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Digital Degrowth – From Rebound to Regeneration

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Abstract: Digitalisation plays a central role in the transition to more sustainable futures. However, it also has negative impacts, such as rebound effects, significantly undermining digitalisation's efficiency gains. Digital degrowth is a relatively new concept in discourses on sustainable digitalisation. Building forth on the concept of degrowth, first proposed in 1972 and gaining strength in the past 20 years, digital degrowth refers to realigning digital technologies to become regenerative; ecological sound and socially just, while simultaneously contributing to resource efficiency in digitalisation efforts. This exploratory paper reflects on digital degrowth and the rebound effects of digitalisation.

Introduction

Digitalisation is the application and use of digital information and communication technologies and includes devices, data centres, and the digital infrastructures that make their communication and networking possible. Digitalisation is widely seen as central to the transition to a more sustainable economy. This is especially clear in discourses on the *twin transition*, the coupling between the digital transition and the green (energy) transition. The two transitions are seen as mutually influencing each other, while the digital transition is perceived as an important enabler of the green transition (Dæhlen, 2023; Lange & Santarius, 2022).

At the same time, digitalisation is contributing to a "technological sprawl", the proliferation of digital devices and the growing demand for cloud computing and data centres (Fix, 2024). Natural resource use continues to grow on average by more than 2.3% per year (United Nations Environment Programme, 2024). The increasing application of artificial intelligence (AI) is resulting in rising energy demands because of data centre power needs. There are doubts that even the so-called green data centres can access enough non-fossil energy on time to meet their demand (O'Brien, 2024).

Digitalisation is thought to increase resource use efficiency, but rebound effects undermine these efficiency gains. The most common understanding of the rebound effect is increased consumption due to products and services becoming cheaper because of more effective resource use.

Based on a literature review, Lange and Berner (2022) identified 21 rebound mechanisms and 14 of them resulted in increased growth and, as a result, increased energy consumption, while none resulted in negative growth. On an economy-wide level, the authors implemented an econometric study using EU data to quantify the change in energy consumption due to rebounds, the so-called *growth rebound effect* (GRE). They estimate the GRE to be between 20% and 47% but believe that it is likely much higher. They conclude that the only way to prevent rebound effects is to implement rebound-proof policies that would initiate a post-growth economy.

Post-growth and degrowth are central concepts in proposals to address the ecological impacts of our economic system in the Global North. Degrowth is not a call for less economic growth but for less throughput, i.e., less energy and resources, to bring "the economy back into balance with the living world in a way that reduces inequality and improves human well-being" (Hickel, 2021b, p. 1106).

Degrowth is proposed to address a variety of rebound effects (Lange & Berner, 2022; Schneider, 2008; Sutherland, 2022). Rebound effects, lower-than-expected gains from efficiency policies and strategies, are also the result of efficiency improvements in digital technologies, so-called digital rebound. This paper explores whether digital degrowth is proposed as a strategy to counter digital rebound effects.

Digital Rebound

In a review of various studies, Coroama and Mattern (2019) conclude that “one of the main flaws of existing assessments [of the environmental impact of digital technologies] is their disregard of rebound effects”. The concept of rebound was first mentioned in the context of coal in the 19th century and became known as the Jevon paradox, but has gained renewed attention in the 1980s and shows significant increase in research in the past 10 years (Lange et al., 2021). This has led to a deeper understanding of the different types of digital rebound effects.

Based on a literature review, Lange et al. (2021) developed a typology of rebound effects and mechanisms, consisting of four economic levels – *micro*, *meso*, *macro* and *global* – and two time frames – *short run and long run* (Lange & Berner, 2022). The effects can be direct or indirect:

- Direct rebound effect refers to the relationship between efficiency, price, and consumption. If the resource efficiency of a digital product increases, its price will decrease, which can lead to a rise in consumption. As a result, the efficiency gains are eroded by increased demand. For example, increased energy efficiency in blockchain hashing for bitcoin mining enabled miners to expand their operations tremendously (Fix, 2024). The Bitcoin mining network grew 90% in 2023 (CoinShares, 2024).

