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Redesigning Computing for Openness: The Ethics of Consuming Devices

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Abstract

Consumer electronics design is an easily relatable and fast-cycling field of interest to students of all kinds, but particularly to those studying information science. Within this field, the e-waste problem is a significant ethics issue. Why does the logic of using computers involve the repeated purchasing and consumption of new machines, or “molded plastic epics” (Gabrys, 2011), and their significant manufacturing expenditure of carbon? Thinking back on calculating devices which support problem-solving and this ethical problem of repeated consumption, the simple solar calculator stands out for its durability. The reason may be the initial sustainability design: early calculators, like more recent Citizen Eco-Drive watches, use a solar ambient-energy harvesting strategy that doesn’t store electricity in batteries; consequently they are very long lasting and low maintenance. As there are very few energy-harvesting electronics devices in the market reflecting emerging green narratives of degrowth, reuse, and upcycling, this research paper reviews the history and design of some of these rare devices while discussing their energy experience design strategies in the context of modern consumer electronics. I also present a series of speculative prototypes which feature broad affordability, openness, and a more ethical consumption ethos as discussion artifacts for design education students engaging with this problem.

Keywords: sustainability, consumption, green growth, circular economy, upcycling, electricity storage

Introduction

Critical design (Dunne, 2005) involves consideration of social and ethical issues, the nature of materials, and the role and assumptions of designers and users. A design is a congealed artifact of critical ideas, even as it exists as a set of cost/benefit perspectives, design and material choices, and a technological agent for an identified context and in the world. Media archaeology studies of consumer devices, which is to say the history of electronics, suggest and reveal design alternatives to modern logics of convenience repurchasing—perhaps more consistent with older notions of repairing, upgrading, or trading, and low-cost practices including thriftiness. These are goals we would now recognize as additionally supporting carbon-reduction, degrowth, and ethical consumption. Critical making pedagogy (Ratto, 2019), like critical design, is further a chance to foreground and discuss social framing of design practices, particularly in relation to the design and cultural effects of artifacts (devices).

Method

This study discusses the detailed collection of sustainable electronics devices, articulation of their histories, study and abstraction of useful design patterns, and their application in new speculative designs involving contemporary renewable energy capabilities from my graduate thesis. The resulting collection of historical and response objects form the foundation of an exhibit to stimulate critical design conversations and embodied learning experiences around sustainable design in consumer electronics for future application to design education.

Selected Vignettes in Energy-Harvesting Design History

In design teaching, artifact-exemplars of past products highlight useful characteristics of various kinds, constituting what might be broadly called collections, histories, styles, approaches, or canons, even while they present specific use-features. Over a period of about 8 years, I collected about 100 electronics devices, dating from 1954 to present day, that function in an unusual way: they absorb ambient energy for their operation from their surroundings using photovoltaics, a strategy which has recently garnered the name “energy harvesting” but can also be known as energy scavenging or net-zero (where this latter term is sometimes used to describe energy offsets). The online [Museum of Solar Energy](https://solarmuseum.org/) (https://solarmuseum.org/) presents a widely accessible pictorial survey of some of the historical devices, but in some ways, it lacks an underlying design narrative about their development, particularly their decline or decay as effective exemplars of a technology type. See Figure 1.

Figure 1

Casio "Dual Leaf" Calculator Design Decay

Note. The newer, "two-way power" version on the right has a smaller solar panel and doesn't work under the same illumination without a battery.

