Powering the Digital: From Energy Ecologies to Electronic Environmentalism

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Electronics and all that they plug into are energy intensive. An increasing amount of energy (and resulting carbon emissions) is required to power everything from Google searches to spam and text messages, which in turn involve a vast range of resources including data centers, digital devices, and fiber optic cabling to connect and transmit information. Varying estimates place the quantity of energy consumed to power digital devices and networks at around 1.5 to 2 percent worldwide between 2008 and 2011. This is a quantity roughly similar to the aviation industry, and is expected to grow to 3 percent of total world energy use by 2020.[1] Fossil fuels in the form of coal and oil provide a primary proportion of the energy consumed by electronics and their networks, because these continue to be the main sources of energy worldwide.[2] Indeed, data centers, as Greenpeace notes, could be seen as the "factories" of modern-day economies, because 50 to 80 percent of the electricity used to power data centers is obtained from coal.[3]

The material and media ecologies that connect up coal to data and devices are disparate and do not significantly register at the point of using digital technologies. Yet energy is used not just to power data centers, but also for air conditioning to keep servers from overheating, to power numerous electronic technologies that connect up to data centers, and to manufacture devices in the first place. Energy then contributes to powering devices and their networks, and to the energy needed to produce machines, which is a highly energy-intensive process. Because the manufacture of electronics now principally takes place in countries such as China, Taiwan, and India, a considerable amount of the energy used to manufacture electronics is also generated from coal. Eric Williams has explained that over their lifecycle, electronics are "probably the most energy intensive of home devices aside from furnaces and boilers."[4] The energy to manufacture, power, and connect electronics is consumed in quantities that are far more abundant than these seemingly immaterial devices imply. Indeed, if one were to account for all the energy used to manufacture, power, connect, cool, maintain, and eventually recycle and dispose of electronics, estimates of electronics-related energy use would increase even further. To date, however, estimates of energy use have largely focused on the manufacture and use of devices and networks.

In this chapter, I consider how electronics generate distinct materializations and media ecologies through distributions, use, and arrangements of energy.[5] The energy required to power electronics and their networks is a seemingly immaterial but operative aspect of digital technologies as an industry. Yet as electronics become pervasive and supplant non-digital media and exchanges such as books and social networking, and as computing becomes ubiquitous so that new forms of "smartness" are embedded in environments, questions emerge related to what types, quantities, and distributions of energy resources are required to power these digital worlds.

First, I discuss the amount and type of energy that electronics consume as a form of (electronic) waste, and I further take up a consideration of how electronics have become central operators in *managing* energy use in order to achieve sustainability. The smart meter is the emblematic technology for achieving energy efficiency, but a whole host of digital devices, apps, smart grids, and assorted technologies have been developed to address issues of energy consumption in relation to climate change. In what ways are the materialities of energy articulated and experienced, whether through the relatively remote infrastructures of energy in the form of data centers and manufacturing sites; or in the form of technologies to manage energy use? In what ways do digital technologies mobilize, distribute, materialize, and activate energy practices and relations?

Second, I attend to the ways in which energy efficiency is operationalized through electronics, while also asking in what ways practices of consuming or rerouting energy use through electronics raise questions that go beyond efficiency. Estimates of energy used to power electronics are significant in one sense because they are an indication of the material immaterialities of electronics and their networks, which operate seemingly free of resources. In another sense, the energy required to power electronics results in distinct forms of pollution that are different from the stacks of abandoned digital devices often associated with electronic waste. The material fallout from electronic energy registers in different ways, both in the resources used to power these devices and in the embedded energy used to manufacture them: through carbon footprints, coal dust, greenhouse gas emissions, and extensive land use taken up with data centers (and power plants).

In many cases, information technologies are now promoted as devices that help to achieve efficiencies within any number of processes, from energy supply and distribution to urban transport. Digital technologies appear to be green because they seem more immaterial, and because they can make processes more efficient. Together with the proliferation of personal mobile and computing devices, there is projected to be a massive increase in the number of smart technologies, such as energy meters and smart grids, that will ostensibly be directed toward making systems more efficient and environmentally sound. These developments raise real dilemmas as to what "green technology" means: can a technology be green if it is hazardous in its manufacture, prone to obsolescence, and difficult to dispose; and can a technology be green if it is largely powered by coal energy and contributes to increasing carbon emissions?

