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Critical Perspectives in Social Innovation 4:2026

THE MYTH OF GREEN IT

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Contents

Foreword

The *Critical Perspectives in Social Innovation* series of working papers is designed to provide rigorous and challenging analyses. The purpose of the series is to critically examine prevailing assumptions, practices, and narratives within social innovation. By bringing together academic research and practitioner insights, the series seeks to bridge the gap between theory and practice, encourage reflection, and support the development of a critically informed social innovation for a more equitable, inclusive, and sustainable world.

In this essay, Antonios (NYU & Fellow of CCSI) and Neil extend that mission by turning a critical lens onto one of the most influential narratives of our time: that technological progress, particularly when branded as "efficient," "innovative," or "green", will deliver sustainability and social benefit. This essay examines the problems of Green IT. A subsequent essay will outline how to tackle Green IT's worst excesses.

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Green Information Technology (Green IT) is often presented as the reconciliation of digital progress with environmental responsibility[1, 2]. It encompasses energy-efficient computing, lower-carbon data infrastructure, and initiatives to reduce e-waste and material extraction.

Yet the dominant Green IT narrative frequently relies on selective accounting: operational efficiency is emphasised while embodied emissions, extractive supply chains, and end-of-life harms are externalised[3, 4, 5] - often onto communities least responsible for the demand that drives them. For social innovators who embrace digital or AI solutions to social problems, our analysis should give pause for thought. In attempting to solve one set of problems we compound or create new ones.

In this essay we examine the myths and realities of Green IT by exploring three interrelated dimensions: (1) energy consumption, (2) recycling and resource management, and (3)

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[1] Mickoleit, A. (2010) *Greener and smarter: ICTs, the environment and climate change*. OECD Green Growth Papers, No. 2010/01. Paris: OECD Publishing. Available at: https://doi.org/10.1787/5k9h3635kdbt-en.

[2] Murugesan, S. (2008) 'Harnessing green IT: principles and practices', *IT Professional*, 10(1), pp. 24–33. Available at: https://doi.org/10.1109/MITP.2008.10.

[3] Fors, P., Kreps, D. and O'Brien, A. (2024) 'Green IT: The evolution of environmental concerns within ICT policy, research and practice', in T. Lynn, P. Rosati, D. Kreps and K. Conboy (eds.) *Digital Sustainability*. Palgrave Macmillan, pp. 25–48. Available at: https://doi.org/10.1007/978-3-031-61749-2_2.

[4] Bieser, J.C.T., Hintemann, R., Hilty, L.M. and Beucker, S. (2023) 'A review of assessments of the greenhouse gas footprint and abatement potential of information and communication technology', *Environmental Impact Assessment Review*, 99, article 107033, pp. 1–12. Available at: https://doi.org/10.1016/j.eiar.2022.107033.

[5] Ogunseitan, O.A. (2023) 'The environmental justice agenda for e-waste management', *Environment: Science and Policy for Sustainable Development*, 65(2), pp. 15–25. Available at: https://doi.org/10.1080/00139157.2023.2167457.

technology renewability through repair, longevity, and upgrading. For each of these, we outline our concerns with how current initiatives address environmental impacts and what hidden costs or unintended consequences persist. We argue that many green initiatives within IT are *symbolic* rather than *transformative,* serving more as signalling than substantive change.

In this essay we lay out the problems. In a forthcoming essay we will set out a framework grounded in lifecycle accountability, right-to-repair policies, and responsible sourcing, reframing Green IT as a social innovation agenda that embeds sustainability, justice, and systemic/institutional responsibility into technological practice.

Green Information Technology

Discourse on Green Information Technology (Green IT) provide narratives of hope through the reconciliation of technological advancement and economic growth with environmental stewardship[3, 6, 7]. The focus is on efforts to reduce the environmental and social impacts of the digital sector itself, not only the operational energy use of particular systems[8, 9]. This

[6] Berthon, P. and Donnellan, B. (2011) 'The Greening of IT: Paradox or promise?', *Journal of Strategic Information Systems*, 20(1), pp. 3–5. Available at: https://doi.org/10.1016/j.jsis.2011.02.001.

[7] Davidson, E.J., Vaast, E. and Wang, P. (2011) 'The Greening of IT: How discourse informs IT sustainability innovation', *2011 IEEE 13th Conference on Commerce and Enterprise Computing (CEC)*. Luxembourg-Kirchberg, Luxembourg, 5–7 September. IEEE Computer Society, pp. 421–427. Available at: https://doi.org/10.1109/CEC.2011.69.

[8] McMahon, K., Mugge, R. and Hultink, E.J. (2024) 'Overcoming barriers to circularity for internal ICT management in organizations: a change management approach', *Resources, Conservation and Recycling*, 205, article 107568. Available at: https://doi.org/10.1016/j.resconrec.2024.107568.

[9] Martin-Ortega, O., Outhwaite, O. and Rook, W. (2015) 'Buying power and human rights in the supply chain: legal options for socially responsible public procurement of electronic goods', *The International Journal of Human Rights,* 19(3), pp. 341–368. Available at: https://doi.org/10.1080/13642987.2015.1029295.

includes the design, procurement, operation, and disposal of devices, networks, data centres, and cloud services, as well as the software practices and organisational policies that shape demand for computing[10, 11].

We define Green IT as the development and adoption of practices, systems, and policies aimed at reducing the environmental impact of information technologies[2, 3]. Examples include energy-efficient data centres, cloud infrastructures, e-waste recycling programmes and circular economy initiatives. We consider Green IT to be a lifecycle challenge rather than a narrow operational one. The impacts extend from extraction and manufacturing through transport and use and on to end-of-life processing and waste governance[3].

Beneath the optimistic framing a more complex and troubling reality lies. The production, operation, and disposal of IT systems remain deeply resource-intensive and environmentally damaging. Data centres consume vast amounts of electricity, often derived from fossil-fuel-based grids, i.e., non-renewable energy sources[12, 13]. The mining and processing of critical minerals for electronics is frequently tied to ecologically destructive

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[10] Patón-Romero, J. D., Baldassarre, M. T., Rodríguez, M., Runeson, P., Höst, M. and Piattini, M. (2021) 'Governance and Management of Green IT: a Multi-Case Study', *Information and Software Technology*, 129, article 106414. Available at: https://doi.org/10.1016/j.infsof.2020.106414.