- Indirect rebound effects are the result of, for example, *consumer rebound*, savings from cost reductions enable more income to be spent on other products (Maxwell et al., 2011), *time rebound*, when the time saved through digitalisation is used on other resource-intensive activities (Coroamă & Pargman, 2020), and *skill rebound*, when digitalisation lowers the level of skill needed to perform an activity, making it accessible to larger groups of potential users who didn’t have the necessary skill before (Coroamă & Pargman, 2020).

Kunkel and Tyfield (2021) argue that digital rebound should also be explored as a sociopolitical process. For example, Santarius and Soland (2018) explore rebound effects from a behavioural science perspective and identify a *motivational rebound* mechanism: “an increase in energy service demand due to a change in consumer preferences that can be attributed to an increase in technological energy efficiency”.

While most of the research focuses on consumers and individual companies and microeconomic rebound mechanisms, mesoeconomic rebound focuses on how sectors and markets react to energy efficiency improvements (Santarius et al., 2018). What is called the *circular economy rebound* (Zink & Geyer, 2017) may fall under this category. Circular economy rebound is based on the understanding that repaired, used or refurbished digital products often don’t compete in the same market as new products. For example, refurbished mobile phones which are sold to consumers in the Global South who would otherwise not be able to buy a phone.

Macro-level economy-wide rebound research focuses on national economies while global rebound research focuses on the global economy. Globally, one can identify a m*aterial rebound*, which is the result of digital technologies becoming smaller, but more resource intensive, as well as an increased production and use (Santarius, 2017). In addition, the more efficient a device becomes in its digitalisation performance, the less efficient it becomes in its material resource use (Valero et al., 2021). The idea that digitalisation would lead to dematerialisation never materialised (Taffel, 2024).

In the period 2013-2023, the digital economy grew about three times faster than the total economy across OECD countries as a result of further digitalisation and use of artificial intelligence, with an average growth rate of 7.6% in 2023 (OECD, 2024). The UN Trade and Development report on the digital economy (2024) describes an up to a four-fold increase in minerals demand in the period 2020 – 2025. Resource extraction for minerals needed to meet the growing demand for low-carbon technologies, such as graphite, lithium and cobalt, could see a production increase by nearly 500 per cent by 2050 (ibid.).

Data extractivism, the massive extraction and commodification of user data by private companies, is another driver of the digital economy. The never-ending quest for more data, also termed data colonialism (Couldry &

Mejias, 2019) or surveillance capitalism (Zuboff, 2019), and the development and application of AI models to analyse and use the data, require the exponential growth of data centres and associated ICT systems and infrastructures, which will increase the demand for minerals, water, and energy. Castro et al. (2024) show that the increase in renewable energy production is insufficient to cover the increasing energy needs of digital data.

In the current economic system based on GDP-led economic growth, addressing digital rebound effects is not a priority. Decoupling economic growth from consumption is, therefore, a major challenge (Laurenti et al., 2016). Incremental innovation and different forms of obsolescence create an "engine of growth" and lead to what Laurenti et al. call a "consumption rebound effect".

Decoupling economic growth from natural resource use forms the basis of green growth policies, such as the EU's Green Deal and the UN's Sustainable Development Goals. Digitalisation is perceived as central to decoupling as its technologies provide increased efficiency in resource use. Research has pointed out the contradictions between 'green' and 'growth' (Lerpold & Sjöberg, 2023; Santarius et al., 2020; Ward et al., 2016). Research also shows that, until now, digitalisation has not decoupled economic growth from energy consumption (e.g., Lange et al., 2020; Ren et al., 2021; Salahuddin & Alam, 2016).

