Aebischer, B. (eds) ICT Innovations for Sustainability. Cham: Springer International Publishing (Advances in Intelligent Systems and Computing), pp. 435-448.

Gossen, M.; Frick, V.; Kettner, SE. (2022): Digitale Vermarktungsstrategien – Relevanz und Einfluss auf nachhaltigen Konsum. Umweltbundesamt, 41.

Gossen, M.; Heinrich, A. (2021): Encouraging consumption reduction: Findings of a qualitative study with clothing companies on sufficiency-promoting communication. Cleaner and Responsible Consumption, 3; p. 100028. DOI: 10.1016/j.clrc.2021.100028.

Greening, LA.; Greene, DL.; Difiglio, C. (2000): Energy efficiency and consumption – the rebound effect – a survey. Energy Policy, 28(6); pp. 389-401. DOI: 10.1016/S0301-4215(00)00021-5.

Gröger, J.; Herterich, M. (2019): Obsoleszenz durch Software - Wie wir digitale Geräte länger am Leben halten können. In: Höfner, A. and Frick, V. (eds) Was Bits und Bäume verbindet - Digitalisierug nachhaltig gestalten. München: Oekom, pp. 24–27. https://www.oekom.de/buch/was-bits-und-baeume-verbindet-9783962381493.

Haas, M. (2021): Smartphone-Markt: Konjunktur und Trends. Berlin: bitkom. https://www.bitkom.org/Presse/Presseinformation/35-Milliarden-Euro-Umsatz-rund-um-Smartphones. Viewed: 27.06.2022.

Hardware for Future (2022): Hardware for Future. Leipzig. https://hardwareforfuture.de/. Viewed: 22.07.2022.

Hilty, LM.; Lohmann, W.; Huang, E. (2011): Sustainability and ICT – an overview of the field. Politeia, 27(104); pp. 13–28. DOI: 10.5167/uzh-55640.

Hilty, LM.; Aebischer, B. (2015): ICT for Sustainability: An Emerging Research Field. in Hilty, L. M. and Aebischer, B. (eds) ICT Innovations for Sustainability. Cham, CH: Springer International Publishing, pp. 3-36. DOI: 10.1007/978-3-319-09228_1.

Hilty, LM.; Arnfalk, P.; Erdmann, L.; Goodman, J.; Lehmann, M.; Wäger, PA. (2006a): The relevance of information and communication technologies for environmental sustainability - A prospective simulation study. Environmental Modelling & Software, 21; pp. 1618-1629. DOI: 10.1016/j.envsoft.2006.05.007.

Hilty, LM.; Köhler, A.; Von Schéele, F.; Zah, R.; Ruddy, T. (2006b): Rebound effects of progress in information technology. Poiesis & Praxis, 4(1); pp. 19-38. DOI: 10.1007/s10202-005-0011-2.

Hintemann, R. (2018): Effizienzgewinne reichen nicht aus: Energiebedarf der Rechenzentren steigt weiter deutlich an. Berlin: Borderstep Institut für Innovation und Nachhaltigkeit gGmbH. https://d-nb.info/1215359780/34

Hong, SH.; Oreszczyn, T.; Ridley, I. (2006): The impact of energy efficient refurbishment on the space heating fuel consumption in English dwellings. Energy and Buildings, 38(10); pp. 1171-1181. DOI: 10.1016/j.enbuild.2006.01.007.

Hurtz, S. (2019): Wer ein billiges Handy kauft, zahlt mit seinen Daten. Süddeutsche Zeitung. https://www.sueddeutsche.de/digital/android-smartphone-datenschutz-xiaomi-tracking-1.4716518. Viewed: 06.07.2022.

IEA – International Energy Agency (2022): A 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas. International Energy Agency. https://www.iea.org/reports/a-10-point-plan-to-reduce-the-european-unions-reliance-on-russian-natural-gas.

IPCC (2022): Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Itten, R.; Hischier, R.; Andrae, ASG.; Bieser, JCT.; Cabernard, L.; Falke, A.; Ferreboeuf, H.; Hilty, LM.; Keller, RL.; Lees-Perasso, E.; Preist, C.; Stucki, M. (2020): Digital transformation - life cycle assessment of digital services, multifunctional devices and cloud computing. The International Journal of Life Cycle Assessment, 25(10); pp. 2093-2098. DOI: 10.1007/s11367-020-01801-0.

