Towards a World of Fixers

Examining barriers and enablers of widely deployed third-party repair for computing within limits

Josh Lepawsky
Department of Geography
Memorial University
St. John's Newfoundland & Labrador Canada

jlepawsky@mun.ca

ABSTRACT

Repair of computing devices is a potentially valuable pathway to energy and material conservation. I examine current barriers and enablers in design, manufacturing, policy, and practice arenas to more efficacious and widely deployed networks of third-party repair by 2030. Current barriers include design practices that reduce device service life; manufacturing practices that fail to mitigate or eliminate toxicants and externalities (e.g., pollution, waste), the socialization of costs of harms (e.g., pollution, waste) and the privatization of profits from device sales; restrictive end-user licensing agreements (EULAs), and the criminalization of third-party repair. Current enablers include public advocacy for legislation and regulation that reduce or eliminate toxicants in electronics design and manufacturing, require manufacturers to disclose pollution releases and transfers, and enhance right-to-repair; and growing networks of independent and do-it-yourself ICT maintenance and repair (INDIY ICT M&R) practitioners and advocates. After examining these barriers to, and enablers of, more efficacious and widely deployed third-party repair, I draw together findings from our existing research on INDIY ICT M&R activity and its potential to contribute to material and energy conservation for computing within limits over the next decade.

CCS CONCEPTS

• Social and professional topics • General and reference~Document types~Surveys and overviews

KEYWORDS

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1 INTRODUCTION

Manufacturing computing devices is an energy and material intensive process [46]. To take just one example, the electronics sector is the world's second-largest consumer of copper [45] and for every kilogram of copper mined some 210 kilograms of mine waste arise [10]. Mitigating the negative ecological effects of such material and energy consequences of computing is a key concern of LIMITS research [26]. Independent and do-it-yourself ICT maintenance and repair activity (INDIY ICT M&R) is held up as an important contributor to such goals [27]. Scholarly interest in repair and maintenance has blossomed in the wake of calls to “rethink repair” as practices fundamental to maintaining not just specific technical systems, but broader social, economic, and ecological orderings as well [11,16,30]. There is a burgeoning body of work investigating these broader issues as they apply to the repair and maintenance of ICT systems more specifically [e.g., 1,6,9,14,32,34]. Some previous work has identified a number of barriers to ‘open access repair’ in the EU and US, where consumers are able to perform repairs themselves and/or contract third-parties (i.e., non-OEM) repair services [38]. The barriers identified are principally legislative and policy oriented with some attention to design. Building on these insights I examine both barriers to, and enablers of, more widely deployed third-party repair systems that might enhance material and energy conservation. In addition, I discuss how these barriers and enablers impact on the capacity of repair as a pathway to energy and material conservation in ways relevant to the concerns of computing within limits [26].

2 BARRIERS

Barriers to INDIY ICT M&R make service, repair and reuse more challenging for device users and third-party repair. Such challenges, intentionally or otherwise, encourage higher device turnover through the discarding of used devices and purchase of replacement or new models, thus militating against resource and energy conservation. The barriers discussed below include design practices that obstruct service or reduce the service life of devices, the use of toxicants that make repair harmful to health and environment, the shifting of environmental remediation costs from producers to consumers, and attempts to impose regulatory restrictions on third-party repair.

2.1 DESIGN FOR REDUCED SERVICE LIFE

Design practices, especially for consumer grade electronics, are leading to shorter service lives for those devices. This situation includes both hardware and software issues. Ever since the pathbreaking work of Packard, planned obsolescence has been understood as a problematic strategy pursued by brand manufacturers [29]. Nevertheless, evidence of a shortening of service lives of devices as a broadscale and deliberate strategy to enhance profit margins remains murky. Ultimately, however, if the service life of devices is foreshortened due to design factors, it matters less what the intention or causative reasons behind such factors are and more what the effects of those decisions are with respect to device service life.

There is much variety in the design of different classes of consumer electronics (e.g., phones, laptops, tablets), but common features exist that reduce service life by making replacement of components (e.g., batteries, screens), repair, or upgrading difficult or impossible. For example, phone designs have seen broad cross-brand evolution to slate form factors (i.e., sealed one-piece units with touchscreens and few external buttons). An important change in design concomitant with this form factor is the loss of user-detachable batteries which were once a common feature across phone brands and models. While battery replacement is not impossible in most cases of slate form factor phones, it is typically challenging for users who do not have previous repair experience or access to the necessary tools.