By focusing on the ways in which energy use and management is articulated through digital technologies, specifically the smart meter, I develop the concept of *electronic environmentalism* in order to attend to the ways in which digital technologies have become central to how we identify and act on environmental problems to arrive at potential solutions—and what the effects of these distinctly digital approaches may be. On the one hand, what I am calling electronic environmentalism emerges as a way of using electronic technologies to monitor and manage energy use, while also supplanting potentially more carbon-intensive activities with energy-saving virtual parallels, for instance, teleconferencing rather than flying to a meeting. On the other hand, the mostly remote infrastructures of energy and material resource use that support these electronic activities show up in the form of data centers, as well as the vast array of related infrastructures from manufacturing to disposal sites, that make the extensive materiality and resource footprints of electronics less evident. Electronics are developed to achieve environmental targets, and along the way, electronics generate new environmental problems. Electronic environmentalism is a term that captures and analyzes how digital approaches to managing environmental problems are entangled with distinct material politics, effects, and concerns.

Transforming the Material Politics (and Ecologies) of Digital Pollution

While energy use contributes to the material resource use and waste of electronics, the residues from digital devices also include everything from discarded electronics at end-of-life to resource-intensive manufacturing processes, information overload, and software obsolescence. I have previously written about these other forms of electronic waste in the study *Digital Rubbish,* where I developed a material method, or "natural history" approach, to rematerializing electronics by focusing on the ways in which they generate waste. Electronic waste is one of the fastest growing waste streams worldwide, and the volumes of e-waste generated are estimated to be between 20–25 million tons per year to 35–40 million tons per year (and rising).[6] Electronic waste is hazardous and difficult to recycle at end-of-life, and is often processed in harmful ways, which raises consider- able environmental justice issues. Lead, mercury, and brominated flame- retardants are just a few of the harmful chemical-material components that make up electronics.[7] Electronics also require and generate hazardous waste products during their manufacture, and the working conditions of electronics manufacturing and recycling are typically harmful to human health.

Yet there continues to be a widespread sense that digital media are relatively resource-free technologies, and that they may even promote a green lifestyle by using fewer resources than analog equivalents, or through ongoing monitoring of consumption activities. Although digital technologies appear to be immaterial, as the environmental issue of electronic waste indicates, the material effects of digital media are significant. But what do I mean by material effects? What is the material life of digital media? Materiality here does not signal a sort of rawness, hardness, or physical evidence of material, as some writers may emphasize, but instead refers to processes whereby materialities cohere and stabilize, and so inform our ways of life, as well as everyday practices and relations. While electronic waste demonstrates the materiality of digital media, it signals not the fact of all that is *solid* in contrast to the apparently *virtual* movement of information. Materials are not simply hard or raw or inert stuff. Instead, electronic waste demonstrates the *processes of materialization* that digital media are entangled with. These processes include our contemporary material cultures of technological fascination, repetitive cycles of consumption, built-in obsolescence, poor resource use, and labor inequalities, in addition to environmental pollution.

A practice of taking into account the material effects of digital technologies is not simply a matter of tabulating a life-cycle analysis, where physical inputs and outputs are added up and assessed for damages to be remedied, but rather requires attending to the relations, practices, and inhabitations that are put in place through these material arrangements. So what does this processual approach to materiality afford? An approach to *materiality as process* is important not just for understanding the environmental and socio-cultural effects of digital media, but also for rethinking the material politics and ecologies of these technologies, and for developing possible sites and strategies for creative intervention.[8] To discuss electronic waste as an environmental issue, it would then be necessary to include the complex material cultures of digital technologies, including the apparently virtual or immaterial qualities of those technologies, the environmental health and unfair working conditions that are a part of their manufacture, the digital economies that revolve around increasing rates of electronics consumerism and obsolescence, and the accumulation of discards and environmental fallout that comes with the decay of these technologies at end-of-life.