With some very few exceptions, solar-powered consumer electronics products were short-lived, and design practices stabilized around the copious use of batteries, dependency on centralized electricity, and telecom-based networking services. Parts-paired manufacturing, a plethora of transformer voltages, and the difficulty of repairing, upcycling, or reusing devices also has induced friction for consumers. These phenomena occur on a larger scale with more sophisticated and expensive mass-manufactured electronics, resulting in a "fast-cycling" consumption culture—repeated purchases occur, resulting in a lot of e-waste. The majority of e-waste is undocumented, unrecycled, and transboundary (Baldé et al., 2022). Faster and more effective recycling systems are important, but this may not be the best way forward to address the root problem of pace and fast-cycling consumption. A recent study by the United Nations suggested that "the rise in e-waste generation is ... outpacing the rise in formal recycling by a factor of almost 5" (Baldé et al., 2022). This, in part, is due to the established cultural behaviour of prematurely recycling devices or discarding them rather than repairing, refurbishing, or upcycling them. Cultural behaviour is influenced by the manufactured design and sustainability features, such as the difficulty to repair and upgrade known as "use friction." It is clear, however, "digital devices are scrapped at an alarming rate" (Franquesa et al., 2015).

The collection of early devices, which I use as teaching examples for design students in Information Studies, is described in greater detail in my dissertation *Energy Harvesting Information Systems and Design in the Energy Transition* (http://hdl.handle.net/1807/130114).

Some of these have revealed a number of sustainability characteristics which are desirable from the consumer's point of view, but which manufacturers have rolled back, for various reasons, as in Figure 1. For example, if we look at the 1960s when photovoltaic cells were introduced, solar powered radios were expensive but more commonly available to purchase, such as the Hoffman Trans-Solar, shown in Figure 2. A similar introduction of solar panels occurred in smartphone products circa 2011 (Figure 3). Where is this feature now?

Figure 2

Rare 1959 Hoffman Trans-Solar Radio

Note. This radio was available in holiday red with early, unique tessellated solar cells and CONELRAD emergency broadcast markings, and was featured in the January 1959 issue of *Popular Electronics* magazine (shown in the background).

Figure 3

Contemporary Samsung Solar Phone From 2011

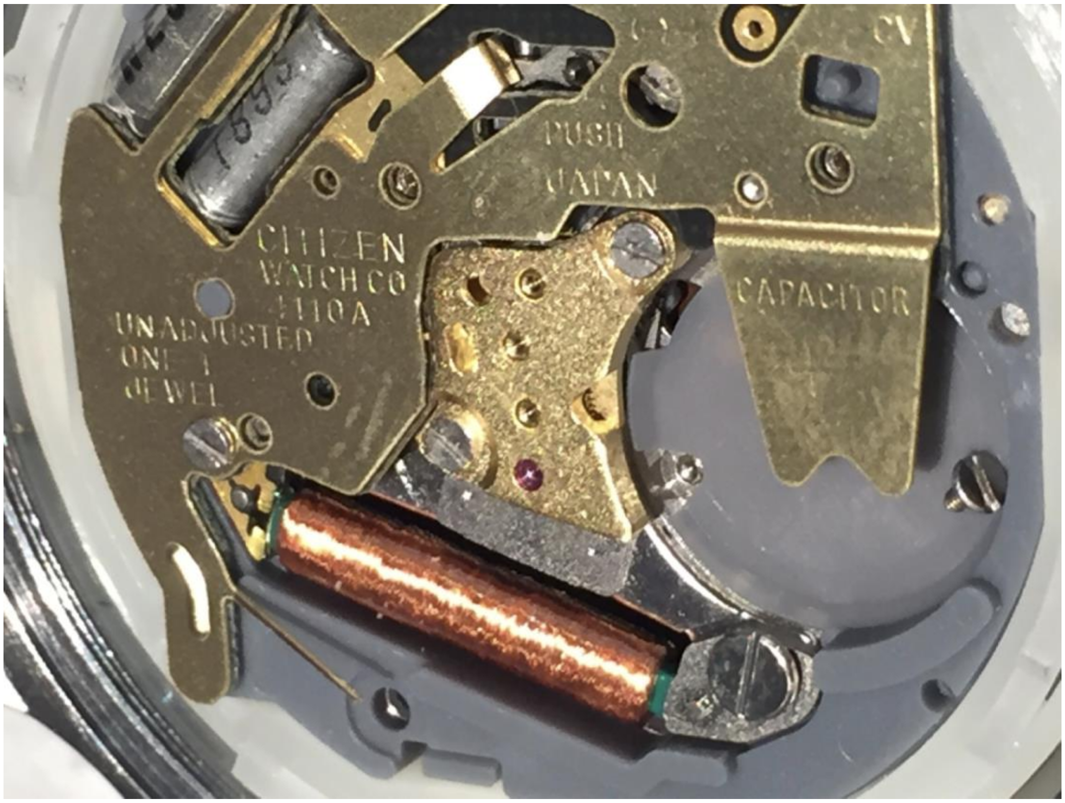
Note. Making use of a suggestive backdrop, the phone has been positioned atop Howard A. Innis's *Empire and Communications* (Clarendon Press, 1950).