The challenges of battery replacement in phones is an example of broader design decisions common across other device classes. In particular, the use of adhesives and soldering of components (e.g., RAM) to boards instead of using fasteners (e.g., screws, bolts) also contributes to shortened device service lives [4]. Adhesives can make opening devices to effect component repairs or upgrades difficult or impossible. Soldering of components, such as RAM, means it is no longer an option to swap out failed components or upgrade them, despite the relative ease of doing so in earlier device designs [15]. The use of proprietary fasteners (e.g., pentalobe screws) further contribute to reducing or eliminating options for component upgrade or repair. Thus, a variety of design decisions combine, whether intentionally or not, to increase friction toward repair and to prematurely reduce friction toward full device replacement. Full device replacement typically means substantial portions of the embodied energy and materials of discarded devices are lost in the process of destruction for materials recovery (i.e., recycling).

2.2 TOXICANTS AND MANUFACTURING EXTERNALITIES

Digital devices are frequently associated with images of dematerialized or virtual existence, as if they are both made of and support an ethereal netherworld operating at the speed of light. Yet, toxicants and externalities (e.g., pollution, waste) arising

from electronics manufacturing are pervasive in their tonnage, toxicity, heterogeneity, and harms.

Toxicants are synthetic, industrially produced chemicals. Data from the US Toxic Release Inventory (TRI) show that the US-based electronics manufacturing sector uses and releases at least 114 chemicals deemed toxic by TRI definitions. Such chemicals released in the manufacturing process enter workers' bodies and the broader environment.

Toxicological research has demonstrated since the early 1980s that workers in the electronics sector experience disproportionate rates of occupational illness and that amongst this group, women are particularly affected [18,19].

Evidence abounds of toxicological harm to the broader environment from chemical releases of electronics manufacturing. For example, Santa Clara county, the locus of Silicon Valley, has over 20 active Superfund sites (see Section 2.3). Legacy releases of toxicants from electronics manufacturing facilities in the region continue to effect workers in contemporary 'tech' companies housed in the Valley, including Google. Indeed, ongoing treatment processes for toxicant releases to ground water will require as much as 700 years of further treatment using contemporary methods to reach drinking water standards deemed safe by the EPA [21,41].

An important example of externalities from electronics manufacturing are greenhouse gas emissions. The majority of such emissions released during the lifetime of electronic devices occurs in production, rather than during use or after discard. This is broadly the case across all major categories and brands of consumer computing (e.g., desktops, laptops, tablets, and phones) [21]. One important example of such externalities comes from flat panel display (FPDs) manufacture which relies on fluorinated greenhouse gases (F-GHGs) for cleaning and etching. Emerging research on these industrial applications of F-GHGs indicate that emissions of over 1.7 million metric tons carbon equivalent occur. Broad shifts in the industry toward less-greenhouse intensive F-GHGs are observed, but even these mitigations rely on gases with global warming potentials 17,200 times higher than CO₂ and atmospheric lifetimes beyond 700 years [40].

TRI data show a wide range of chemical hazards are emitted from US-based electronics manufacturing facilities. Although Silicon Valley is almost synonymous with the electronics industry in the US, TRI data show that chemical releases from the sector occur from facilities unevenly scattered across 46 states. At the state level, California leads with 16.9 million pounds of hazardous chemical releases from facilities between 1991-2015. Alabama, Oregon, Minnesota, and New York round out the top five (see Table 1).

State	Total Releases (lbs.)
CA	16,998,335
AL	15,594,011
OR	14,791,927
MN	14,096,259
NY	11,608,936

Table 1. Total hazardous chemical releases from computing and electronics manufacturing facilities, 1991-2015. Data source: Toxic Release Inventory.

As the electronics industry has globalized over the last 40 years, the ability to track hazardous chemical releases from manufacturing in the sector has declined because few countries beyond Canada, Mexico, the US (under NAFTA) and Europe (under the EU), even collect emissions data, let alone make it public. Among the most significant instances of this data gap is China, where a large portion of electronics manufacturing and assembly work gets done [42].