[11] Capra, E., Francalanci, C. and Slaughter, S.A. (2012) 'Is software "green"? Application development environments and energy efficiency in open source applications', *Information and Software Technology*, 54(1), pp. 60–71. Available at: https://doi.org/10.1016/j.infsof.2011.07.005.

[12] Rong, H., Zhang, H., Xiao, S., Li, C. and Hu, C. (2016) 'Optimizing energy consumption for data centers', *Renewable and Sustainable Energy Reviews*, 58, pp. 674–691. Available at: https://doi.org/10.1016/j.rser.2015.12.283.

[13] International Energy Agency (2025) *Energy and AI*. Paris: International Energy Agency. Available at: https://www.iea.org/reports/energy-and-ai (Accessed: 5 May 2026).

and exploitative practices[14]. At the end of the technology lifecycle, recycling programmes, while well-intentioned, often shift the burden of electronic waste to the Global South[15, 16], where informal and unsafe recycling exposes vulnerable communities to toxic hazards and entrenches environmental injustice.

Moreover, emerging technologies such as artificial intelligence (AI), blockchain, and large-scale cloud computing compound these issues[13, 17]. While they are often presented as "green", their underlying infrastructure frequently relies on energy sources, supply chains, and replacement cycles, that negate claimed environmental benefits. This disjuncture/tension between rhetoric and reality raises the question whether Green IT represents meaningful progress, a sophisticated form of greenwashing, or a pathway that, without structural change, is a fundamental threat to people and the planet. In the next sections we lay out the significant problems with Green IT today.

Energy consumption

A major focus of Green IT is reducing energy consumption and associated carbon emissions. Much of the industry's sustainability narrative rests on visible improvements in data centre operations such as renewable-energy procurement, more efficient cooling,

[14] Ali, S.H. (2014) 'Social and environmental impact of the rare earth industries', *Resources*, 3(1), pp. 123–134. Available at: https://doi.org/10.3390/resources3010123.

[15] Doyon, J.A. (2015) 'The international impact of electronic waste: a case study of Western Africa', in G. Barak (ed.) *The Routledge International Handbook of the Crimes of the Powerful*. Abingdon: Routledge, pp. 247–261. Available at: https://doi.org/10.4324/9781315815350-22.

[16] Kuper, J. and Hojsik, M. (2008) *Poisoning the poor: electronic waste in Ghana*. Greenpeace Special Report, August. Amsterdam: Greenpeace International. Available at: https://www.greenpeace.ch/static/planet4-switzerland-stateless/2019/05/d6b1201a-d6b1201a-2008_stu_en_ghanaelwaste.pdf (Accessed: 8 June 2026).

[17] International Energy Agency (2023) *Data Centres and Data Transmission Networks*. Paris: International Energy Agency. Available at: https://www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks (Accessed: 8 June 2026).

workload migration to hyperscale cloud infrastructure, and commitments to carbon-neutral or climate-neutral operations. For instance, Equinix cites its 2030 climate-neutral goal and reports 96% renewable-energy coverage across its global data-centre portfolio as evidence of greener digital infrastructure[18, 19]. Google highlights that it has matched 100% of its annual electricity use with renewable energy since 2017, is pursuing 24/7 carbon-free energy on every grid where it operates by 2030 and says its data centre energy emissions fell 12% in 2024 despite electricity use rising 27%[20, 21]. Microsoft presents advanced cooling as a sustainability milestone, saying its newer data centre design uses zero water for cooling[22], while a Microsoft-led life-cycle assessment published in *Nature*[23] found that cold-plate and immersion cooling could reduce lifecycle greenhouse-gas emissions by approximately 15%-21%, energy demand by roughly 15-20%, and water use by 31–52%.

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[18] Equinix (2024*) Equinix Sustainability Report 2024*. Available at: https://www.equinix.com/resources/infopapers/2024-corporate-sustainability-report (Accessed: 22 March 2026).

[19] Equinix (no date) 'Efficiency and Clean Power', *Equinix Sustainability*. Available at: https://sustainability.equinix.com/environment/efficiency-and-clean-power/ (Accessed: 22 March 2026).

[20] Google (no date a) 'Operating sustainably', *Google Data Centers*. Available at: https://datacenters.google/operating-sustainably/ (Accessed: 22 March 2026).

[21] Google (no date b) 'Sustainable & Efficient Operations', *Google Sustainability*. Available at: https://sustainability.google/operations/ (Accessed: 22 March 2026).

[22] Solomon, S. (2024) 'Sustainable by design: next-generation datacenters consume zero water for cooling', *The Microsoft Cloud Blog*, 9 December. Available at: https://www.microsoft.com/en-us/microsoft-cloud/blog/2024/12/09/sustainable-by-design-next-generation-datacenters-consume-zero-water-for-cooling/ (Accessed: 22 March 2026).

[23] Alissa, H., Nick, T., Raniwala, A., Arribas Herranz, A., Frost, K., Manousakis, I., Lio, K., Warrier, B., Oruganti, V., DiCaprio, T.J., Oseen-Senda, K., Ramakrishnan, B., Gupta, N., Bianchini, R., Kleewein, J., Belady, C., Fontoura, M., Sinistore, J., Natarajan, M., Johnson, L., Mealing, V., Arshi, P. and Frieze, M. (2025) 'Using life cycle assessment to drive innovation for sustainable cool clouds', *Nature*, 641, pp. 331–338. Available at: https://doi.org/10.1038/s41586-025-08832-3.

While such developments should not be dismissed, the problem is that they address the efficiency of specific systems, not the scale of aggregate demand, which is clearly outgrowing supply[24]. Moreover, they in turn lead to what are known as rebound effects[25, 26]. These occur when an efficiency gain reduces the energy or environmental impact of each unit of digital activity, but also makes that activity cheaper, easier, or more convenient, thereby increasing total use[27]. The growing popularity of energy-intensive IT services, such as streaming video, online gaming, cloud computing, cryptocurrency mining, and artificial intelligence, continue to drive up overall consumption, often outpacing the savings achieved through efficiency improvements[28].