A number of these solar products also had novel capabilities around sustainable energy storage. The Hoffman 709 solar radio, for example, had the ability to trickle-charge what we now consider to be single-use batteries from the solar panel, batteries which actually support recharging. Given that batteries are presently consumed at the rate of 15 billion each year, the ability to reuse batteries even a few times could have been a significant sustainability feature. Instead, we have devices domesticated around a repetitive-consumption design pattern.

A related design solution which touches on the electricity storage problem is the use of *storage capacitors* instead of *batteries*. Storage capacitors can recharge 250,000–1,000,000 times without significantly degrading, much more than the few thousand times afforded by the best rechargeable batteries that consume critical minerals. Storage capacitors were used with much success in the solar-powered Citizen Eco-Drive watches of the 1980s and 1990s, shown in Figure 4. We might wonder why this approach to powering electronics isn't more common, given the 40-year success of Eco-Drive watch technology which has saved millions of batteries from being remitted to landfill each year.

Figure 4

1980s Citizen Eco-Drive Watch Movement



Note. The interior view of the Citizen Eco-Drive watch showing the location of the storage capacitor.

Aside from highlighting durability, low maintenance, and minimal consumption, this research illuminates repairability as a key feature, in the sense that communities of consumers, repairers, and collectors share information and are often responsible for maintaining old electronics devices. They are aided in this task by open and universally recognized standards, the availability of parts for multiple years of a design, parts interchangeability between model years, full access to repair documentation, and user-accessible repair spaces which make it easy to perform maintenance. From these communities of enquiry come proposals concerning right-to-repair legislation, systems criteria, parts criteria, and rating systems for the calculation and display of the repairability index. For example, the French government has a program where manufacturers of electric equipment and electronics are systematically studied, rated, and incentivized to achieve a high repairability index according to specific desirability criteria logically broken down by consumer groups and repairer groups (République française, 2020).

Speculative Electronics Designs for Openness and Sustainability

Aside from the necessary framing relations to reinforce sustainability values within design and manufacturing communities, design histories, features, and innovations which support sustainability, ones we can get behind, are important to understand and document: to illuminate ways and means to future goals. The response designs in this exhibit therefore reflect the above study of historical sustainability (or durability) features, characteristics which, in a speculative way, address necessary reforms to the consumer electronics industry from fast cycling to a less consumption-oriented future—one also involving greater consumer satisfaction.

My first design intervention is based on the Public Radio (https://www.thepublicrad.io/) by Zach Dunham and Spencer Wright. See Figure 5. This project was crowdfunded into being about 2015, and its blueprints, bill of materials, software, and so forth are open source and available online. The Public Radio is essentially a solid-state, ultra-low-power FM radio designed to fit in a wide-mouth standard Mason jar lid, powered by two AA batteries. By swapping the batteries for an energy-harvesting system consisting of parallel hybrid supercapacitors, a Schottky diode, and an inexpensive solar cell, the public radio can work for a week, similar to the way it normally does when it consumes AA batteries, but with an ambient energy collection system and permanent energy storage that could last multiple user-lifetimes. The Mason jar has been around since 1858, a singularly open design—there will be no problem replacing parts! There's also an aesthetic resonance to the idea of electricity storage within a Mason jar—which was designed for storage—and with the history and creation of capacitors involving the Leiden jar. More explicitly, this speculative design reflects an electronics ethos that is broadly documented and open: the radio container is a common, universal format (probably reused), and, in theory, the ambient-energy harvesting and storage system should maintain the radio working without any further consumption of energy or materials for *decades*.

