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Limits to Growth: Analyzing Technology's Role

THESIS

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by

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DEDICATION

To

Professor Bonnie Nardi for her wonderfully astute thinking and guidance that has taught me to research and write with passion about things I truly care about

and

my family and friends for being a constant source of support and encouragement

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ABSTRACT OF THE THESIS

Limits to Growth: Analyzing Technology's Role

By

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Professor Bonnie Nardi, Chair

In today's world, we are plagued by environmental issues that endanger the existence of our planet. A number of initiatives and measures could probably address such issues, with or without the help of technology. However, ecological economists assert that limitless growth is not possible in a planet of finite limits and that there are alternatives to economic growth. What are these alternatives and how does the design and development of technology fit in? More importantly, how can technology fundamentally change the way our economies and societies function? In this work, I identify specific narratives of technology and explain how they foster more sustainable ways of development. These technological practices also conform to the larger narrative around alternate economic models and its underlying values.

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CHAPTER 1: INTRODUCTION

Sustainability concerns are worldwide, multi-faceted, linked to socio-economic issues, and require long times to reverse adverse effects, if that is even possible. They are also systemic in the sense that they require a holistic approach. One research finding, intervention or technological innovation cannot combat these issues. A multitude of inter-connected issues needs to be addressed. These include but are not limited to - pollution, climate change, food and/or water scarcity, degrading natural resources, forests, biodiversity conservation, disasters and so on. They are all linked, one leading up to another and aggravating the situation.

In this work, I study problems of environmental limits and sustainability by analyzing the work of ecological economists. By starting from the rebound effect, I connect how economic functions are central to issues of environmental sustainability. I discuss in detail; how economic growth is not viable, the alternate economic models that have been proposed, and how these models uphold different values. This key difference can support the cultural change that is essential to address issues of environmental limits.

Data reports show that as of March 2019, 56.1% of the world population are Internet users [46], and the number of mobile phone users is projected to reach 4.68 billion in 2019 [47]. Ray Kurzweil asserts that technological change follows rates of exponential growth [21]. What does this pervasive and widespread use of technology mean for problems of environmental sustainability and reorganizing our economies? How can it support or be detrimental to these efforts? I discuss points both with respect to how technology can

facilitate change and how technology, its design, development, and use should change in and of itself.

Finally, I present case studies of sociotechnical systems and trends in technology development and use. Though they cannot fix the anything on their own, they are designed, developed, or deployed in a manner that is considerate of these issues, albeit on a small-scale (for example locality-wide or city-wide). I will derive implications from this work to understand how we can scale up such efforts.

CHAPTER 2: ECONOMIC GROWTH

2.1 The Rebound Effect

The Jevons paradox is probably the earliest study on the rebound effect and arises from William Stanley Jevons' observation in 'The Coal Question' published in 1865 [16]. It states that though technology might increase the efficiency with which a resource(coal) is used, the overall consumption of the resource will increase due to lower costs and rising demands. It also spurs economic growth, further increasing resource use. Thus, it is counterintuitive to assume that efficiency would always help lower the consumption of a resource.

The Jevons paradox is a complex situation that concerns not only the environment but also the economy. Environmental economists posit that The Jevons paradox could be avoided if cost of use of the resource is increased to discourage overuse. The costs could also be maintained at the same rates, without making them cheaper, after efficiency gains. Energy economist Harry Saunders postulated the 'Khazzoom-Brookes', equivalent to the Jevons Paradox [33]. This postulate states that increased energy efficiency would paradoxically lead to increased energy use, equivalent to the Jevons paradox [33]. For example, fuel efficient cars might only encourage more driving. In Figure 2.1 depicts this possible scenario. An increase in fuel efficiency has decreased its costs by 20%, but this decrease has resulted in an increase in travel by 40%.