Streaming video illustrates this tension. The IEA notes that video streaming has become less energy-intensive per hour because data centres and networks have become more efficient, but it also warns that rising demand and rebound effects can still increase the sector's

[24] Rouch, M., Denman, A., Hanbury, P., Renno, P. and Gray, E. (2024) 'Utilities must reinvent themselves to harness the AI-driven data center boom', *Bain & Company*, October. Available at: https://www.bain.com/insights/utilities-must-reinvent-themselves-to-harness-the-ai-driven-data-center-boom/ (Accessed: 23 May 2026).

[25] Planet A Ventures (2025) 'The rebound effect: AI's silent backfire', *Medium*, 19 June. Available at: https://planet-a.medium.com/the-rebound-effect-ais-silent-backfire-e92c1aa8b90f (Accessed: 19 March 2026).

[26] Sorrell, S. (2009) 'Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency', *Energy Policy*, 37(4), pp. 1456–1469. Available at: https://doi.org/10.1016/j.enpol.2008.12.003.

[27] Rabot, A. (2023) *Benchmark Green IT 2023*. GreenIT.fr. Available at: https://www.greenit.fr/wp-content/uploads/2023/12/2023-10-Benchmark_Green_IT-2023-report_v1_EN.pdf (Accessed: 30 May 2026).

[28] Manner, J. (2023) 'Black software — the energy unsustainability of software systems in the 21st century', *Oxford Open Energy*, 2, article oiac011. Available at: https://doi.org/10.1093/ooenergy/oiac011.

overall footprint[29]. Ericsson's[30] latest mobility data show the scale of this demand. Global mobile network data traffic reached 200 exabytes per month in Q4 2025, with video accounting for 76% of all mobile data traffic by the end of that year. Gaming follows a similar pattern. Console efficiency measures have reduced per-device electricity use, yet overall gaming-related energy consumption has continued to rise. The European Commission reports that games-console electricity use increased from 4.7 TWh per year in 2010 to 5.1 TWh in 2020, even though efficiency measures were saving about 4 TWh annually[31]. Research from Lawrence Berkeley National Laboratory further suggests that a strong shift toward cloud gaming can raise energy demand above the baseline, with cloud gaming using up to three times as much energy as local gaming in the most extreme cases[32].

Cryptocurrency mining provides an even clearer example of efficiency being overwhelmed by scale. Bitcoin mining alone used approximately 138 TWh of electricity annually in 2025, equivalent to around 0.54% of global electricity use[33]. While another study placed Bitcoin's

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[29] Kamiya, G. (2020) 'The carbon footprint of streaming video: fact-checking the headlines', *IEA Commentary*, 10 December. Paris: International Energy Agency. Available at: https://www.iea.org/commentaries/the-carbon-footprint-of-streaming-video-fact-checking-the-headlines (Accessed: 22 March 2026).

[30] Ericsson (no date) 'Mobile network traffic Q4 2025', *Ericsson Mobility Report data and forecasts*. Available at: https://www.ericsson.com/en/reports-and-papers/mobility-report/dataforecasts/mobile-traffic-update (Accessed: 22 March 2026).

[31] European Commission (no date) *Games consoles*. Available at: https://energy-efficient-products.ec.europa.eu/product-list/games-consoles_en (Accessed: 8 June 2026).

[32] Mills, E., Bourassa, N., Rainer, L., Mai, J., Shehabi, A. and Mills, N. (2019) 'Toward greener gaming: estimating national energy use and energy efficiency potential', *The Computer Games Journal*, 8(3–4), pp. 157–178. Available at: https://doi.org/10.1007/s40869-019-00084-2.

[33] Neumueller, A., Pieters, G.C., Mohaddes, K., Rousseau, V. and Zhang, B.Z. (2025) *Cambridge Digital Mining Industry Report: Global operations, sentiment, and energy use*. Cambridge: Cambridge Centre for Alternative

electricity use at about 150 TWh, describing it to be more than what is consumed by Argentina, a country of approximately 45 million people[34]. Although mining hardware has become more efficient, the U.S. Energy Information Administration notes that these gains are often offset by rising computational difficulty. It estimates that cryptocurrency mining accounted for approximately 0.6% to 2.3% of total U.S. electricity consumption[35].

Artificial intelligence adds another layer to this problem. Training state-of-the-art AI neural networks require thousands of processors running continuously for extended periods, drawing enormous amounts of power[36]. The International Energy Agency projects that global data centre electricity consumption could more than double to around 945 TWh by 2030, with AI as a major driver of this growth[37]. One analysis warns that, if current trends continue, data centres could account for 20% of global electricity consumption by 2030–2035, largely due to AI workloads[38].

Finance, Cambridge Judge Business School. Available at: https://www.jbs.cam.ac.uk/wp-content/uploads/2025/04/2025-04-cambridge-digital-mining-industry-report.pdf (Accessed: 22 March 2026).

[34] Hinsdale, J. (2022) 'Cryptocurrency's dirty secret: energy consumption', *State of the Planet: News from the Columbia Climate School*, 4 May. Available at: https://news.climate.columbia.edu/2022/05/04/cryptocurrency-energy/ (Accessed: 19 March 2026).

[35] U.S. Energy Information Administration (2024) 'Tracking electricity consumption from U.S. cryptocurrency mining operations', *Today in Energy*, 1 February. Available at: https://www.eia.gov/todayinenergy/detail.php?id=61364 (Accessed: 22 March 2026).

[36] Kandemir, M. (2025) 'Why AI uses so much energy — and what we can do about it', *Penn State Institute of Energy and the Environment*, 8 April. Available at: https://iee.psu.edu/news/blog/why-ai-uses-so-much-energy-and-what-we-can-do-about-it (Accessed: 19 March 2026).

[37] International Energy Agency (IEA) (2025) 'Energy demand from AI', *Energy and AI*. Available at: https://www.iea.org/reports/energy-and-ai/energy-demand-from-ai (Accessed: 24 May 2026).

[38] Buyya, R., Ilager, S. and Arroba, P. (2024) 'Energy-efficiency and sustainability in new generation cloud computing: a vision and directions for integrated management of data centre resources and workloads', *Software: Practice and Experience*, 54(1), pp. 24–38. Available at: https://doi.org/10.1002/spe.3248.