Figure 5

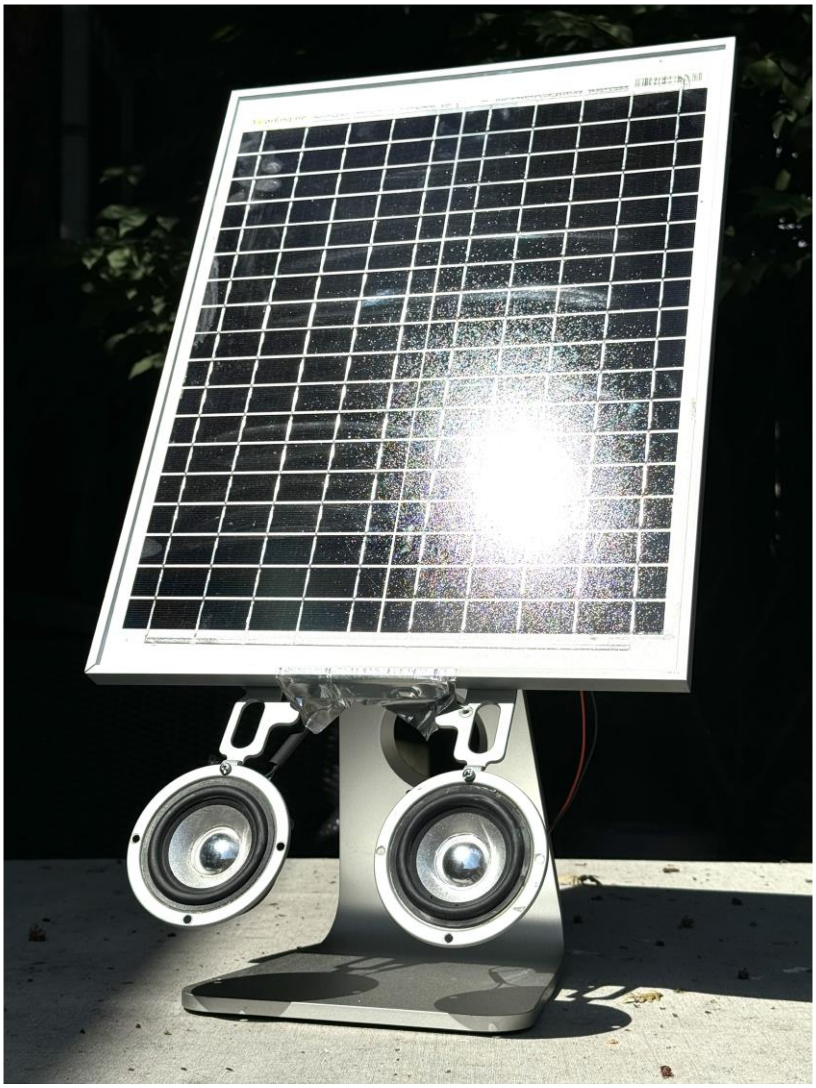
Modified Public Radio by Dunham and Wright

Note. I redesigned this ultra-low-power FM radio (https://www.thepublicrad.io/) to operate with a batteryless energy-harvesting system.

My second design intervention represents a more conscious reuse of the materials of manufacture given the state of electronics recycling previously referred to. It involves a combination of a recycled 27” iMac aluminum foot, a 20W solar panel, six hybrid supercapacitors, and a Bluetooth receiver/amplifier. Aside from their durability and longevity, supercapacitors have the benefit of improving the audio performance of portable-power stereo systems. So this speculative design reflects reuse of mass-produced components bound for e-waste—a computer frame and some speakers—while incorporating a new ambient energy-harvesting system from long-lasting, proven-maintenance-free components.