Jaeger-Erben, M.; Rückert-John, J.; Schäfer, M. (2015): Sustainable consumption through social innovation: a typology of innovations for sustainable consumption practices. Journal of Cleaner Production, 108; pp. 784-798. DOI: 10.1016/j.jclepro.2015.07.042.

Johnston, M. (2022): Biggest Companies in the World by Market Cap. Investopedia, 4 March. https://www.investopedia.com/biggest-companies-in-the-world-by-market-cap-5212784. Viewed: 04.07.2022.

Jones, M. (2022): Civil Society and AI: Striving for ethical governance. Digital Society Blog, 1 March. https://www.hiig.de/en/civil-society-and-ai-striving-for-ethical-governance/. Viewed: 02.11.2022.

Kaack, L.; Donti, P.; Strubell, E.; Kamiya, G.; Creutzig, F.; Rolnick, D. (2021): Aligning artificial intelligence with climate change mitigation. Nature Climate Change, 1-10. https://hal.archives-ouvertes.fr/hal-03368037.

Kayser-Bril, N. (2021): Wie Big Tech europäische Politik, Presse und Forschung umgarnt und bedrängt. AlgorithmWatch, 23 August. https://algorithmwatch.org/de/big-tech-einfluss-europa/. Viewed: 20.07.2022.

Kenney, M.; Zysman, J. (2016): 'The Rise of the Platform Economy'; Issues in Science and Technology, 32(3); pp. 61–69.

Kern, E.; Dick, M.; Naumann, S.; Guldner, A.; Johann, T. (2013): Green Software and Green Software Engineering - Definitions, Measurements, and Quality Aspects. In: Hilty, LM., Aebischer, B., Andersson, G., and Lohmann, W. (eds) ICT4S – ICT for Sustainability. Zürich: ETH Zürich, pp. 87–94.

Köver, C.; Dachwitz, I. (2019): Ein Geschenk auf Raten. netzpolitik.org, 18 December. https://netzpolitik.org/2019/ein-geschenk-auf-raten/. Viewed: 06.07.2022.

Krempl, S. (2017): EU-Experten warnen: Abhängigkeit von Microsoft gefährdet die digitale Souveränität. heise online. https://www.heise.de/newsticker/meldung/EU-Experten-warnen-Abhaengigkeit-von-Microsoft-gefaehrdet-die-digitale-Souveraenitaet-3679559.html. Viewed: 06.07.2022.

Lange, S.; Pohl, J.; Santarius, T. (2020): Digitalization and energy consumption. Does ICT reduce energy demand?. Ecological Economics, 176; 106760. DOI: 10.1016/j.ecolecon.2020.106760.

Lange, S.; Santarius, T. (2020): Smart Green World? - Making Digitalization Work for Sustainability. Routledge, Abington, New York. DOI: 10.4324/9781003030881.

Lange, S.; Santarius, T.; Zahrndt, A. (2019): Von der Effizienz zur digitalen Suffizienz - Warum schlanke Codes und eine reflektierte Nutzung unerlässlich sind. in Was Bits und Bäume verbindet - Digitalisierung nachhaltig gestalten. Oekom. https://www.oekom.de/buch/was-bits-und-baeume-verbindet-9783962381493.

Light, A.; Miskelly, C. (2019): Platforms, Scales and Networks: Meshing a Local Sustainable Sharing Economy. Computer Supported Cooperative Work (CSCW), 28(3); pp. 591-626. DOI: 10.1007/s10606-019-09352-1.

López Dávila, M.; Luth Richter, J.; Dalhammar, C.; Mikolajczak, C.; Schweitzer, J.-P. (2021): Removable, replaceable and repairable batteries. International Institute for Industrial Environmental Economics (IIIEE), European Environmental Bureau (EEB). https://eeb.org/library/battery-repair-report/.

Lorek, S.; Fuchs, D. (2013): Strong sustainable consumption governance – precondition for a degrowth path?. Journal of Cleaner Production, 38; pp. 36-43. DOI: 10.1016/j.jclepro.2011.08.008.

Mahaux, M.; Heymans, P.; Saval, G. (2011): Discovering Sustainability Requirements: An Experience Report. in Proceedings of the 17th International Working Conference on Requirements Engineering: Foundation for Software Quality (REFSQ 2011), 28-30 March 2011. Essen, Germany: Springer-Verlag Berlin/Heidelberg, pp. 19–33. DOI: 10.1007/978-3-642-19858-8_3.