In response to these pressures, major technology companies are increasingly turning to large-scale renewable-energy procurement and alternative power sources. Nuclear power is now being adopted or pursued by several tech firms[39, 40, 41, 42]. Google has invested heavily in renewable energy and has signed a deal to power AI workloads using small modular nuclear reactors[43]. Microsoft has also pursued nuclear power through an agreement connected to the reopening of the Three Mile Island site[44]. Such initiatives are often framed as evidence that computing can continue to scale without a corresponding increase in carbon emissions. However, they also reveal the scale of the underlying energy problem. Rather than reducing demand, the industry is seeking ever-larger sources of electricity to sustain continued growth.

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[39] Gardner, T. (2025) 'Meta signs power agreement with Constellation nuclear plant', *Reuters*, 3 June. Available at: https://www.reuters.com/sustainability/climate-energy/meta-signs-power-agreement-with-constellation-nuclear-plant-2025-06-03/ (Accessed: 8 June 2026).

[40] Mandler, C. (2024) 'Three Mile Island nuclear power plant will reopen to power Microsoft AI', *NPR*, 20 September. Available at: https://www.npr.org/2024/09/20/nx-s1-5120581/three-mile-island-nuclear-power-plant-microsoft-ai (Accessed: 21 March 2026).

[41] U.S. Department of Energy (2023) 'At COP28, countries launch declaration to triple nuclear energy capacity by 2050, recognizing the key role of nuclear energy in reaching net zero', *U.S. Department of Energy*, 1 December. Available at: https://www.energy.gov/articles/cop28-countries-launch-declaration-triple-nuclear-energy-capacity-2050-recognizing-key (Accessed: 19 March 2026).

[42] Mairura, J. (2024) 'Google's $10 billion nuclear reactors project', *Construction Review Online*, updated 15 November. Available at: https://constructionreviewonline.com/construction-projects/how-is-googles-10b-nuclear-reactors-project-going-to-power-its-ai-data-centers/ (Accessed: 19 March 2026).

[43] BBC News (2024) 'Google signs deal to use nuclear power for AI data centres', *BBC News*, 15 October. Available at: https://www.bbc.co.uk/news/articles/c748gn94k95o (Accessed: 19 March 2026).

[44] Sherman, N. (2024) 'Microsoft chooses infamous nuclear site for AI power', *BBC News*, 20 September. Available at: https://www.bbc.co.uk/news/articles/cx25v2d7zexo (Accessed: 19 March 2026).

Some data centres are marketed as operating entirely on renewable power, either because operators purchase renewable electricity or energy-attribute certificates, or because the facilities are located in grids already dominated by renewable generation. Verne[45] in Iceland, and Green Mountain[46] and Lefdal Mine[47] in Norway, are often cited as examples of data centres effectively powered by renewable electricity. However, such a claim is stronger on a location-based basis in Iceland and Norway than it would be in fossil-heavy grids, as government and international energy statistics show that Iceland's electricity supply is generated almost entirely from hydropower and geothermal resources[48, 49]. Similarly Norway's electricity system is dominated by hydropower and has very low carbon intensity[50, 51]. This distinction matters because location-based reporting reflects the average emissions intensity of the grid where electricity is consumed, whereas market-based

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[45] Verne (no date) 'Sustainability and renewable energy'. *Verne*. Available at: https://www.verneglobal.com (Accessed: 11 January 2026).

[46] Green Mountain (no date) 'Powered by 100% renewable energy'. *Green Mountain*. Available at: https://www.greenmountain.no (Accessed: 11 January 2026).

[47] Lefdal Mine Datacenter (no date) 'Sustainability'. *Lefdal Mine Datacenter*. Available at: https://www.lefdalmine.com (Accessed: 11 January 2026).

[48] Orkustofnun – National Energy Authority of Iceland (2022) *Energy in Iceland*. Reykjavík: Government of Iceland. Available at: https://www.nea.is (Accessed: 11 January 2026).

[49] International Energy Agency (IEA) (2023) *Electricity information: Iceland*. Paris: IEA. Available at: https://www.iea.org (Accessed: 11 January 2026).

[50] Norwegian Water Resources and Energy Directorate (NVE) (2022) *Electricity production and consumption in Norway*. Oslo: Ministry of Petroleum and Energy. Available at: https://www.nve.no (Accessed: 11 January 2026).

[51] International Energy Agency (IEA) (2023) *Electricity information: Norway*. Paris: IEA. Available at: https://www.iea.org (Accessed: 11 January 2026).

reporting reflects contractual instruments such as power-purchase agreements, renewable-energy certificates, guarantees of origin, or supplier-specific electricity products[52].

Despite public sustainability pledges, a significant share of data centre energy still comes from fossil fuels. Amazon Web Services (AWS), for example, has been criticised for operating in regions with coal- and gas-heavy energy grids. In 2024, a group of Amazon employees revealed that only 22% of the power used by its data centres was from renewable sources, arguing that the company's expansion "in the heart of coal country" is in fact driving up demand for fossil fuel-based generation[53]. They also accused Amazon of "distorting the truth" by relying on renewable energy credits and offsets rather than directly sourcing clean energy. Even companies making substantial green investments face trade-offs. Microsoft, which has pledged to become carbon-negative by 2030, initially achieved "carbon neutrality" largely by purchasing carbon offsets rather than reducing fossil energy use[54]. While both Microsoft and Google have since committed to 24/7 renewable power matching, these goals remain unrealised in many regions where grids continue to rely on coal and gas.

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[52] Aslan, J., Mayers, K., Koomey, J.G. and France, C. (2018) 'Electricity intensity of internet data transmission: untangling the estimates', *Journal of Industrial Ecology*, 22(4), pp. 785–798. Available at: https://doi.org/10.1111/jiec.12630.

[53] Gooding, M. (2024) 'Amazon staff say company is "distorting the truth" on renewable energy progress', *Data Center Dynamics*, 15 July. Available at: https://www.datacenterdynamics.com/en/news/amazon-staff-say-company-is-distorting-the-truth-on-renewable-energy-progress/ (Accessed: 19 March 2026).

[54] United Nations Framework Convention on Climate Change (UNFCCC) (2023) 'Microsoft carbon negative goal', *United Nations Framework Convention on Climate Change*. Available at: https://unfccc.int/climate-action/un-global-climate-action-awards/climate-neutral-now/microsoft-carbon-negative-goal (Accessed: 19 March 2026).