Repair cannot, on its own, mitigate or reduce the use of toxicants or the externalities arising in manufacturing. At best, it may be able to conserve the chemical footprint of manufacturing embodied in devices put on the market by keeping devices in use over a longer period of time. In this respect, repair is always dealing with devices after they have already been given a chemical fate in the upstream phases of design and manufacturing. Therefore, it is important for repair advocates to align their work with that of anti-toxicants advocates, including grassroots initiatives (e.g., the Silicon Valley Toxics Coalition; the International Campaign for Responsible Technology), green chemistry, and clean production advocacy (e.g., Clean Production Action).

2.3 SOCIALIZATION OF COSTS & PRIVATIZATION OF PROFITS

Moving the monetary costs of harms from the private accounts of corporations to the public accounts of tax-payer funded government is a common strategy and not unique to the electronics industry. Two specific cases from the electronics manufacturing sector illustrate this broader phenomenon.

In the heart of what is today colloquially called Silicon Valley is an area known as the Middlefield-Ellis-Whisman (MEW) Study Area. MEW comprises three Superfund sites totaling some 88 acres related to clean-up of toxic pollution from Fairchild Semiconductors, Raytheon, and Intel [44]. ‘Superfund’ is the informal name given to the law passed by the US Congress in 1980 called the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). In essence, CERCLA is funded by a tax on chemical and petroleum companies. The law enables the EPA to enforce cleanup operations paid for by parties (e.g., corporations) found liable

under CERCLA, but when no such parties can be found (e.g., after a corporation has gone out of business), then public funds (taxes) can be used to finance the cleanup costs [43].

Cleanup work has been under way at MEW since the 1980s, but is still not complete. Although the EPA reached a settlement with Intel and Raytheon in 2011, Fairchild was acquired by another company in 2016 and no longer exists as a legal entity. Thus, the costs of its legacy contaminants are being borne by public CERCLA (‘Superfund’) funds.

MEW primarily concerns contamination of groundwater and secondarily, airborne pollution from the seepage of volatile organic compounds (VOCs) out of contaminated groundwater sources. These contaminants currently impact workers at well-known Silicon Valley firms, such as Google, some of whose facilities are sited in the MEW area as well as residents of the region [35]. Yet, the costs for cleaning up the legacy pollutants associated with electronics in the region are at best only partially borne by the firms directly responsible for that pollution. A substantial portion of those costs are covered by public funds, ultimately derived from taxes on other industries.

A second case is found in how electronics recycling legislation has been instituted in the US and the similarities it shows with other jurisdictions. Legislation of this kind began to be passed in the early 2000s. In the US the legislation has proceeded principally at the state level, resulting in a patchwork regulatory landscape covering the recycling of electronics. Among the important differences that exist between states is in what categories of devices the laws cover. These differences mean, for example, that printers and other peripherals may be covered under the law in one state (e.g., Minnesota), but not another (e.g., New Hampshire). Despite these kinds of state-to-state differences, the legislation shares one commonality: the actual financing of the electronics recycling system is borne by consumers, not producers (i.e., brand manufacturers). Although the details of financing differ from state-to-state, what generally happens is that consumers pay a fee at the point of purchase to cover the later cost of recycling end-of-life devices. The net effect is that the ‘price signal’ that would be sent to manufacturers were they made responsible for the subsequent costs of recycling the devices they produce, is lost. Instead, it is consumers that bear the costs of managing end-of-life electronics (where such laws exist). Yet, it is manufacturers that have the most power to make design changes that would enhance product durability and repairability [20]. Consequently, the costs of managing end-of-life devices is socialized to consumers, while the profits accrued from producing and selling devices go to the brand manufacturers.

The degree to which devices are repairable (or not) can directly impact product cycles. Where repairability is not merely possible, but also accessible and affordable, lengthening the product cycles can amortized the use of energy and materials in mining and manufacturing (and subsequently embodied in devices) over

longer periods of time. Lengthening product cycles, in effect, is conservation of energy and materials with the possibility of concomitant socially and environmentally beneficial effects.