Degrowth

"How can the digital revolution be reconceptualised to serve a sufficiency revolution?" asks Santarius (2017). Sufficiency is a central aspect of degrowth and is conceptualised as both a means and an end. As an end, sufficiency is about "'enoughness' of human doings in relation to ecosystems—an end in itself and a means for sustainable consumption and production" (Jungell-Michelsson & Heikkurinen, 2022). Sufficiency as a means to combat rebound effects should be implemented on a collective and institutional level (Sachs & Santarius, 2013). Such sufficiency policies can be defined as "policies for less, lighter, slower, closer, and more personal modes of consumption and production (iii) to comply with planetary boundaries (i) while satisfying fundamental human needs (ii)" (Iten et al., 2024). In terms of economic growth, sufficiency thus results in less growth or no growth (Jungell-Michelsson & Heikkurinen, 2022). Sufficiency is called the missing ingredient for sustainable digitalization (Cologna et al., 2020). The concept of digital sufficiency is proposed to understanding how ICT can become part of the essential environmental transformation (Santarius et al., 2023)

Degrowth is "a planned reduction of energy and resource use designed to bring the economy back into balance with the living world in a way that reduces inequality and improves human well-being" (Hickel, 2021b, p. 1106). Hickel further specifies that degrowth is not about less GDP, but less energy and resource use. In that sense, degrowth is GDP-agnostic, but will often result in less GDP.

Degrowth was first mentioned in the 1972, by Austrian/French philosopher André Gorz (Kallis et al., 2015), in a discussion about the proposal for zero growth in the Club of Rome report (Meadows et al., 1972). Discourses on degrowth gained renewed strength in the past decennia (Escobar, 2015; Hickel, 2021a; Kallis, 2011; Kothari et al., 2014; Zoellick & Bisht, 2018).

The role of technology is perhaps the most controversial question in degrowth theory and practice and answers varies from primitivism to techno-optimism (Heikkurinen, 2018; Kerschner et al., 2018). Degrowth doesn't necessarily mean less technology. "[D]egrowth scholarship embraces technological change and efficiency improvements, to the extent (crucially) that these are empirically feasible, ecologically coherent, and socially just" (Hickel, 2023, p. 1).

Digital Degrowth and Digital Rebound

Digital degrowth is a more recent concept in discourses around sustainable digitalisation. Digital degrowth refers to degrowth specific to the digital economy or digital sector. According to España et al. (2023), digital degrowth can mean *degrowth of ICT*, the reduction of the production and consumption of ICT through, for example, repair and a ban on planned obsolescence or *ICT for degrowth*, the use of ICT to create degrowth in other sectors, for example, the use of ICT to facilitate the circular economy or to further dematerialisation.

Aanestad (2023) describes digital degrowth as “digital solutions that support continuous on earth […]. It requires a deeper awareness of the intricate relations of the web of life integral to holistic/systems perspectives” (p. 59). Kwet (2024) discusses digital degrowth in the context of digital colonialism and sees a connection between digital justice and environmental justice. The basis for Kwet’s digital degrowth proposal are *People Tech* and the ecosocialist *Digital Tech Deal*. People Tech is about the democratisation of technology and is based free software licenses and the interoperability of different applications. The Digital Tech Deal is based on a ten-point programme that “covers many of the core principles and objectives essential to averting tech-driven ecocide” (p. 212).

In *Strategies for Degrowth Computing*, Sutherland (2022) discusses several practical applications that will lead to less resource use while increasing efficiency. Rather than extending their lifespan, Sutherland looks at how digital technologies can be used more intensively. Sutherland gives the example of a shared distributed computer system of one million devices, faster than the top 100 supercomputer, that was able to simulate the Covid protein structure and its potential interaction with antiviral drugs without the need to produce new supercomputers.