The turn toward alternative energy sources also introduces further complications. Nuclear power, now being pursued by several major technology firms, may help reduce operational carbon emissions in some contexts, but it raises additional concerns around cost, construction timelines, radioactive waste, safety, and the political governance of energy infrastructure[13,55]. Similarly, other clean energy technologies like solar power also carry underexamined environmental risks. While solar photovoltaics are widely viewed as a sustainable alternative, newer technologies, such as quantum dye-sensitised solar cells, and dye-sensitised solar cells co-sensitised with quantum dots, can incorporate cadmium and lead containing nanomaterials, raising toxicity concerns[56, 57, 58, 59]. As solar installations scale globally, especially in regions with weak formal waste-management systems, improper disposal could contaminate soil, water, and food systems. This reinforces the broader pattern that even green technologies can externalise significant harm if lifecycle impacts are ignored.

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[55] Schneider, M., Froggatt, A., Hazemann, J., Gürbüz, Ö., Jobin, P., Johnstone, P., Judson, T., Kobayashi, Y., Koplow, D., Lyman, E., Ramana, M.V., Stier, S., Stirling, A., Suzuki, T., von Hirschhausen, C., Wimmers, A.J. and Winkler, H. (2024) *The World Nuclear Industry Status Report 2024*. Paris: Mycle Schneider Consulting. Available at: https://www.worldnuclearreport.org/The-World-Nuclear-Industry-Status-Report-2024-HTML (Accessed: 8 June 2026).

[56] Kharboot, L.H. and Altaf, A.A. (2025) 'Quantum dot-sensitized solar cells: broader implications for renewable energy solutions from (2020–2025)', *Inorganica Chimica Acta*, 588, article 122882. Available at: https://doi.org/10.1016/j.ica.2025.122882.

[57] AlGhamdi, J.M., AlOmar, S., Gondal, M.A., Moqbel, R. and Dastageer, M.A. (2020) 'Enhanced efficiency of dye co-sensitized solar cells based on pulsed-laser-synthesized cadmium-selenide quantum dots', *Solar Energy*, 209, pp. 108–117. Available at: https://doi.org/10.1016/j.solener.2020.08.091

[58] Liu, Y. and Wang, J. (2010) 'Co-sensitization of TiO_2 by PbS quantum dots and dye N719 in dye-sensitized solar cells', *Thin Solid Films*, 518(24 Suppl.), pp. e54–e56. Available at: https://doi.org/10.1016/j.tsf.2010.03.126.

[59] Hardman, R. (2006) 'A toxicologic review of quantum dots: toxicity depends on physicochemical and environmental factors', *Environmental Health Perspectives*, 114(2), pp. 165–172. Available at: https://doi.org/10.1289/ehp.8284.

Recycling and resource management form the second dimension of Green IT. Modern electronics are composed of complex materials, including plastics, glass, precious metals (e.g., gold, silver, palladium), and rare earth elements (e.g., neodymium). Industry often promotes a circular economy, where devices are disassembled at end of life and materials are recovered for reuse. Some initiatives illustrate the use of technology to realise recycling. For example, Apple's Daisy robot can disassemble 15 iPhone models at 200 devices per hour, recovering cobalt and other materials and diverting tens of thousands of metric tons of e-waste from landfills[60]. This is part of Apple's closed-loop supply strategy, reclaiming rare materials such as cobalt and tin from discarded devices[61, 62]. Toyota's Prius hybrid is over 85% recyclable, with 95% battery material recovery and recycling that accounts for about 2% of lifecycle CO_2 emissions[63, 64]. These examples suggest that high-value components can be reclaimed to reduce demand for virgin extraction.

[60] Apple (2019) 'Apple expands global recycling programs', *Apple Newsroom*, 18 April. Available at: https://www.apple.com/newsroom/2019/04/apple-expands-global-recycling-programs/ (Accessed: 19 March 2026).

[61] Apple (2023) 'Apple will use 100 percent recycled cobalt in batteries by 2025', *Apple Newsroom*, 13 April. Available at: https://www.apple.com/uk/newsroom/2023/04/apple-will-use-100-percent-recycled-cobalt-in-batteries-by-2025/ (Accessed: 19 March 2026).

[62] Apple (2026) 'Apple accelerates environmental progress with highest-ever recycled material in its products', *Apple Newsroom*, 16 April. Available at: https://www.apple.com/newsroom/2026/04/apple-accelerates-progress-with-highest-ever-recycled-material-in-its-products/ (Accessed: 7 June 2026).

[63] Toyota UK Magazine (2009) 'Recycling hybrid car batteries in the Toyota Prius', *Toyota UK Magazine*. Available at: https://mag.toyota.co.uk/recharge-reuse-recycle/ (Accessed: 19 March 2026).

[64] Toyota (2009) 'New Prius recycling', *Toyota Media Site*, 1 July. Available at: https://media.toyota.co.uk/new-prius-recycling/ (Accessed: 19 March 2026).

But recycling outcomes remain poor. In 2022, global e-waste reached about 62 billion kg, yet only 13.8 billion kg, or 22.3% was documented as formally collected and recycled[65]. Much of the remainder is disposed of, undocumented, or handled outside formal systems, including through informal recycling in low- and lower-middle-income countries[66]. Some cross-border e-waste also moves as used or second-hand equipment, which can support reuse but may also enable unsafe dumping and processing[66], which critics term as a form of "toxic colonialism" [67]. It is called "colonialism" because the pattern follows older power inequalities. Specifically, wealthier actors keep the profits and cleaner environments, while poorer or marginalised communities absorb the pollution and health harms. The phrase is used in two related ways. Internationally, it means exporting hazardous waste, e-waste, or toxic chemicals to poorer countries. More broadly, it can also describe placing "dirty" industries or waste sites in poor, racialized, or Indigenous communities with less political power to resist[68]. Thus, toxic colonialism encompasses the Global North's externalisation of hazardous production as well as hazardous waste. In doing so, a disproportionate share of

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[65] Baldé, C.P., Kuehr, R., Yamamoto, T., McDonald, R., D'Angelo, E., Althaf, S., Bel, G., Deubzer, O., Fernandez-Cubillo, E., Forti, V., Gray, V., Herat, S., Honda, S., Iattoni, G., Khetriwal, D.S., Luda di Cortemiglia, V., Lobuntsova, Y., Nnorom, I., Pralat, N. and Wagner, M. (2024) *Global e-waste monitor 2024*. Geneva/Bonn: International Telecommunication Union (ITU) and United Nations Institute for Training and Research (UNITAR). Available at: https://ewastemonitor.info/wp-content/uploads/2024/12/GEM_2024_EN_11_NOV-web.pdf (Accessed: 1 June 2026).