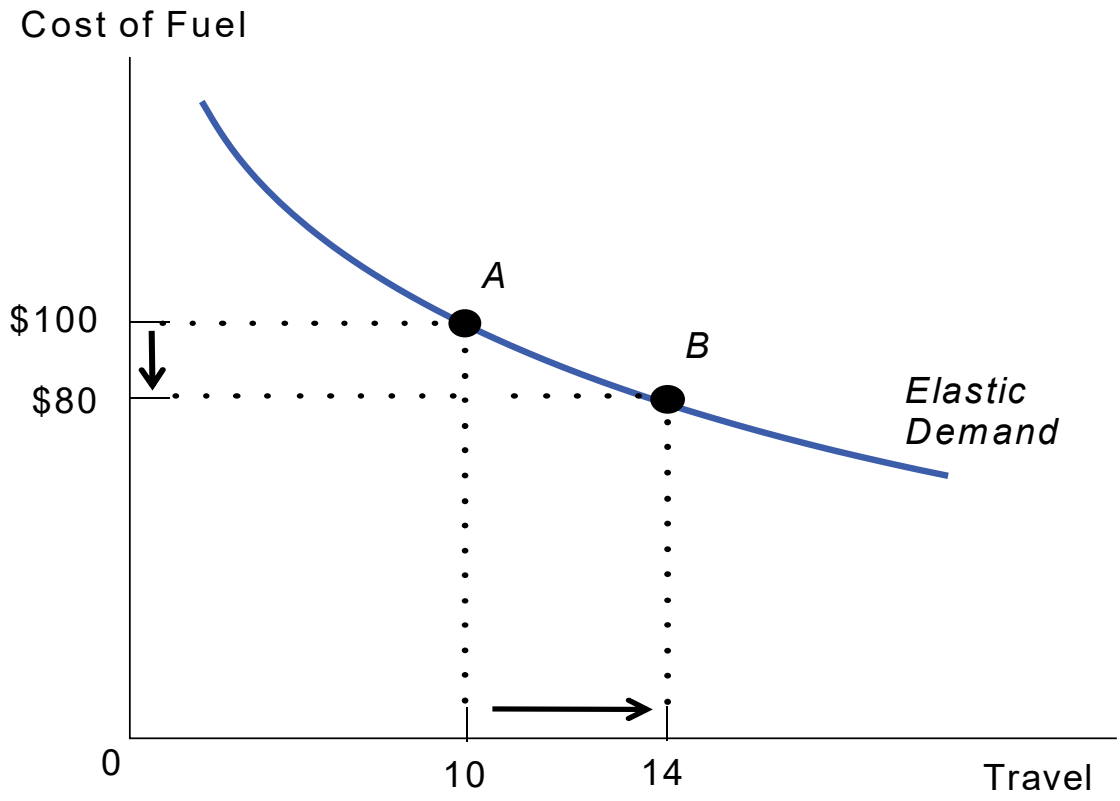

Figure 2.1 An observation of the Rebound Effect and The Jevons Paradox [44]

A *direct rebound effect* (or first-order effect) occurs when energy efficiency of a service or product leads to lower prices for that service or product which in turn increases consumption. The conservation attempted in the first place is counteracted by this increased consumption and energy spent for it [34]. *Indirect effects* (or second-order effects) occur when costs saved are redirected towards other services or product that consume energy. An example would be spending savings from a fuel-efficient car on flight ticket [48]. An *economy-wide effect* (or third-order effect) occurs when energy costs go down, and resource use increases, booming economic growth [34]. Energy prices and resource use are invariably linked to economic growth.

Efficiency might not be the solution to sustainability because of the Jevons paradox. Energy efficient resource consumption doesn't necessarily mean we are cutting down on our emissions, since at the macroeconomic level we could be consuming more. Efficiency with which a resource is mined or consumed will not have major impacts on sustainability overall because of the different kinds of rebound effects.