The case of energy as a form of electronic waste raises related yet distinct issues concerning the materiality of electronics. While all of these processes are critical issues for addressing the ways in which electronic technologies generate complex material ecologies and economies, yet another aspect of "digital rubbish" is the increasing amount of energy (and resulting carbon emissions) required to power electronics in the form of devices, networks, and processes. Energy from electronics constitutes distinct types of material processes and waste in the form of distant resource use and airborne emissions, which contribute to the heat of a warming planet.

The specific ways in which electronics might be identified to generate waste in the form of energy are often told through the tool of the carbon footprint, where a Google search has been calculated to generate carbon emissions between 0.2 grams and 7 grams of CO_2,[9] while an average spam email generates "emissions equivalent to 0.3 grams of carbon dioxide (CO_2) per message." Multiplied by 62 trillion spam emails sent in 2008, and this cumulative amount of emissions from spam is equivalent to "driving around the Earth 1.6 million times."[10] Whereas each individual search, page use, or email sent might have a comparatively small resource or greenhouse gas footprint, the amounts of data sent, received, stored, and otherwise processed contributes to overall energy use and emissions of considerable quantities.

Attempting to demonstrate the increasing demand for energy needed to power and connect up digital technologies, these carbon footprints make evident the resource requirements of seemingly fleeting and immaterial activities such as internet searching and social media browsing. But energy use inevitably has an impact that goes beyond the measurement of how much more CO_2 is entering the atmosphere and accelerating the effects of climate change. Indeed, with ongoing coal use there are issues of coal- mining extraction as a highly damaging land use, and coal mining also as an occupation that generates significant health risks and environmental justice issues. Or with nuclear energy, a whole attendant set of issues emerge related to where power plants are sited, how they are subsidized, where the waste goes, and what happens if power plants fail. And with unconventional oil and gas production, the details of groundwater contamination, air pollution, or land-use conflicts also become significant energy-related problems. Even with these quickly noted energy dilemmas, it becomes evident that the energy used to power electronic technologies has political, social, and environmental effects that go beyond the increase of carbon emissions to encompass much more complex ecologies. As Kate Rich has pointed out, the imagined and much touted commons of the internet does not translate well into a commons of infrastructure, land use, and energy production that is required to power the digital commons.[11] These relatively unmapped geographies of (digital) energy support our seemingly common and materially immaterial digital ventures.

Moreover, energy and energy use do not readily register as waste. Waste and dirt might often been seen to be "matter out of place."[12] In this well-known assertion from anthropologist Mary Douglas, dirt is an object or material effect transgressing socio-cultural boundaries and categories, some- thing that is expressive of states of disorder. These forms of dirt may become visible by showing up in the wrong places: by crossing boundaries and categories, what would otherwise seamlessly circulate within systems here disrupts them. Waste offends and dirt displeases because they are visible in the wrong places when they would otherwise be overlooked or out of sight. Douglas attributes dirt with the qualities of taboo, impurity, ritual, and pollution; this analysis migrates into a discussion of "secular" pollution and risk, with an attention to the types of pollution that develop as sites of social concern with the rise of environmental awareness in the 1970s and beyond.

Yet the pollution from electronic energy that circulates in the form of greenhouse gases and excess CO_2 is often not evident in an overt material form. It is present as indeterminate matter. Dirt and pollution are not registered through a first-hand encounter, necessarily, but rather through arrangements that are political, scientific, bodily, and environmental. The "dirt" of energy does not turn up as litter or rubbish in the same way that Styrofoam containers or plastic bottles do, but rather circulates in the relatively immaterial if no less potent form of CO_2 emissions, particulate matter, and other airborne emissions. The material infrastructures of energy and electronic networks might be made evident—in the form of data centers and devices and coal—but the emissions that are the primary form of pollution from energy are often detected only in their effects and material transformations that take place within systems, bodies, and ecologies.[13] Making emissions—particularly CO_2—sensible involves a whole host of infrastructures and practices, from scientific models to policy to ecological field studies.[14] But this is not matter out of place, as much as pollution that becomes relevant in relation to material-political and environmental processes.