Does digital degrowth address digital rebounds? An initial exploration of the literature on digital rebounds shows that eliminating certain technologies can prevent digital rebound effects. Sharma et al. (2023) discuss the role of digital design in rebound effects and propose to “undesign design”, e.g., prevent the certain use of a technology, limit the use of a technology, or eliminate a technology, to limit rebound effects. Also Selwyn (2023) discusses eliminating destructive technologies, such as cryptocurrency and blockchain, and so-called sustainable technologies that, because of their zero emissions promise, will result in market expansion. One of the alternatives Selwyn discusses is *permacomputing*, “which seeks to extend permaculture approaches into digital domains, thereby encouraging principles of re-use, repair, maintenance, non-waste, dramatic decreases in the use of artificial energy, and an interdependent and co-operative relationship with natural systems”.

Santarius (2017) discusses several digital rebound effects: material, economic, psychological, and structural, and concludes: “The only unambiguous way using digital technologies for sustainability reasons is not for pursuing greater efficiency, but for enabling greater *sufficiency* in human action and *degrowth* in material consumption”. In their discussion of digital rebound effects, Coroama and Mattern (2019) argue that these effects are not the result of technology but of economics and human behaviour. They present some examples in which digitalisation does not result in rebounds, such as a distributed conference using video-conferencing, which resulted in less CO_2 emissions than a conference in which everyone attended in person. The authors disagree with the conclusion of Santarius (2017) that digitalisation should only be used for enabling sufficiency and degrowth. They argue that more efficiency through digitalisation will result in less digital rebounds.

Discussion

Techno-optimism and technosolutionism are the main ideologies guiding sustainability policies and implementations. In addition, when it comes to digital technologies, a small group of tech companies, Alphabet, Amazon, Apple, Meta, Microsoft, Nvidia (chipmaker), Tesla, also called Big Tech, have become global monopolies. Their ever-increasing economic power enables control over resources, markets, and now also politics. It may be hard to see how digital degrowth alone, with its connotations of sufficiency and ecosocialism, could make enough inroads in current digitalisation policies to make a real difference. In order to break up tech monopolies and prohibit their surveillance capitalism, radical regulation of the tech sector is needed, as well as other measures, such as requirements for interoperability (Doctorow, 2024), sharing of data and computer power, and implementation of democratic processes for deciding what parts of a society or community would benefit from digitalisation. In addition, radical regulation of the design of the digital technologies can extend the lifetime of digital products. In particular, a ban on planned obsolescence and the design of durable products and systems need to be considered, as incentives to reuse, repair, and refurbishing, as the latter may trigger rebound effects

(Bisschop et al., 2022; Bubinek et al., 2025; Makov & Font Vivanco, 2018).

Digitalisation can result in more efficiency, but this leads to economic growth, which increases energy and material resource consumption. Is digitalisation possible without these rebound effects? The degrowth literature implicitly accepts digital degrowth as a remedy against digital rebounds. Digital degrowth is not about less digitalisation but a different digitalisation, one that is ecologically coherent and socially just (Hickel, 2023). Or as Aanestad writes, different kind of solutions that enable “reducing energy and material resource use while maintaining wellbeing and collective sufficiency” (p. 59). There is a growing amount of literature that provides alternative frameworks for technology and system designs that support such values (e.g., Heikkilä, 2021; Howson et al., 2021; Kerschner et al., 2018; Vetter, 2018; Zoellick & Bisht, 2018b). Further research is needed to understand how digital degrowth can enable sustainable digitalisation without rebound effects.

Concluding Remarks

Pansera et al. (2019) asked members of the Degrowth community to imagine wise and unwise futures of digitalisation in 2068. They summarised their findings as follows: “Key concerns of unwise futures include increasing disconnection of humans from the natural environment and from one another as individuals, the use of digital technology for optimising the allocation of scarce resources to the benefit of the wealthy few and authoritarian governance of technologies and life itself. Wise technological futures, in turn, allow people to freely access digital technologies that are convivial, just, environmentally sustainable and guided by democratic deliberation”.