Malmodin, J.; Coroama, V. (2016): Assessing ICT's enabling effect through case study extrapolation — The example of smart metering. in Proceedings of the Electronics Goes Green 2016+ (EGG), 6-9 September 2016. Berlin: IEEE, pp. 1-9.

Malmodin, J.; Lundén, D. (2018): The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010–2015. Sustainability, 10(9); 3027. DOI: 10.3390/su10093027.

Manhart, A.; Vogt, R.; Priester, M.; Dehoust, G.; Auberger, A.; Blepp, M.; Dolega, P.; Kämper, C.; Giegrich, J.; Schmidt, G.; Kosmol, J. (2019): The environmental criticality of primary raw materials — a new methodology to assess global environmental hazard potentials of minerals and metals from mining. Mineral Economics, 32(1); pp. 91-107. DOI: 10.1007/s13563-018-0160-0.

Marschneider-Weidemann, F.; Langkau, S.; Hummen, T.; Erdmann, L.; Espinoza, L. T.; Angerer, G.; Marwede, M.; Benecke, S. (2016): Rohstoffe für Zukunftstechnologien 2016. Berlin: Fraunhofer ISI & Bundesanstalt für Geowissenschaften und Rohstoffe. https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccn/2016/Studie_Zukunftstechnologien-2016.pdf

Mont, O.; Palgan, YV.; Bradley, K.; Zvolska, L. (2020): A decade of the sharing economy: Concepts, users, business and governance perspectives; Journal of Cleaner Production, 269; 122215. DOI: 10.1016/j.jclepro.2020.122215.

Murugesan, S. (2022): 10 Recommendations for Green Software Development; Green Software Foundation. https://greensoftware.foundation/articles/10-recommendations-for-green-software-development. Viewed: 27.05.2022.

netzpolitik.org (2020): Medienmäzen Google. netzpolitik.org. https://netzpolitik.org/tag/medienmaezen-google/. Viewed: 07.05.2022.

Niessen, L.; Bocken, NMP. (2021): How can businesses drive sufficiency? The business for sufficiency framework. Sustainable Production and Consumption, 28; pp. 1090-1103. DOI: 10.1016/j.spc.2021.07.030.

Obringer, R.; Rachunok, B.; Maia-Silva, D.; Arbabzadeh, M.; Nateghi, R.; Madani, K. (2021): The overlooked environmental footprint of increasing Internet use. Resources, Conservation and Recycling, 167; 105389. DOI: 10.1016/j.resconrec.2020.105389.

Ortega-Gras, JJ.; Bueno-Delgado, MV.; Cañavate-Cruzado, G.; Garrido-Lova, J. (2021): Twin Transition through the Implementation of Industry 4.0 Technologies: Desk-Research Analysis and Practical Use Cases in Europe. Sustainability, 13(24); 13601. DOI: 10.3390/su132413601.

Ozman, M.; Gossart, C. (2018): Digital Social Innovation: Exploring an Emerging Field. SSRN. https://papers.ssrn.com/abstract=3434363.

Parmar, M. (2021): Microsoft could lower CPU requirements for Windows 11. Windows Latest. https://www.windowslatest.com/2021/06/29/microsoft-could-lower-cpu-requirements-for-windows-11/. Viewed: 06.07.2022.

Penzenstadler, B.; Raturi, A.; Richardson, D.; Tomlinson, B. (2014): Safety, Security, Now Sustainability: The Nonfunctional Requirement for the 21st Century. IEEE Software, 31(3); pp. 40-47. DOI: 10.1109/MS.2014.22.

Pereira, R.; Couto, M.; Ribeiro, F.; Rua, R.; Fernandes, J. P.; Cunha, J.; Saraiva, J. (2017): Energy Efficiency across Programming Languages. in Proceedings of the International Conference on Software Language Engineering. Vancouver, Canada: Association for Computing Machinery, pp. 256-267. DOI: 10.1145/3136014.3136031.