[66] Baldé, C.P., D'Angelo, E., Luda, V., Deubzer, O. and Kuehr, R. (2022) *Global transboundary e-waste flows monitor 2022*. Bonn: United Nations Institute for Training and Research (UNITAR). Available at: https://ewastemonitor.info/wp-content/uploads/2022/06/Global-TBM_webversion_june_2_pages.pdf (Accessed: 1 June 2026).

[67] Njoku, A., Agbalenyo, M., Laude, J., Ajibola, T.F., Attah, M.A. and Sarko, S.B. (2024) 'Environmental Injustice and Electronic Waste in Ghana: Challenges and Recommendations', I*nternational Journal of Environmental Research and Public Health*, 21(1), article 25. Available at: https://doi.org/10.3390/ijerph21010025.

[68] Bullard, R.D. (2004) *Environment and morality: Confronting environmental racism in the United States*. UNRISD Programme Papers on Identities, Conflict and Cohesion, PP ICC 8. Geneva: United Nations Research Institute for Social Development. Available at: https://www.csu.edu/cerc/documents/EnvironmentandMorality-ConfrontingEnvironmentalRacismInTheUnitedStates-Bullard2004.pdf (Accessed: 21 March 2026).

the pollution and health risks are forced onto the Global South. Waste ends up in places with fewer resources, weaker regulatory protection, and less political power or capacity to refuse it. Toxic colonialism results from the actions of both states and companies[67, 68].

To be sure, there has been some regulatory progress. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal[69] was adopted on 22 March 1989, after growing international concern in the 1980s about hazardous wastes being shipped from industrialised states to Africa and other developing regions. It entered into force on 5 May 1992[70]. Under this system, the exporting state must inform the relevant importing and transit states before a shipment occurs, and the movement cannot proceed unless the states concerned give written consent[71, 72]. Although this framework has strengthened international waste governance, it has not eliminated unequal waste flows or informal processing[67].

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[69] Basel Convention (1989) *Text of the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal*. Available at: https://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx (Accessed: 21 March 2026).

[70] Peiry, K.K. (2010) 'Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal', *United Nations Audiovisual Library of International Law*. Available at: https://legal.un.org/avl/pdf/ha/bcctmhwd/bcctmhwd_e.pdf (Accessed: 1 June 2026).

[71] Basel Convention (no date a) 'Overview', *Basel Convention*. Available at: https://www.basel.int/theconvention/overview/tabid/1271/default.aspx (Accessed: 21 March 2026).

[72] Basel Convention (2014) *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal and Protocol on Liability and Compensation for Damage Resulting from Transboundary Movements of Hazardous Wastes and Their Disposal: texts and annexes*. Geneva: Secretariat of the Basel Convention. Available at: https://www.basel.int/portals/4/basel%20convention/docs/text/baselconventiontext-e.pdf (Accessed: 21 March 2026).

The Ban Amendment[73], which entered into force on 5 December 2019, strengthened the Basel Convention by requiring Annex VII parties bound by the amendment to prohibit covered hazardous-waste exports to states not listed in Annex VII, including exports for final disposal and certain recovery or recycling operations. Further reforms followed at COP15 in 2022, when parties adopted amendments to bring both hazardous and non-hazardous e-waste under the Basel Convention's prior informed consent procedure from 1 January 2025[74]. Moreover, the Convention's e-waste work has also expanded through PACE II[75], which now covers a wider range of used and waste electrical and electronic equipment, including mobile phones, computing equipment, television and audio-visual equipment, refrigerators, and cooling and heating equipment[75].

These legal developments are significant, and mark real progress in international waste governance, but they have not ended unequal or informal waste flows. For instance, in China, the informal e-waste recycling sector functions as what Orlins and Guan[76] call a "well-

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[73] Basel Convention (no date b) 'The Basel Convention Ban Amendment', *Basel Convention*. Available at: https://www.basel.int/Implementation/LegalMatters/BanAmendment/Overview/tabid/1484/Default.aspx (Accessed: 1 June 2026).

[74] Basel Convention (no date c) 'E-waste amendments', *Basel Convention*. Available at: https://www.basel.int/Implementation/Ewaste/EwasteAmendments/Overview/tabid/9266/Default.aspx (Accessed: 1 June 2026).

[75] Basel Convention (no date d) 'Partnership for Action on Challenges relating to E-waste, PACE II', *Basel Convention*. Available at: https://www.basel.int/Implementation/TechnicalAssistance/Partnerships/PACEII/Overview/tabid/9284/Default.aspx (Accessed: 1 June 2026).

[76] Orlins, S. and Guan, D. (2016) 'China's toxic informal e-waste recycling: Local approaches to a global environmental problem', *Journal of Cleaner Production*, 114, pp. 71–80. Available at: https://doi.org/10.1016/j.jclepro.2015.05.090.

established shadow economy." In such systems, workers may use manual dismantling, open burning, acid leaching, and other low-tech recovery methods to extract valuable metals; these practices can release toxic fumes and contaminate soil and water with lead, mercury, cadmium, arsenic, and other hazardous substances[77, 78].

The town of Guiyu illustrates the human and environmental costs of such practices, where studies have documented severe contamination from informal recycling there, including open burning, acid-based recovery practices, and elevated blood-lead levels among children[79, 80]. Huo et al.[80] found that 81.8% of sampled children had blood lead levels above 10 µg/dL, compared with 37.7% in the comparison town of Chendian. However, Guiyu should not be presented as unchanged. Wang, Zhao and Handwerker[81] describe Guiyu as a case of a "systematic effort to transform and integrate the informal sector into the formal recycling industry," while also noting that the transition retained older informal characteristics such as "manual dismantling and private e-waste collection networks." In addition, a health-risk assessment in an e-waste area of China found migrant workers faced

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[77] Perkins, D.N., Brune Drisse, M.-N., Nxele, T. and Sly, P.D. (2014) 'E-Waste: a global hazard', *Annals of Global Health*, 80(4), pp. 286–295. Available at: https://doi.org/10.1016/j.aogh.2014.10.001.