Figure 6

Speculative Electronic Design: A Batteryless Bluetooth Speaker



Note. Assembled from a 12V, 20W solar panel, a recycled iMac computer stand, and audio components, this speculative design functions as a Bluetooth stereo, diverting e-waste from the landfill and running without batteries!

In addition to larger entertainment devices that reflect degrowth and low carbon values, more complex machines with digital outputs have been powered by energy harvesting, storage, computers, and server networks. [Solar Protocol](https://solarprotocol.net/) (https://solarprotocol.net/), for example, uses networks to provide research materials from solar-rich areas, swapping out Raspberry Pi servers as the sun travels across the sky in an energy-centred design provocation (Brain et al., 2022). A further example of energy harvesting for public rendering of Internet services occurs as I serve the entire [Project Gutenberg](https://www.gutenberg.org/) (https://www.gutenberg.org/) collection of free e-books from a tiny Internet-of-Things energy-harvesting computer hotspot, the [Sustainable Little Free eBook Library](https://www.youtube.com/watch?v=ZnWGR28lSd4) (https://www.youtube.com/watch?v=ZnWGR28lSd4), which also uses supercapacitors instead of batteries, in addition to deep-sleep modes, to conserve power between uses.

The third design device I created was a small workstation computer consisting of a Raspberry Pi4 and LCD screen, both powered by an industrial rooftop solar panel and large ultracapacitors (Figure 7). Because of the limited energy storage potential of the capacitors, as the sun sets, the computer begins to run out of power, and the user must more consciously strategize energy-aware behaviours involving use as well as winding up work tasks, a practice which, it might be argued, is conducive to work-life balance and healthy disconnection from digital networks for physical ones. It would be a true "digital sunset." Energy-experience design reflects a new way to evaluate consumer-use experiences involving sustainability and the application of energy within a sustainable lifestyle (Sutherland, 2024).

Figure 7

Work Station Powered by Solar and Ultracapacitors

Note. This Raspberry Pi 4 and 27″ HP monitor are batteryless, powered by a solar panel and ultracapacitors, to yield a speculative design of a workstation that promotes work-life balance.

While the desirable sustainability goal would be batteryless electronics which are extremely long-lasting right from the initial manufacturer's design, in order to reduce repeated performances of consumption, we might also seek opportunities for more sustainable operation from our existing infrastructure, engaging emergent sustainability possibilities with upcycling. For example, the energy consumption of laptops that use the Apple silicon or ARM processor is such that with low-power software modes, the laptop's normal operation is within the range of the solar-generation potential afforded by small solar panels. One might prevent one's laptop battery from running down during use, or charge it during periods of non-use, simply by connecting it to a portable system. My last design, shown in Figure 8, consists of a recycled artist's suitcase, a 20W Solar Engine panel, and a conventional laptop to make a kind of portable energy-harvesting portmanteau, able to prevent a laptop battery from discharging when the system is deployed in full sun. With a long USB cable, the user can be comfortably ensconced in shade while the panel collects the required energy. Of course in outdoor public settings, physical security for devices is more of a concern, but the concept of portable charging from a briefcase is nevertheless a useful speculative design, particularly as wireless network infrastructure densifies to support mobile work practices in urban areas.

Figure 8

Portable Workstation Powered by a Solar Panel

Note. Speculative design for a solar panel portmanteau and Macbook Pro 16 (2021). Includes a 20W Solar Engine panel, 12V to USB-A adapter, and a yellow Ikea Sittbrunn USB-A to USB-C cable.

Educational Application

Speculative work involving sustainability occasionally overlaps with wider interventions involving the digital divide, providing access to digital content and computing for development. Pargman and Raghavan (2014), speaking about sustainable human-computer interaction, noted that “remaking today’s unsustainable societies and shifting today’s unsustainable trajectories” involves “breaks with centuries-long processes and entrenched mindsets” (p. 645). In this space of a fuller understanding of consumption and a remaking of the electronics industry, this design case study is situated. Ethical systems contribute to the resilience of societies abundantly served by networks of manufacturing, energy, and information, but they may also benefit societies underserved in these areas, where sufficiency, repair, and adaptation skills, rather than repeated, unreflective consumption, serves as the more logical, ethical objective of design. The creation of speculative designs informed by historical understanding is key to moving these conversations forward with new generations of students.