Petschow, U.; aus dem Moore, N.; Pissarskoi, E.; Korfhage, T.; Lange, S.; Schoofs, A.; Hofmann, D. (2018): Gesellschaftliches Wohlergehen innerhalb planetarer Grenzen - Der Ansatz einer vorsorgeorientierten Postwachstumsposition. Umweltbundesamt. https://www.umweltbundesamt.de/publikationen/vorsorgeorientierte-postwachstumsposition

Princen, T. (2003): Principles for Sustainability: From Cooperation and Efficiency to Sufficiency. Global Environmental Politics, 3(1); pp. 33-50. DOI: 10.1162/152638003763336374.

Princen, T. (2005): The logic of sufficiency. Cambridge, MA: MIT Press.

Rolnick, D.; Donti, PL.; Kaack, LH.; Kochanski, K.; Lacoste, A.; Sankaran, K.; Ross, AS.; Milojevic-dupont, N.; Jaques, N.; Waldman-Brown, A.; Luccioni, A.; Maharaj, T.; Sherwin, ED.; Mukkavilli, SK.; Konrad, KP.; Gomes, C.; Ng, AY.; Hassabis, D.; Platt, JC.; Creutzig, F.; Chayes, J.; Bengio, Y. (2019): Tackling Climate Change with Machine Learning. Cornell University. https://arxiv.org/abs/1906.05433.

Sachs, W. (2015): Planet Dialectics: Explorations in Environment and Development. Bloomsbury Publishing.

Sachs, W.; Loske, R.; Linz, M. (1998): Greening the North: A Post-Industrial Blueprint for Ecology and Equity. Zed Books.

Salahuddin, M.; Alam, K.; Ozturk, I. (2016): The effects of Internet usage and economic growth on CO2 emissions in OECD countries: A panel investigation. Renewable and Sustainable Energy Reviews, 62; pp. 1226–1235. DOI: 10.1016/j.rser.2016.04.018.

Sandberg, M. (2021): Sufficiency transitions: A review of consumption changes for environmental sustainability. Journal of Cleaner Production, 293; 126097. DOI: 10.1016/j/jclepro.2021.126097.

Santarius, T. (2017): Digitalization, Efficiency and the Rebound Effect; degrowth, 16 February. https://degrowth.info/fr/blog/digitalization-efficiency-and-the-rebound-effect. Viewed: 14.07.2022.

Santarius, T.; Bieser, JCT.; Frick, V.; Höjer, M.; Gossen, M.; Hilty, LM.; Kern, E.; Pohl, J.; Rohde, F.; Lange, S. (2022): Digital sufficiency: conceptual considerations for ICTs on a finite planet. Annals of Telecommunications, pp. 1-19. DOI: 10.1007/s12243-022-00914-x.

Schneidewind, U.; Zahrnt, A.; Zahrnt, V. (2013): Damit gutes Leben einfacher wird: Perspektiven einer Suffizienzpolitik. 2nd edition. München: Oekom.

Schreiber, K.; Hickey, GM.; Metson, GS.; Robinson, BE.; MacDonald, GK. (2021): Quantifying the foodshed: a systematic review of urban food flow and local food self-sufficiency research. Environmental Research Letters, 16(2); 023003. DOI: 10.1088/1748-9326/abad59.

Schulte, P.; Welsch, H.; Rexhäuser, S. (2016): ICT and the Demand for Energy: Evidence from OECD Countries. Environmental and Resource Economics, 63(1); pp. 119-146. DOI: 10.1007/s10640-014-9844-2.

Schultz, PW.; Estrada, M.; Schmitt, J.; Sokoloski, R.; Silva-Send, N. (2015): Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms. Energy, 90; pp. 351-358. DOI: 10.1016/j.energy.2015.06.130.

Schwettmann, J. (2014): The Role of Cooperatives in Achieving the Sustainable Development Goals. Geneva, Switzerland: International Labour Office. http://ccr.ica.coop/sites/ccr.ica.coop/files/attachments/1.1 Jurgen Schwettmann.pdf.

SDA – Sustainability in the Digital Age (2020a): Digital Disruptions for Sustainability Agenda (D^2S Agenda): Research, Innovation, Action. Future Earth - Sustainability in the Digital Age. https://sustainabilitydigitalage.org/d2s-agenda/.

SDA – Sustainability in the Digital Age (2020b): The Montreal Statement on Sustainability in the Digital Age. Future Earth - Sustainability in the Digital Age. DOI: 10.5281/zenodo.7140314.