I believe that wise technological futures need to be regenerative, consisting of “a system of technologies and strategies based on an understanding of the inner working of ecosystems that generates designs that regenerate socio-ecological wholes (i.e., generate anew their inherent capacity for vitality, viability, and evolution) rather than deplete their underlying life support systems and resources” (Mang & Reed, 2012, p. 116). Regenerative futures become possible if we embrace the interaction and the co-evolution of the human and natural worlds in a whole systems and living systems perspective.

However, having breached the 1.5° C. ceiling established by the Paris Accords (Peters, 2024) and an average material resource use growth of 2.3% per year (United Nations Environment Programme, 2024), we are on the path towards a very unwise future. To find ways to get off that path, I suggest we start asking the following questions to any, old or new, digitalisation project or digital technology design: Does it “(1) promotes justice; (2) restores reciprocity; (3) confers divisible or indivisible benefits; (4) favors people over machines; (5) whether its strategy maximises gain or minimises disaster; (6) whether conservation is favored over waste; and (7) whether the reversible is favored over the irreversible?” (Franklin, 1999, p. 126). Taking a systems perspective to address these questions is a good start on the path to regenerative technological futures.

References

Aanestad, M. (2023). Digital Degrowth – Beyond Solutionism. In M. R. Jones, A. S. Mukherjee, D. Thapa, & Y. Zheng (Eds.), *After Latour: Globalisation, Inequity and Climate Change* (Vol. 696, pp. 55–60). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-50154-8_6

Bisschop, L., Hendlin, Y., & Jaspers, J. (2022). Designed to break: Planned obsolescence as corporate environmental crime. *Crime, Law and Social Change*, *78*(3), 271–293. https://doi.org/10.1007/s10611-022-10023-4

Bubinek, R., Knaack, U., & Cimpan, C. (2025). Reuse of consumer products: Climate account and rebound effects potential. *Sustainable Production and Consumption*, *54*, 190–201. https://doi.org/10.1016/j.spc.2024.12.019

Castro, V., Georgiou, M., Jackson, T., Hodgkinson, I. R., Jackson, L., & Lockwood, S. (2024). Digital data demand and renewable energy limits: Forecasting the impacts on global electricity supply and sustainability. *Energy Policy*, *195*, 114404. https://doi.org/10.1016/j.enpol.2024.114404

CoinShares. (2024). *CoinShares Mining Report 2024*. https://coinshares.com/fr/resources/research/2024-mining-report/

Cologna, V., Creutzburg, L., & Frick, V. (2020). Sufficiency: The missing ingredient for sustainable digitalisation. *SocietyByte*, 6.

Coroamă, V. C., & Pargman, D. (2020). Skill rebound: On an unintended effect of digitalization. *Proceedings of the 7th*