Conclusion

The historical and speculative devices presented in this paper (there are others not discussed here) illustrate that the project of redesigning electronics for openness and ethics, and to reduce consumption, would benefit from using widely accessible standardized hardware (in the case of the Raspberry Pi, it is supported by a foundation), high energy efficiency designs, the ability to repair, swap, upgrade, and reuse parts, and an effective energy-harvesting strategy. Such designs also benefit from software and hardware concepts not discussed here, such as checkpointing software for power interruptions, new forms of long lasting memory (FRAM), and systems of standardized, user-accessible interchangeable parts. I suggest that overcoming the fast-cycling culture of portable electronics requires exploring in a very deliberate and tactile way—and in education spaces—prototypes which have designed-in sustainability features that resist consumption and manifest long-lasting, upcyclable device-design. An open system which absorbs energy from the environment and does not suffer from battery obsolescence, the premature reduction in the useful life of a device due to the chemical deterioration of battery storage, is particularly an important part of this conversation around ethical consumption and future design enquiry.

Author’s Contributions

This is my original work.

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Ethics Statement

Ethical approval was not required for the work described in this article.

Conflict of Interest

The author does not declare any conflict of interest.

Data Availability Statement

Not applicable to this research.

References

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., di Cortemiglia, V. L., Lobuntsova, Y., Nnorom, I., Pralat, N., & Wagner, M. (2024). *The global e-waste monitor 2024*. International Telecommunication Union (ITU) & United Nations Institute for Training and Research (UNITAR). https://web.archive.org/web/20240914104157/https://ewastemonitor.info/wp-content/uploads/2024/03/GEM_2024_18-03_web_page_per_page_web.pdf

Brain, T., Nathanson, A., & Piantella, B. (2022). Solar protocol: Exploring energy-centered design. *Eighth workshop on Computing Within Limits 2022*. https://limits.pubpub.org/pub/solar

Dunne, A., & Raby, F. (2024, June 5). *Critical design FAQ*. Dunne & Raby. https://web.archive.org/web/20250128201451/https://dunneandraby.co.uk/content/bydandr/13/0

Franquesa, D., Navarro, L., L'opez, D., Bustamante, X., & Lamora, S. (2015, January 1). Breaking barriers on reuse of digital devices ensuring final recycling. In V. K. Johannsen, S. Jensen, V. Wohlgemuth, C. Preist, & E. Eriksson (Eds.), *Proceedings of EnviroInfo and ICT for Sustainability 2015.* Atlantis Press. https://doi.org/10.2991/ict4s-env-15.2015.32

Gabrys, J. (2011). *Digital rubbish: A natural history of electronics*. University of Michigan Press. https://doi.org/10.3998/dcbooks.9380304.0001.001

Pargman, D., & Raghavan, B. (2014). Rethinking sustainability in computing: From buzzword to non-negotiable limits. In V. Roto & J. Häkkilä (Chairs), *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, fast, foundational* (pp. 638–647). ACM. https://doi.org/10.1145/2639189.2639228

Ratto, M. (2019, April 9). *Critical making*. Open Design Now. https://web.archive.org/web/20250525083532/https://opendesignnow.org/index.html%3Fp=434.html

République française. (2020). *Décret no. 2020–1757 du 29 décembre 2020 relatif à l'indice de réparabilité des équipements électriques et électroniques* [Decree no. 2020-1757 of 29

December 2020 on the repairability index for electrical and electronic equipment]. https://www.legifrance.gouv.fr/loda/id/JORFTEXT000042837821

Sutherland, B. (2018). *Sustainable little free e-book library* [Video]. YouTube. https://www.youtube.com/watch?v=ZnWGR28lSd4

Sutherland B. (2024). Energy experience design. *Tenth workshop on Computing Within Limits 2024*. https://doi.org/10.48550/arXiv.2508.05869