2.4 RESTRICTING THIRD-PARTY REPAIR

End-user license agreements (EULAs) that restrict how purchasers may use hardware and software are now a common feature of those products. However, the use of EULAs in the consumer electronics sector grew substantially after a legal decision in 2003 involving a case of a printer manufacturer against a printer cartridge refurbisher whom the manufacturer claimed was violating the EULA on its cartridges. The court ruled in favor of the printer manufacturer, upholding its claim of EULA violation. A subsequent case in 2008 involving another hardware manufacturer came to an opposite conclusion. Here the court ruled that EULAs cannot violate prevailing legal doctrines of first sale and patent exhaustion that prevent patent holders from placing conditions on the sale of products to consumers. This unsettled legal landscape “allows for patent owners to experiment with after-sale license agreement tactics” and modify sales to consumers (and thus the transfer of property rights) into ‘conditional sales’ “with restrictions on post-sale activities, such as resale, repair, and modification” [von Lohmann cited in 20][31].

Evidence of such experimentation can be found in the proliferation of warranty stickers affixed to electronics hardware that warn consumers of ostensible loss of warranty if those stickers are removed or the conditions they attempt to place on devices are violated in the eyes of manufacturers [5]. The practice has proliferated well beyond the consumer electronics sector across a broad array of industries in which key pieces of infrastructure include computational components, including farming [48]. This practice is being strongly resisted by advocates of right to repair (see Section 3.3), but the stakes of this industry-wide practice have recently been raised substantially with the onset of the COVID-19 pandemic. What previously might have seemed a more esoteric debate about consumer rights has, with the pandemic, shifted the frame to include how manufacturers attempts to monopolize repair, combined with complex transnational supply-chains are matters of life and death for even those people and places that would otherwise have ready access to products. The pandemic has laid bare how medical device manufacturers—whose devices are often packed full of electronics—have used tactics around warranty and repair similar to that of the consumer electronics sector and have been slow (or outright refused) to publicly release service manuals and other necessary repair documentation [25]. To put it very starkly: barriers to repair can be barriers to life.

3 ENABLERS

In contrast to barriers to repair, I identify as enablers modes of public policy intervention and emerging forms of citizen activity and advocacy that aim to make INDIY ICT M&R more accessible

and less hazardous to the environment and to those who seek to engage in it. The enablers I highlight here include public advocacy to reduce toxicants in ICT devices, the implementation of pollution release and transfer registries to assess accountability for toxicant and pollution loads, advocacy for right to repair, and the material and energy conservation potential of INDIY ICT M&R

3.1 PUBLIC ADVOCACY FOR REDUCED TOXICANTS

Although repair can prolong the useful life of devices and thereby conserve their embodied materials and energy, devices will eventually be discarded in whole or part. Thus, the conservation value of repair can be enhanced by reducing or eliminating toxicants in the design phase before devices are made in the first place. Reducing or eliminating toxicants makes for safe(r) disposal or reuse of discarded device components or the processing of them for recycling of embodied materials (e.g., plastics, metals, glasses).

Public policies exist that go some distance toward enhancing the conservation value of repair in these ways. These include legislation in the European Union such as the Reduction of Hazardous Substances (RoHS, which pertains specifically to the electronics industry) and the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). Other key legislation includes the US Lautenberg Chemical Safety Act (LSCA, an update of the Toxic Substances Control Act). While none of this legislation is explicitly about repair, nevertheless positive co-benefits arise from them that positively impact the conservation value of repair by reducing or eliminating the toxic burden of devices or their components that can no longer be repaired and are discarded into waste- or material-recovery streams.

RoHS took effect in 2006 and restricts the use of specific toxicants in the manufacture of a wide range of electronic devices. It works on a principle of maximum allowable concentrations, though the legislation maintains exemptions for some classes of equipment and some chemicals.

REACH is considerably broader in scope, covering all manufacturers and importers in the EU. REACH is also intended to phase out the use of a wide range of hazardous substances, rather than regulate based on maximum concentrations. Among its requirements, REACH obliges chemical manufacturers to register with the European Chemical Authority as well as develop and market safe(r) chemical alternatives.

LSCA is a major reform of the United States’ Toxic Substances Control Act (TSCA). In essence, LSCA provides additional regulatory power to the Environmental Protection Agency (EPA) to evaluate risks from chemicals. The LSCA changes how chemical risks are assessed. The law enables the EPA to demand

chemical risk elimination, including the potential to stop production of chemicals deemed high risk [7].