[78] Geneva Environment Network (2026) The growing environmental risks of e-waste. 14 February. Available at: https://www.genevaenvironmentnetwork.org/fr/ressources/nouvelles/the-growing-environmental-risks-of-e-waste/ (Accessed: 19 March 2026).

[79] Leung, A., Cai, Z. and Wong, M. (2006) 'Environmental contamination from electronic waste recycling at Guiyu, southeast China', *Journal of Material Cycles and Waste Management*, 8, pp. 21–33. Available at: https://doi.org/10.1007/s10163-005-0141-6.

[80] Huo, X., Peng, L., Xu, X., Zheng, L., Qiu, B., Qi, Z., Zhang, B., Han, D. and Piao, Z. (2007) 'Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China', *Environmental Health Perspectives*, 115(7), pp. 1113–1117. Available at: https://doi.org/10.1289/ehp.9697.

[81] Wang, C., Zhao, F. and Handwerker, C. (2022) 'Transforming and integrating informal sectors into formal e-waste management system: A case study in Guiyu, China', *Clean Technologies and Recycling*, 2(4), pp. 225–246. Available at: https://doi.org/10.3934/ctr.2022012.

approximately 3.8 times higher PCB-related health risk than local residents, driven by exposures at work, in transit, and at home, which the authors describe as evidence of a new wealth gap in environmental rights[82].

Similar risks have also been documented around the former Agbogbloshie site in Ghana[67] and in e-waste dismantling communities in Buriram Province, Thailand[83]. De Albuquerque et al.[84] reinforce this broader point by arguing that e-waste treatment in developing countries is often shaped more by financial incentives than environmental protection.

Corporate take-back and robotics initiatives still cover only a small share of waste. Even though Apple's Daisy can process up to 1.2 million iPhones per year[60], the company sells more than 200 million annually[85], and billions of other devices also enter waste streams[86].

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[82] Wang, Y., Hu, J., Lin, W., Wang, N., Li, C., Luo, P., Hashmi, M.Z., Wang, W., Su, X., Chen, C., Liu, Y., Huang, R. and Shen, C. (2016) 'Health risk assessment of migrant workers' exposure to polychlorinated biphenyls in air and dust in an e-waste recycling area in China: indication for a new wealth gap in environmental rights', *Environment International*, 87, pp. 33–41. Available at: https://doi.org/10.1016/j.envint.2015.11.009.

[83] Assawadithalerd, M., Srisa-ard, S., Akkajit, P. and Prueksasit, T. (2020) 'E-waste dismantling community toward circular economy with ineffective hazardous waste management: a case study in Buriram Province, Thailand', in H.Y. Jeon (ed.) *Sustainable Development of Water and Environment*. Cham: Springer, pp. 127–136. Available at: https://doi.org/10.1007/978-3-030-45263-6_12.

[84] de Albuquerque, C.A., Mello, C.H.P., Gomes, J.H. de F., Santos, V.C. dos and Zara, J.V. (2020) 'E-waste in the world today: an overview of problems and a proposal for improvement in Brazil', *Environmental Quality Management*, 29(3), pp. 63–72. Available at: https://doi.org/10.1002/tqem.21682.

[85] Reuters (2025) 'Counterpoint Research cuts 2025 global smartphone shipment growth amid tariff uncertainty', *Reuters*, 4 June. Available at: https://www.reuters.com/business/media-telecom/counterpoint-research-cuts-2025-global-smartphone-shipment-growth-amid-tariff-2025-06-04/ (Accessed: 14 June 2026).

[86] United Nations Institute for Training and Research (UNITAR) (2024) 'Global e-Waste Monitor 2024: electronic waste rising five times faster than documented e-waste recycling', *United Nations Institute for Training and Research*, 20 March. Available at: https://unitar.org/about/news-stories/press/global-e-waste-monitor-2024-electronic-waste-rising-five-times-faster-documented-e-waste-recycling (Accessed: 8 June 2026).

Material recovery also faces cost and technical barriers. Lithium-ion batteries contain valuable cobalt, nickel, and lithium, but safe recycling is expensive, while informal smelting or acid leaching pollutes heavily. Only about 30% of cobalt in e-waste is currently recovered, although technologies could achieve up to 95% with proper investment[87]. Upstream, raw-material extraction imposes significant social and environmental costs. About 70% of global cobalt supply comes from the Democratic Republic of Congo, with documented deforestation in the Congo Basin, hazardous artisanal mining that employs children, and human rights abuses around some industrial operations[88]. Any claim that cobalt-containing lithium-powered devices are simply green must reckon with these off-balance-sheet impacts. Design practices further limit circularity. Devices are often sealed or glued, which impedes repair and upgrades. Battery replacement frequently requires device replacement. While manufacturers often cite design constraints, Regulation (EU) 2023/1542[89], will generally require products containing portable batteries placed on the EU market to make those batteries readily removable and replaceable by end-users from 18 February 2027, subject to certain exemptions, pushing a shift toward more repairable designs[90].

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[87] World Economic Forum (2019) *A new circular vision for electronics: time for a global reboot*. Geneva: World Economic Forum. Available at: https://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf (Accessed: 19 March 2026).

[88] Davey, C. (2023) 'The environmental impacts of cobalt mining in Congo', *Earth.org*, 28 March. Available at: https://earth.org/cobalt-mining-in-congo/ (Accessed: 19 March 2026).

[89] European Union (2023) *Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC. Official Journal of the European Union*, L 191, 28 July, pp. 1–117. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023R1542 (Accessed: 8 June 2026).

[90] Flash Battery (2025) 'From production to recycling: A comprehensive guide to the new European Battery Regulation 2023/1542', *Flash Battery*, 14 May. Available at: https://www.flashbattery.tech/en/blog/eu-battery-regulation-obligations-updates/ (Accessed: 19 March 2026).