Smith, S. (2022): Right to Repair. European Parliament. European Parliament Research Service. https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/698869/EPRS_BRI(2022)698869_EN.pdf.

Sommerville, I. (2007): Software Engineering. 8th edn. Harlow, United Kingdom: Pearson Education Limited.

Sorrell, S.; Dimitropoulos, J. (2008): The rebound effect: Microeconomic definitions, limitations and extensions. Ecological Economics, 65(3); pp. 636–649. DOI: 10.1016/j.ecolecon.2007.08.013.

Spangenberg, JH. (2014): Institutional change for strong sustainable consumption: sustainable consumption and the degrowth economy. Sustainability: Science, Practice and Policy, 10(1); pp. 62–77. DOI: 10.1080/15487733.2014.11908125.

Spengler, L. (2016): Two types of "enough": sufficiency as minimum and maximum. Environmental Politics, 25(5); pp. 921–940. DOI: 10.1080/09644016.2016.1164355.

Tagesschau (2022): Mehr Tempo beim Recht auf Reparatur; tagesschau.de, 7 January. https://www.tagesschau.de/wirtschaft/verbraucher/recht-auf-reparatur-verbraucherschutz-nachhaltigkeit-elektroschrott-101.html. Viewed: 16.07.2022.

TeleGeography (2022): Submarine Cable Map. https://www.submarinecablemap.com/. Viewed: 16.06.2022.

The Shift Project (2019): Lean ICT - Towards Digital Sobriety. https://theshiftproject.org/en/article/lean-ict-our-new-report/

The Shift Project (2020): Implementing digital sufficiency. Executive Summary. https://theshiftproject.org/en/article/implementing-digital-sufficiency/

UN – United Nations (2015): Sustainable Development Goals; SDG Knowledge Platform. https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals. Viewed: 06.11.2021.

UNEP – United Nations Environment Programme (2015): Waste Crime – Waste Risks: Gaps in Meeting the Global Waste Challenge. Nairobi: United Nations Environment Programme. https://repub.eur.nl/pub/99476

Vinuesa, R.; Azizpour, H.; Leite, I.; Balaam, M.; Dignum, V.; Domisch, S.; Felländer, A.; Langhans, S. D.; Tegmark, M.; Fuso Nerini, F. (2020): The role of artificial intelligence in achieving the Sustainable Development Goals. Nature Communications, 11(1); pp. 1-10. DOI: 10.1038/s41467-019-14108-y.

Voigt, M. (2022): Nachhaltige Produkte: Wir müssen über geistiges Eigentum reden. netzpolitik.org. https://netzpolitik.org/2022/nachhaltige-produkte-wir-muessen-ueber-geistiges-eigentum-reden/. Viewed: 04.07.2022.

WCED – World Commission on Environment and Development (1987): Our Common Future. World Commission on Environment and Development. http://www.un-documents.net/our-common-future.pdf.

WEED – World Economy, Ecology & Development (2017): At the Other End of the Supply Chain – ICT brands' approaches to responsible minerals sourcing. (May). https://www2.weed-online.org/uploads/report_executive_summary_en.pdf.

Winzer, C. (2012): Conceptualizing energy security. Energy Policy, 46; pp. 36-48. DOIL 10.1016/j.enpol.2012.02.067.

Ytre-Arne, B.; Syvertsen, T.; Moe, H.; Karlsen, F. (2020): Temporal ambivalences in smartphone use: Conflicting flows, conflicting responsibilities. New Media & Society, 22(9); pp. 1715-1732. DOI: 10.1177/1461144820913561.

Zell-Ziegler, C.; Thema, J.; Best, B.; Wiese, F.; Lage, J.; Schmidt, A.; Toulouse, E.; Stagl, S. (2021): Enough? The role of sufficiency in European energy and climate plans. Energy Policy, 157; 112483. DOI: 10.1016/j.enpol.2021.112483.

Zuboff, S. (2019): Datenökonomie. Politik und Zeitgeschichte, 69(24–26). https://www.youtube.com/watch?v=DeaSxCN2uw8 (English version), Viewed: 06.07.2022.

Zuloaga, F.; Schweitzer, JP.; Anastasio, M.; Arditi, S. (2019): Coolproducts don't cost the Earth. Brussels: European Environmental Bureau. https://eeb.org/wp-content/uploads/2019/09/Coolproducts-report.pdf.