In just this way, the US Environmental Protection Agency (EPA) under- took one notable project that sought to make greenhouse gases visible as pollution. The organization reclassified greenhouse gases as air pollutants in 2007, and with this designation attempted to use the policy instruments of the Clean Air Act to mitigate climate change.[15] Here, a typically colorless and odorless gas such as CO_2 that is a common substance in the Earth's atmosphere becomes evident within environmental policy spaces as a pollutant because its increased concentration changes relationships within environments, populations, politics, and futures. Carbon emissions—the fallout from energy—become evident not as a material out of place, but as a set of relationships that emerge through the matter of increased concentrations and altered materialities. In this respect, pollution could be seen as an ongoing and transformative material relationship, rather than a sequestered space or boundary beyond which waste-based materialities are identified.

Rather than focus on the ways in which boundaries or classifications might be seen as productive of order, or forms and places of matter—the structuralist emphasis that is at times drawn out of Douglas's work in relation to dirt—how might an attention to pollution as material process shift understandings of what constitutes waste? If we extend this analysis, waste and pollution could be seen to be about matter*ing,* or about generating new material arrangements that also give rise to distinct matters of concern. Here mattering is also about how things have relevance.[16] The waste and material fallout from energy reveals that not only are the qualities of pollution shifting, but also that they are entangled in a set of transformative materiality effects. CO_2, for instance, has a transformative effect on a whole host of other materialities, including potentially forcing previously non-polluting entities such as methane-storing permafrost into pollution-making modalities. The mattering that takes place involves complex feedbacks among different forms and trajectories of pollution. The materialities that emerge and the forms of mattering that might be described in this context have less to do with "things" in coherent, disassembled, or disordered states,[17] and more to do with complex material politics, processes, effects, and (media) ecologies of mattering.[18]

Michel Serres is a writer who attends to the ways in which waste and pollution are part of the processes of material transformation. Working with an approach to waste and pollution that is more topological, Serres relies less on the notion of things being out of place, and more on how things transform and are transformative of places and things. For Serres, mattering—or material transformations—do not necessarily involve boundary-crossings across which order and disorder are mediated, but rather consist of transformations that occur through relationships to entropy and flux.[19] The expanded modes of mattering that energy gives rise to include CO_2 and other airborne emissions, heat, coal dust, and wasted heat and energy that leak from the multiple distribution infrastructures. Pollution describes these shifting and transformative arrangements of mattering— rather than matter necessarily out of place.

If the pollution of energy could be seen to emerge in different ways and through different modes of mattering, how might these processes begin to be described, particularly in relation to electronics? By undertaking a processual approach to materiality, it may then be possible to expand beyond treating materiality only as that which is tangible, visible, or physical, to suggest instead that materiality relates to sedimentations, arrangements, and relationships that continue to hold our existing energy practices together. A "material" intervention in the space of electronic energy, in this sense, might not necessarily even consist of an object as such, but instead might consist of a new arrangement of energy practices that rematerialize or recast the taken-for-granted sedimentations that make up our everyday energy ecologies.[20] Immateriality, moreover, might be an important part of the performance of materiality, where electronics operate as though they are resource-free; or where energy appears to be endless and in constant supply. What are the arrangements of mattering that are articulated through electronic energy consumption? How might an expanded understanding of these arrangements point toward ways of unsettling and rematerializing current energy practices?

Digital Energy: Monitoring the Crisis as We Create It

Imagine a near future of electronic waste, where alongside the more prehistoric artifacts of desktop computers there also accumulate piles of energy monitors and assorted smart grid technologies, which amass as the debris of the drive toward efficiency and, apparently, sustainability. Electronics such as smart meters have emerged to monitor and track energy processes in order to lessen environmental burdens, and yet at the same time require resources and energy for their manufacture and use, and are eventual contributors to electronic debris at end-of-life. These digital technologies are the anticipated debris from using electronics to manage and monitor an environmental crisis in the form of climate change, while contributing to other crises in the form of fossil fuel extraction and land use degradation, hazardous pollution, impairment of environmental and human health, as well as climate change. The identification and management of one crisis, in fact, seems to give rise to and even occlude others.