International Conference on ICT for Sustainability, 213–219. https://doi.org/10.1145/3401335.3401362
Coroama, V., & Mattern, F. (2019). *Digital Rebound – Why Digitalization Will Not Redeem Us Our Environmental Sins*. 10. https://ceur-ws.org/Vol-2382/ICT4S2019_paper_31.pdf
Couldry, N., & Mejias, U. A. (2019). Data Colonialism: Rethinking Big Data's Relation to the Contemporary Subject. *Television & New Media*, *20*(4), 336–349. https://doi.org/10.1177/1527476418796632
Dæhlen, M. (2023). *The Twin Transition Century: The role of digital research for a successful green transition of society?* (No. 5). The Guild of European Research-Intensive Universities. https://boris.unibe.ch/184458/
Doctorow, C. (2024). *The Internet Con: How to seize the means of computation*. Verso.
Escobar, A. (2015). Degrowth, postdevelopment, and transitions: A preliminary conversation. *Sustainability Science*, *10*(3), 451–462. https://doi.org/10.1007/s11625-015-0297-5
España, S., Hulst, W., Jansen, N., & Pargmam, D. (2023). Untangling the Relationship Between Degrowth and ICT. *2023 International Conference on ICT for Sustainability (ICT4S)*, 1–12. https://doi.org/10.1109/ICT4S58814.2023.00010
Fix, B. (2024). *A Tour of the Jevons Paradox: How Energy Efficiency Backfires*. https://doi.org/10.59350/155kj-52e89
Franklin, U. (1999). *The real world of technology*. House of Anansi Press.
Heikkilä, V.-M. (2021). Permacomputing update 2021. *Viznut*. http://viznut.fi/textsen/permacomputing_update_2021.html
Heikkurinen, P. (2018). Degrowth by means of technology? A treatise for an ethos of releasement. *Journal of Cleaner Production*, *197*, 1654–1665. https://doi.org/10.1016/j.jclepro.2016.07.070
Hickel, J. (2021a). *Less is More: How Degrowth Will Save the World*. Penquin Group.
Hickel, J. (2021b). What does degrowth mean? A few points of clarification. *Globalizations*, *18*(7), 1105–1111. https://doi.org/10.1080/14747731.2020.1812222
Hickel, J. (2023, July 1). On Technology and Degrowth. *Monthly Review*. https://monthlyreview.org/2023/07/01/on-technology-and-degrowth/
Howson, P., Crandall, J., & Balaguer Rasillo, X. (2021). Digital degrowth innovation: Less growth, more play. *Political Geography*, *88*, 102415. https://doi.org/10.1016/j.polgeo.2021.102415
Iten, T., Seidl, I., & Pütz, M. (2024). Sufficiency policy: A definition, conceptual framework, and application to municipalities. *Sustainability Science*, *19*(5), 1709–1734. https://doi.org/10.1007/s11625-024-01534-1
Jungell-Michelsson, J., & Heikkurinen, P. (2022). Sufficiency: A systematic literature review. *Ecological Economics*, *195*, 107380. https://doi.org/10.1016/j.ecolecon.2022.107380
Kallis, G. (2011). In defence of degrowth. *Ecological Economics*, *70*(5), 873–880. https://doi.org/10.1016/j.ecolecon.2010.12.007
Kallis, G., Demaria, F., & D'Alisa, G. (2015). Introduction to 'Degrowth: A Vocabulary for a New Era' (2015) PDF. *Degrowth: A Vocabulary for a New Era*, 1–17.
Kerschner, C., Wächter, P., Nierling, L., & Ehlers, M.-H. (2018). Degrowth and Technology: Towards feasible, viable, appropriate and convivial imaginaries. *Journal of Cleaner Production*, *197*, 1619–1636. https://doi.org/10.1016/j.jclepro.2018.07.147
Kothari, A., Demaria, F., & Acosta, A. (2014). Buen Vivir, Degrowth and Ecological Swaraj: Alternatives to sustainable development and the Green Economy. *Development*, *57*(3), 362–375. https://doi.org/10.1057/dev.2015.24
Kunkel, S., & Tyfield, D. (2021). Digitalisation, sustainable industrialisation and digital rebound – Asking the right questions for a strategic research agenda. *Energy Research & Social Science*, *82*, 102295. https://doi.org/10.1016/j.erss.2021.102295
Kwet, M. (2024). *Digital Degrowth: Technology in the Age of Survival*. Pluto Press. https://www.plutobooks.com/9780745349879/digital-degrowth
Lange, S., & Berner, A. (2022). The growth rebound effect: A theoretical–empirical investigation into the relation between rebound effects and economic growth. *Journal of Cleaner Production*, *371*, 133158. https://doi.org/10.1016/j.jclepro.2022.133158
Lange, S., Kern, F., Peuckert, J., & Santarius, T. (2021). The Jevons paradox unravelled: A multi-level typology of rebound effects and mechanisms. *Energy Research & Social Science*, *74*, 101982. https://doi.org/10.1016/j.erss.2021.101982
Lange, S., Pohl, J., & Santarius, T. (2020). Digitalization and energy consumption. Does ICT reduce energy demand? *Ecological Economics*, *176*, 106760. https://doi.org/10.1016/j.ecolecon.2020.106760
Lange, S., & Santarius, T. (2022). *Digital Reset. Redirecting Technologies for the Deep*