Taken together, such legislation moves the manufacturing of computing devices toward safe(r) chemical composition. Such a move reduces risks of exposure to potentially harmful chemicals by those who directly engage in repair. It also enhances the conservation value of repair by reducing or eliminating the toxic burdens that can emerge once devices or their parts reach an end-of-life state and are sent either for materials recovery (i.e., recycling) or disposal.

3.2 POLLUTION RELEASE AND TRANSFER REGISTRIES

Pollution release and transfer registries (PRTRs) are publicly accessible databases that disclose releases of chemical substances from industrial facilities [23]. The US was the first country to establish a PRTR in 1986. Known as the Toxic Release Inventory (TRI), it is a regulatory response to the Union Carbide disaster in Bhopal, India of 1984 [39]. The TRI requires a range of industries to disclose toxic chemical releases at the individual facility level, including some 1,500 such facilities in the computer and electronics manufacturing sector.

The benefits of PRTRs include enhancing public right to know through public data disclosure. Such data can assist private citizens assess their own risk of exposure to toxic chemicals. The data are also of use to researchers for answering questions about environmental justice and environmentally grounded sectoral analysis of industries of interest [36]. PRTR data are also essential for assessing the effectiveness of environmental regulations and the behavior of firms required to disclose such information. It has been found, for example, that merely the requirement to disclose toxic chemical releases can result in improvements at the level of both facilities and industrial sectors [23].

Today, some 50 countries have active PRTRs, although there are important differences in the reporting requirements between these jurisdictions [42]. Such differences place limits on what can be known about total releases of different chemicals across the different ranges of industries covered by each jurisdiction's PRTR program. Such limits to knowing pollution from a given industry, such as the computing and electronics manufacturing sector, arises because quite often manufacturing supply chains sprawl across multiple national jurisdictions, not all or even most of which may even have PRTRs in place. For example, Apple Inc. publishes a list of facilities of its top 200 suppliers totaling 770 facilities. Those 770 facilities are located in 26 countries, of which only 15 countries covering 265 (of 770 total) facilities have PRTRs. Among the most important locations not covered by a PRTR register is China where 353 facilities of Apple suppliers are located [37]. Thus, for just one electronics manufacturer, albeit an important one, Apple, it is currently only possible to glean pollution release data for roughly a third of its top 200 suppliers.

PRTRs are indirect enablers of repair infrastructure. Data from such registries are crucial for making the case about the conservation value of repair. PRTR data assist researchers and advocacy groups by making it possible to demonstrate the toxic chemical footprint of the industry—although with important limits to what can be demonstrated. Making the chemical footprint of the industry more visible helps build the case for why devices should be designed not just with repair in mind, but with repair actively facilitated through ease of accomplishment, access to parts, and to technical documentation, all of which are factors central to current public advocacy for the right to repair.

3.3 PUBLIC ADVOCACY FOR RIGHT TO REPAIR

The US-based Repair Association (RA) incorporated as a lobby organization in July of 2013 to advocate for independent third-party repair and against growing attempts by original equipment manufacturers (OEMs) to monopolize repair. RA seeks reform of legislation, regulation, and standards that will improve “the quality and longevity of products” [33]. Each year since RA incorporated, more and more US state legislatures are hearing right-to-repair bills. 2019 saw a record number of such bills heard in 20 states, although none of these bills managed to be passed, principally as a consequence of counter-lobbying on the part of OEMs.

While advocacy in the US driven by RA efforts has grown, OEMs continue to block such efforts and experiment with anti-repair tactics such as affixing warning labels on products that threaten loss of warranty coverage if device owners or third-party repair businesses attempt their own repairs. These OEM tactics are illegal, according to the Federal Trade Commission [12].

Meanwhile in Europe, a multi-year effort to pass a standard for assessing ease of repair of products put on the market came to fruition in February of 2020 [28]. European standard EN45554 creates a standard way to measure the feasibility of repair of products put on the market [49]. That the standard is directed at informing consumer purchasing behavior, it is only an initial step in requiring manufacturers to design and produce more repairable and longer lasting products. Nevertheless, as a pan-EU standard its effects will be far reaching as it covers one of the wealthiest markets in the world.

The advocacy for right-to-repair legislation in the US and EU share some commonalities. Among these are a conviction that enhancing repairability of devices is a pathway to material and energy conservation. This kind of conservation is important, advocates argue, not just for electronics per se but because of the broader social and environmental consequences of unfettered production and consumption [28][17].