For the remainder of this chapter, I now turn to the discussion of one of the objects and ecologies of digital energy—the smart meter—in order to draw out the ways in which electronics are entangled with the management and use of energy. Energy monitors and their associated infrastructures are not typically regarded as digital media, but I would like to suggest that we approach these technologies as media forms, practices, and ecologies, which further function within and through processes of materialization and dematerialization that are characteristic of so many other digital technologies. The point of doing this is to draw attention to the ways in which digital functionalities are not exclusively located within an identifiable computational object, and furthermore, the sites and distributions of computation may even shift through electronic appliances as banal as energy monitors. What digital operations are enabled vis-à-vis energy monitors, and how might energy monitors rework what counts as digital media? What sorts of computational processes do these electronics generate, so that these technologies inevitably need to be approached and understood as more than devices? What are the media ecologies that emerge with smart meters, and how might a materialized digital media analysis shed light on their environmental effects?

Energy monitors might be considered as one of many technologies that are now made up of electronic components and so constitute electronic waste at end-of-life. A seemingly less "expressive" technology than social media and other digital media for which revolutionary claims are frequently made, energy monitors are one of many newly emerging electronics that are developed for the specific purpose of increasing sustainability through awareness and efficiency mechanisms. Energy monitors promise to be technologies that will remake our material practices in order to generate greater sustainability and efficiency. And energy monitors, smart meters, and designed interventions into energy use and interaction are presented as explicit strategies to visualize and materialize energy use.

One smart meter, plugged into the electrical mains in any house, monitors domestic energy use from this central point, gathering data on electricity (and gas) use, while in some scenarios potentially talking to appliances through a Home Area Network (HAN), gathering and sending several hundred packets of data per day via GMS radio signals, continually duty cycling while potentially hopping across neighboring energy meters in order to find the most efficient pathway to the nearest mobile phone tower, from there talking to the Wide Area Network (WAN) first to a data management company that is likely a subsidiary of a multinational outsourcing corporation, which holds the data in a cloud architecture, processes and makes available this data to energy companies, governments, and other "relevant parties" still to be determined. Software may be used at various stages across this cycle to manage energy use in the home and across the grid, to make predictions and optimize configurations, while seeking to lower costs, thereby requiring a smart grid and smart meters, as well as the ability to program and reprogram meters remotely, as new meters are rolled out in a first phase, second phase, and an endless array of next phases of testing and updating.

Some of the technologies in this smart meter assemblage are currently existing, such as the meters themselves, while other aspects of this scenario are still in development, such as the HANs, which are an anticipated technology underway as part of a larger push toward the internet of things.[21] Meters meant to make energy use more efficient, begin to double as pilot projects for testing the internet of things on a domestic scale—as they initiate the chattering of appliances, the home network, the house-sized computer, all under the banner of managing and reducing resource use—as well as provide a way for energy companies to manage and monitor energy use remotely so as to lower costs and avoid site visits. Along the way, the problem of data security inevitably surfaces: who has access to data, how are data used, and what do these practices mean for surveillance, hacking, and breakdown via energy infrastructures?[22]

In the project of implementing smart meters, which is a computational project, electronics monitor and manage while using and rerouting energy use, and in the process create new materializations of both computation and energy. Within these materializations and matterings of energy, smart meters, animated appliances, and smart grids are part of the emerging apparatuses for measuring, balancing, displaying, and bringing to relevance data on energy consumption, with the intention to mitigate and reduce the levels of energy consumed. On the one hand, electronics, while they consume energy, may point toward more efficient uses of energy, where smart grids may modulate demand and smart meters may aid in the reduction of energy. Efficiency through digital means is also proposed as a way to replace energy-intensive activities such as transport, where online meetings may replace air travel. Electronics, in this sense, are technologies for rematerializing a whole number of inefficient energy uses. At the same time, electronics and computing companies are increasingly making pledges to run their operations and production through efficient (and at times renewable) energy sources.[23]

Setting out to study just how much energy the internet requires for its construction, operation, and maintenance, Barath Raghavan and Justin Ma arrived at a rough estimate of between 170–307 gigawatts (GW) yearly.[24] Calculating both energy and "emergy," or energy that is embodied in devices and infrastructure, the authors suggest, however, that the overall share of energy consumption across internet-based technologies is comparatively small, and that computational technologies may even offer energy-saving strategies by substituting networked processes for resource-intensive industries such as transport or manufacturing. In this estimation and proposal, electronics may consume energy, but they also provide the basis for achieving greater levels of energy efficiency.