Sustainability Transformation. Technische Universität Berlin. https://doi.org/10.14279/DEPOSITONCE-16187

Laurenti, R., Singh, J., Sinha, R., Potting, J., & Frostell, B. (2016). Unintended Environmental Consequences of Improvement Actions: A Qualitative Analysis of Systems' Structure and Behavior. *Systems Research and Behavioral Science*, *33*(3), 381–399. https://doi.org/10.1002/sres.2330

Lerpold, L., & Sjöberg, Ö. (2023). Decoupling and redistribution in realising the Sustainable Development Goals. In *Interlinkages between the Sustainable Development Goals* (pp. 16–36). Edward Elgar Publishing.

Makov, T., & Font Vivanco, D. (2018). Does the Circular Economy Grow the Pie? The Case of Rebound Effects From Smartphone Reuse. *Frontiers in Energy Research*, *6*. https://doi.org/10.3389/fenrg.2018.00039

Mang, P., & Reed, B. (2012). Regenerative Development and Design. In R. A. Meyers (Ed.), *Encyclopedia of Sustainability Science and Technology* (pp. 8855–8879). Springer. https://doi.org/10.1007/978-1-4419-0851-3_303

Maxwell, D., Owen, D., McAndrew, L., Muehmel, K., & Neubauer, A. (2011). *Addressing the rebound effect, a report for the European Commission DG Environment* (p. 133). European Commission DG ENV.

Meadows, D., Meadows, D., Randers, J., & Behrens, W. (1972). *The Limits to Growth: A report for the Club of Rome's project on the predicament of mankind*. Potomac Associates. https://clubofrome.org/publication/the-limits-to-growth/

O'Brien, I. (2024, September 15). Data center emissions probably 662% higher than big tech claims. Can it keep up the ruse? *The Guardian*. https://www.theguardian.com/technology/2024/sep/15/data-center-gas-emissions-tech

OECD. (2024). *OECD Digital Economy Outlook 2024 (Volume 1): Embracing the Technology Frontier*. OECD. https://doi.org/10.1787/a1689dc5-en

Pansera, M., Ehlers, M.-H., & Kerschner, C. (2019). Unlocking wise digital techno-futures: Contributions from the Degrowth community. *Futures*, *114*, 102474. https://doi.org/10.1016/j.futures.2019.102474

Peters, G. P. (2024). Is limiting the temperature increase to 1.5°C still possible? *Dialogues on Climate Change*, 29768659241293218. https://doi.org/10.1177/29768659241293218

Ren, S., Hao, Y., Xu, L., Wu, H., & Ba, N. (2021). Digitalization and energy: How does internet development affect China's energy consumption? *Energy Economics*, *98*, 105220. https://doi.org/10.1016/j.eneco.2021.105220

Sachs, W., & Santarius, T. (2013). *Rethink rather than rebound: A sufficiency revolution must precede the efficiency revolution*.

Salahuddin, M., & Alam, K. (2016). Information and Communication Technology, electricity consumption and economic growth in OECD countries: A panel data analysis. *International Journal of Electrical Power & Energy Systems*, *76*, 185–193. https://doi.org/10.1016/j.ijepes.2015.11.005

Santarius, T. (2017). *Digitalization, Efficiency and the Rebound Effect | degrowth.info*. https://www.degrowth.info/en/2017/02/digitalization-efficiency-and-the-rebound-effect/