3.4 MATERIAL AND ENERGY CONSERVATION POTENTIAL OF WORLDWIDE INDIY ICT M&R

Documenting ICT maintenance and repair at anything other than coarse scales of national or subnational regions is a challenge due to differing jurisdictional definitions of repair as an economic activity and what sectors of the economy are aggregated together to count that activity [24,47]. Using a novel dataset Lepawsky has recently demonstrated the global extent of independent and do-it-yourself ICT maintenance and repair activity (INDIY ICT M&R) [22]. His results show that INDIY ICT M&R involves a growing population of people numbering in the millions of individuals who are ubiquitously, but unevenly, distributed around the world. Importantly, the geographic patterns of this repair activity are only weakly associated with factors such as per capita internet access and underlying population size.

Related work has empirically examined the CO_{2e} emissions reductions attributable to a single cluster of 51 independent ICT repair enterprises performing laptop repairs in Lima, Peru. The results suggest such repair can achieve CO_{2e} emissions reductions of between 1,650–6,650 tonnes [13]. While this work points to promising possibilities of repair of computing devices as a pathway to energy and material conservation, quantifying the efficacy of such possibilities remains a work in progress. Here I briefly examine several important assumptions that must be met for INDIY ICT M&R to be a source of significant energy and material conservation in ways relevant to the concerns of computing within limits.

First, although it has been shown that millions of people are engaged in INDIY ICT M&R activities around the world [22], it remains unclear whether sufficient scale is achieved to impart genuine material and energy savings. There is anecdotal evidence from Apple, the largest OEM by revenue, that third-party repair has slowed sales of iPhones, one of its flagship products [3]. However, slowed sales of one product type is not the same thing as slowed aggregate growth for the OEM, let alone aggregate growth across the entire electronics sector.

The issue of mitigating aggregate growth of material and energy consumption for computing within limits means repair must confront the rebound effect or Jevons' Paradox [2]. The rebound effect occurs when reductions in demand for materials and/or energy result from increased efficiency of use or lengthened product use time. The net effect of per unit efficiency gains or lengthened device use times can be a slackening of demand for material and energy inputs. Reduced demand will, typically, lead to falling prices for those materials and energy resources, making them cheaper and, thus, more accessible to actors who previously used less (or none at all). As access increases, aggregate demand can also increase (i.e., rebound) even as demand falls within a given sector.

While the rebound effect is a general concept in ecological economics, specific cases relevant to computing within limits can be identified. For example, it is estimated that the ICT manufacturing sector is responsible for approximately 15 percent of global demand for tin, tungsten, tantalum, and gold [8]. Thus, if demand from the ICT sector were to fall as a consequence of material conservation effects of repair, prices for those same materials may also decline as a consequence of slackened demand from the ICT sector and, thus, increase demand for them from other sectors responsible for the remaining 85 percent of global demand.

4 CONCLUSION

Creating a world in which INDIY ICT M&R is widely accessible and in which that activity substantively mitigates the resource and energy consumption demands of computing requires action in design, manufacturing, policy, and practice arenas. Looking ahead to the emergence of such a world by 2030 points to key barriers that need to be removed and enablers that need to be promoted. Key barriers include design practices that reduce device service life; manufacturing practices that fail to mitigate or eliminate toxicants and externalities, the socialization of costs of harms and the privatization of profits from device sales; restrictive end-user licensing agreements, and the criminalization of third-party repair. Key enablers include public advocacy for legislation and regulation that reduce or eliminate toxicants in electronics design and manufacturing, require manufacturers to disclose pollution releases and transfers, and enhance right-to-repair; and growing networks of independent and do-it-yourself ICT maintenance and repair.

Important challenges must also be met along the way to this world of repair in 2030. For example, repair of already manufactured devices cannot undo the use of toxicants embodied in those devices or the externalities that arise from their original manufacture. Per unit efficiency gains arising from more robust repair networks are unlikely on their own to overcome the rebound effects of those gains that mean aggregate demand for materials and energy continues to grow. Instead, fundamental changes in design, manufacturing, and the business models on which they are premised must be instituted long before devices are in the hands of consumers and are in need of action to stave off breakdown or, once it has occurred, to overcome it. A world of 2030 in which repair could be part of the scaffold that builds it is one based not on efficiency, but sufficiency.

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