For all of these initiatives, there still exist multiple critiques of efficiency as an energy-saving strategy. While there is not space here to discuss these arguments, discussions around the "rebound effect" in energy literatures have pointed out that energy efficiency does not automatically lead to an overall reduction in energy consumption, and may even have a "backfire" effect by contributing to increased production and consumption due to lower prices or greater availability of resources.[25] Efficiency, these literatures note, is not the same as conservation or actually using less overall energy; nor does it address the need to switch to non-fossil fuel sources of energy. But what is notable within the electronics-making-energy-efficiency proposals are the ways in which electronics are operationalized to make energy reductions, and so become part of the materialities of energy, and part of the understanding of what it means to materialize energy in order to reduce energy use. Electronics for energy efficiency is part of this process of mattering, where attention to the pollution from energy use leads to strategies to intervene within energy ecologies. The problems with an efficiency-only approach may further be made evident as it does not attend to the source of energy, for instance, whether coal or shale oil or solar power or waste heat. The process of making energy use more efficient, where energy sources may be sourced from highly polluting fossil fuels, is clearly problematic if the overall objective of using less energy is to address climate change.

Here, a digital version of materiality is deployed in a specific way to encourage sustainable behavior, or electronic environmentalism. Yet what articulations of materiality are at play here? Electronics on one level might be understood as descriptive technologies, which are ideal devices for capturing, monitoring, and managing current conditions. Energy use may be monitored, usage statistics described and captured, as well as communicated for management of supply and demand. This descriptive monitoring capacity of electronics is important to consider in the context of environ- mental and material approaches to digital media. Energy monitoring performs through a computational logic of enabling an informational approach to evidencing material resources as they are used. But do electronics, which may be ideal for describing and monitoring, through the very act of monitoring make practices for rerouting or changing energy practices more remote? By materializing energy use, what do electronics make matter, or cause to be relevant? And how do these electronic versions of environmentalism sustain distinct approaches to material practices and politics while impeding others?

Electronic environmentalism in many ways might sustain energy practices as they are. The subheading of this section draws attention to this unusual capacity of electronics, which is something that UK-based media artists YoHa have remarked on in describing "Coal-Fired Computers," a project that makes the connections between coal energy, mining, occupational disease, and computer use evident through the creation of a steam engine. YoHa suggest that electronics, or as they term it, the "relentless conceptual machines of software cultures"—may enable us to "monitor the crisis as they create it."[26] Electronics that enable the monitoring of environmental distress may also be contributing to those same problems. And a pressing question emerges as to whether displaying and materializing the "facts" of electricity consumption will necessarily inform or change the material politics of energy use. This is why working with a processual approach to materiality could generate different considerations of how materialities form. This is also why asking after what expressions and forms of materiality are made *operational* is important, because through these electronic environmentalist interactions distinct materialities are made evident so as to promote distinct types of practices and actions—or inactions.

From Media Ecologies to Ecological Media

The energy required to power the vast server farms, networks, and more that support digital devices and processes is a relatively remote but operative aspect of digital technologies as an industry. The increasing demands for power generate waste not just in the form of carbon emissions and land used for new data server centers, but also through power failures and website disruptions. How would an internet of periodic but regular black-outs change our relationships to digital technologies? Would a more deliberate encounter with the energy of digital devices and practices generate alternative materialities for these technologies?