Renewing and upgrading technologies

The third dimension of Green IT involves extending the useful life of devices and infrastructure. This can be achieved through designing products for durability, repairability, upgradability, and long-term software support. In principle, making hardware last longer and be easier to fix or update has a direct environmental benefit. It defers the need for manufacturing new devices (saving materials and energy) and reduces e-waste volumes.

As highlighted by the British Computer Society (BCS)[91], reusing and refurbishing IT equipment is generally far more eco-friendly (and often cheaper) than buying new equipment on a rapid replacement cycle. Products that are modular and built with standard components can allow for longer maintenance cycles, part replacement, and incremental upgrades instead of wholesale disposal. For businesses and consumers, using devices for 5-7 years instead of replacing them every 2-3 years can therefore significantly cut down the total carbon and resource footprint associated with their technology use, provided the devices remain functional, secure, and repairable.

Yet many industry practices undermine technological longevity[92]. Planned (or implicit) obsolescence is common. For example, Apple's AirPods have been widely criticised as essentially unrepairable, glued shut with non-standard micro-batteries, earning a 0/10 iFixit

[91] BCS, The Chartered Institute for IT (no date) 'Green IT: Learn to use digital technology more sustainably', *BCS, The Chartered Institute for IT*. Available at: https://campaign.bcs.org/greenit (Accessed: 19 March 2026).

[92] Golubock, D.G. (2024) 'Fixing right-to-repair law: why efforts to hold manufacturers accountable are faltering', *Arizona Law Journal of Emerging Technologies*, 7(1), pp. 1–26. Available at: https://doi.org/10.2458/azlawjet.6394.

score[93] and effectively becoming e-waste after a few years. Another example can be seen in the Microsoft Surface models. The original Surface Laptop was described by iFixit as a "glue-filled monster", rating it 0/10, with soldered RAM/storage and a glued battery that made replacement extremely difficult[94]. Although Microsoft has improved design in newer generations (e.g., Surface Laptop 7, Surface Pro 11, and models which follow), with more recent models reaching an 8/10[94]. Irrespectively, many vendors still ship sealed devices.

Beyond hardware design, software restrictions also limit device longevity. Some companies lock down their software ecosystems to prevent unofficial repairs or upgrades. Tesla, for example, has faced lawsuits and criticism for its approach to repairs[95]. Tesla's software can detect and disable features on cars that have been repaired with salvaged parts by independent mechanics, and the company historically restricted access to diagnostic tools and parts, effectively forcing owners to use Tesla's own costly repair services[96]. Similarly,

[93] Noronha, E. (2016) 'AirPods teardown', *iFixit*, 20 December. Available at: https://www.ifixit.com/Teardown/AirPods+Teardown/75578 (Accessed: 19 March 2026).

[94] Endicott, S. (2024) 'Microsoft slays "glue-filled monster," makes Surface Laptop 7 and Surface Pro 11 easier to repair', *Windows Central*, 24 June. Available at: https://www.windowscentral.com/hardware/surface/microsoft-slays-glue-filled-monster-makes-surface-laptop-7-and-surface-pro-11-easier-to-repair (Accessed: 19 March 2026).

[95] Putrino, E.S. (2024) 'Tesla, let me fix my car: the right to repair and the need for a balance between public and private enforcement', *Oklahoma Law Review*, 76(2), pp. 351–396. Available at: https://digitalcommons.law.ou.edu/olr/vol76/iss2/4/ (Accessed: 9 January 2026).

[96] Stempel, J. (2024) 'Tesla must face owners' lawsuit claiming it monopolizes vehicle repairs and parts', *Reuters*, 18 June. Available at: https://www.reuters.com/legal/tesla-must-face-owners-lawsuit-claiming-it-monopolizes-vehicle-repairs-parts-2024-06-18/ (Accessed: 19 March 2026).

smartphone[97] and printer manufacturers[98] use software updates to discourage third-party battery replacements or ink refills.

The net effect of such practices is that consumers often replace devices entirely far sooner than necessary. This shortened lifecycle directly contributes to increased resource extraction (for new devices) and e-waste generation from discarded ones. It also undermines any "green" claims of efficiency improvements in new models, because the environmental cost of manufacturing a new device can be quite high relative to the incremental savings of slightly better energy efficiency. For perspective, manufacturing a single laptop (including mining the raw materials) is estimated to emit around 331 kg of CO_2 equivalent[99]. Therefore, extending the life of existing equipment is one of the most impactful steps toward sustainability.

Conclusion

The three dimensions examined in this essay - energy consumption, recycling and resource management, and the renewal and upgrading of technologies - do not merely expose a series of discrete shortcomings, they reveal the contradictions at the heart of Green IT.

[97] Gibbs, S. (2018) 'Apple and Samsung fined for deliberately slowing down phones', *The Guardian*, 24 October. Available at: https://www.theguardian.com/technology/2018/oct/24/apple-samsung-fined-for-slowing-down-phones (Accessed: 19 March 2026).

[98] Tims, A. (2023) 'How can HP block me from using a cheaper printer cartridge?', *The Guardian*, 10 May. Available at: https://www.theguardian.com/money/2023/may/10/how-can-hp-block-me-from-using-a-cheaper-printer-cartridge (Accessed: 19 March 2026).

[99] Network and Security (no date) 'The environmental impact of laptops: understanding their carbon footprint', *Network and Security*. Available at: https://networkandsecurity.co.uk/understanding-laptops-carbon-footprint/ (Accessed: 19 March 2026).

Efficiencies are counted locally, while harms are displaced socially, spatially, and temporally. At the level of energy, improvements in devices, cloud systems, and data centres are persistently overtaken by growth in aggregate demand, as streaming, gaming, cryptocurrency, and AI continue to scale. At the level of materials, the language of circularity too often masks the persistence of toxic colonialism, as hazardous burdens are shifted onto poorer countries and marginalised communities through unequal regimes of trade, regulation, and disposal. At the level of product design, the rhetoric of innovation sits uneasily beside sealed hardware, shortened support cycles, restricted repair, and premature replacement.

In sum, what emerges is not a coherent sustainability transition, but a system in which environmental gains are partial and frequently purchased at someone else's expense. If Green IT is to become more than a corporate slogan, reassuring policy fiction or assuage social innovator's consciences, it must be grounded in justice, restraint, and institutional responsibility. We will address how the problems of Green IT can be addressed in our next Critical Perspective essay.

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