Santarius, T., Bieser, J. C. T., Frick, V., Höjer, M., Gossen, M., Hilty, L. M., Kern, E., Pohl, J., Rohde, F., & Lange, S. (2023). Digital sufficiency: Conceptual considerations for ICTs on a finite planet. *Annals of Telecommunications*, *78*(5), 277–295. https://doi.org/10.1007/s12243-022-00914-x

Santarius, T., Pohl, J., & Lange, S. (2020). Digitalization and the Decoupling Debate: Can ICT Help to Reduce Environmental Impacts While the Economy Keeps Growing? *Sustainability*, *12*(18), Article 18. https://doi.org/10.3390/su12187496

Santarius, T., & Soland, M. (2018). How Technological Efficiency Improvements Change Consumer Preferences: Towards a Psychological Theory of Rebound Effects. *Ecological Economics*, *146*, 414–424. https://doi.org/10.1016/j.ecolecon.2017.12.009

Santarius, T., Walnum, H. J., & Aall, C. (2018). From Unidisciplinary to Multidisciplinary Rebound Research: Lessons Learned for Comprehensive Climate and Energy Policies. *Frontiers in Energy Research*, *6*. https://doi.org/10.3389/fenrg.2018.00104

Schneider, F. (2008). *Macroscopic rebound effects as argument for economic degrowth*. 1st Degrowth Conference for Ecological Sustainability and Social Equity,. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=7c4d1f92ea5e9d2cfb0a1d6c46dbca58ad4e1f0b

Selwyn, N. (2023). Digital degrowth: Toward radically sustainable education technology. *Learning, Media and Technology*, *0*(0), 1–14. https://doi.org/10.1080/17439884.2022.2159978

Sharma, V., Kumar, N., & Nardi, B. (2023). Post-growth Human–Computer Interaction. *ACM Trans. Comput.-Hum. Interact.*, *31*(1), 9:1-9:37. https://doi.org/10.1145/3624981

Sutherland, B. (2022, June 21). Strategies for Degrowth Computing. *Eighth Workshop on Computing within Limits 2022*. Eighth Workshop on Computing within Limits 2022, Virtual. https://doi.org/10.21428/bf6fb269.04676652

Taffel, S. (2024). Fantasies of dematerialization: (Un)sustainable growth and digital capitalism. In *Digital Technologies for Sustainable Futures*. Routledge.

UN Trade and Development. (2024). *Digital Economy Report 2024: Shaping an Environmentally Sustainable and Inclusive Digital Future*. United Nations. https://doi.org/10.18356/9789213589779

United Nations Environment Programme. (2024). *Global Resources Outlook 2024: Bend the Trend – Pathways to a liveable planet as resource use spikes* (p. 181). International Resource Panel. https://wedocs.unep.org/20.500.11822/44902

Valero, A., Valero, A., & Calvo, G. (2021). *The Material Limits of Energy Transition: Thanatia*. Springer International Publishing. https://doi.org/10.1007/978-3-030-78533-8

Vetter, A. (2018). The Matrix of Convivial Technology – Assessing technologies for degrowth. *Journal of Cleaner Production*, *197*, 1778–1786. https://doi.org/10.1016/j.jclepro.2017.02.195

Ward, J. D., Sutton, P. C., Werner, A. D., Costanza, R., Mohr, S. H., & Simmons, C. T. (2016). Is Decoupling GDP Growth from Environmental Impact Possible? *PLOS ONE*, *11*(10), e0164733. https://doi.org/10.1371/journal.pone.0164733

Zink, T., & Geyer, R. (2017). Circular Economy Rebound. *Journal of Industrial Ecology*, *21*(3), 593–602. https://doi.org/10.1111/jiec.12545

Zoellick, J. C., & Bisht, A. (2018). It's not (all) about efficiency: Powering and organizing technology from a degrowth perspective. *Journal of Cleaner Production*, *197*, 1787–1799. https://doi.org/10.1016/j.jclepro.2017.03.234

Zuboff, S. (2019). *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power* (1 edition). PublicAffairs.