Perhaps because electronics appear to be engines of the perpetually new, they are readily adopted to address environmental issues since they seem to be technologies that enable change. What emerges here is not just the novelty and obsolescence of digital media, but also new uses of media and the revolutions they promise to achieve, the new economies and ecologies they promise to generate. Yet as instruments developed to monitor and so lessen environmental burdens, energy monitors at the same time contribute to the material effects and transformations of environments. The electronic environmentalism that materializes at this intersection is then characterized by a complex set of practices that would at once monitor environmental impacts here in the form of energy use, and yet through the act of monitoring potentially lead to an impasse of information disconnected from effective or alternative actions.

In keeping with the themes of this edited collection on media and ecological crisis, in other words, I am asking how energy monitors in their manufacture, use, and eventual disposal, might both contribute to environmental issues while attempting to mitigate them. Energy monitors do not ostensibly register as digital media. Yet this computational arrangement, as I argue here, should be considered both for the ways in which it reworks the materialities of digital media, and also for the extended ecologies and processes it sets in motion. Electronics are then doubly bound up with the mattering of energy, both in the ways in which energy use, as well as its distributions and sources, are relatively remote from the use of these technologies; and in the ways in which, through smart meters, energy encounters are remade a project of electronic environmentalism that tracks and visualizes energy consumption.

I would like to end this chapter by considering how energy monitors as digital media might contribute to thinking through strategies for approaching these technologies in material registers. Environmental problems are approached through specifically electronic operations and materialities. The point about monitoring for efficiency and even sustainability deserves revisiting through these electronic operations, since questions emerge as to what these distributed arrangements and materialities of computation enable, what processes and relations they set in play, and what new environmental effects they generate.

How does such an approach also inform how we might recast the bounds of what counts as digital media, and how it might be theorized and practiced? As this chapter has argued, in many ways the management-based logics of energy meters, even if they achieve efficiencies, do little to change energy practices toward lessening overall greenhouse gas emissions, but instead sustain existing ways of life. These descriptive approaches to energy monitoring give rise to a reconsideration of what practices, relations, and material politics we might articulate through digital modes of engagement. How do practices of electronic environmentalism, potentially even through their failure to achieve a remedy to environmental crisis in the form of climate change, give rise to different ways of engaging with and addressing the problem of energy consumption and the materiality of electronics?

This then leads me to my final point with respect to the initial questions raised here, which is that the computational functionalities of energy monitors and any number of digital media are not contained within a single computational object. From desktop PCs to distributed ubiquitous computing, computation takes place through an extended milieu, and may even inform how we conceptualize the problem of energy use—as a problem that must be computable in order to be addressed. This approach suggests ways of expanding, transforming, and reworking the topologies of media not simply as a content-use relationship located within identifiable media carriers or genres, but rather as media ecologies and relationships that are articulated through a concatenation of computational technologies and practices.

In many ways, this discussion draws on an early argument that I have taken up in other work on the "atmospheres of communication," where I discuss how media exceed devices and extend to media environments.[27] In this sense, media are not locatable in a singular device as such, and an exclusively object-based understanding of media may obscure the extended sites in which they operate and circulate. This would be a way of saying that media might of course be approached as extended ecologies, and that what counts as a medium should perhaps be a question postponed through an extended approach that asks instead, what are the media relationships in play, how are devices a part of these relationships, but also not all there is, because these devices inevitably unfurl into a wider set of technologies, institutions, relations, effects, and events. This work is part of a larger project that I have been attempting to undertake for some time now, which is to think of media in environmental terms: as conducting and generating environments, as processes that influence material conditions, and now as technologies that would apparently bring us into closer contact with environmental issues.

Energy monitors as electronicized technologies enable functionalities for tracking energy use in order to promote sustainable everyday practices, and so ideally abate a possible environmental crisis. And yet, these technologies contribute at the same time to reworking and trans- forming the very environments and problems they would monitor. In this sense, the pollution and waste from our ongoing material practices generates residual materialities that spur new modes of monitoring and technological intervention, as these very computational modalities continually remake digital media in both their material arrangements and processes. In this way, new digital ecologies are always in the making, and giving rise to new material processes and relations. These modes of mattering could open up from electronic environmentalism to alternative engagements if we were to attend to the ways in which digital media organize and give relevance to our material practices, politics, and ecologies.

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Notes

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