2.2 Economic Growth

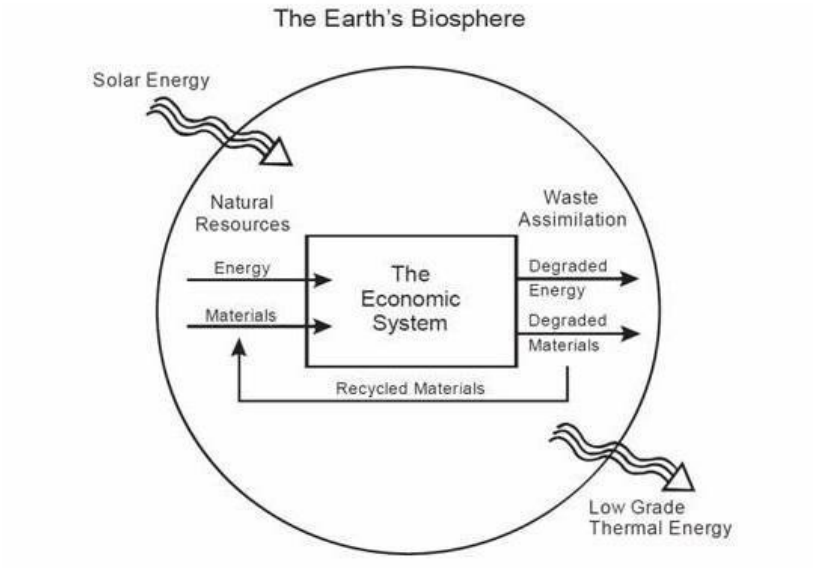

Figure 2.2 Economic system as a subsystem of the ecological system [45]

Herman Daly points out how our planet neither shrinks nor grows in size. It gets the same energy from the Sun, every year throughout. However, our planet is a thriving but *stable* ecosystem [10]. It has sources and sinks for all the necessary interactions that take place within this ecosystem. Daly points out that a major change in this ecosystem is the

growth of our economy. As it keeps growing, it is more important that it conforms to planetary limits and how the Earth itself exists as an ecosystem. As Daly stresses [10], quantitative economic growth increases environmental and social costs. Figure 2.2 depicts how our economic system should be a subsystem of our ecological system [45], as advocated by Herman Daly.

Stutz pulls data to validate how economic growth has been explosive over the last 75-100 years [35]. For example, the average annual increase in emissions (in millions of metric tons), is 12.4 for the period 1820-1950. In comparison, this value is 95.8 for the period 1950-2003. Meadows et al. published a report in 1972, 'The Limits to Growth' [23], where they posit that if our current rates of growth continue as is, we will face limitations and some level of collapse in the next one hundred years.

Why has economic growth been so problematic? How do we alter these explosive growth trends? What kind of an economy should we strive for that ensures both environmental and social sustainability?

2.3 Conventional Economics vs. Ecological Economics

Conventional economics focuses on growth and does not account for or consider our ecological systems [8]. Conventional economists over attribute technology's ability to liberate us from resource constraints and support continued economic growth [8]. Human consumers are central to these economists' world view, where resources are limitless because of 'infinite substitutability' and 'technological progress' [8].

There are limits to how much technology can help. For example, technological advances can

help us harness energy from renewable resources, but these resources have a rate of regeneration. When we use up resources at a rate much more than what our planet can regenerate, there are no solutions. Technology needs input, something in the first place to create outputs. The consumption and pollution of other natural capital is also a cause for concern. We should not exceed the rate of regeneration of natural resources and the rate of assimilation of waste this planet can take. These natural assets support human life and without them, we will face collapse. We can neither revert the state of these natural resources nor fix pollution through technology.

As Meadows et al. state,

> "*Faith in technology as the ultimate solution to all problems can thus divert our attention from the most fundamental problem--the problem of growth in a finite system--and prevent us from taking effective action to solve it.* " [23]

Negligence of ecological systems in functions of economy means any damage we inflict on our life supporting systems because of processes of economic growth, are also ignored [8]. Before we damage these systems beyond restoration, we should include ecology as an important factor in the field of economics.

As opposed to conventional economics, ecological economics is a transdisciplinary field that studies the relationship between ecosystems and economic systems [8]. Nicholas Georgescu-Roegen's 'The Entropy Law and the Economic Process', published in 1971, paved way for establishing ecological economics as a sub-discipline of economics. In this groundbreaking work, Georgescu-Roegen discusses how economic growth is subject to physical resource

limits. He predicted that economic activities could eventually deplete natural resources and extinct human life. He based this argument on the concept of entropy and irreversibility.

Costanza et al. define the world view of ecological economics as follows,

> *"Human preferences, understanding, technology and organization co-evolve to reflect broad ecological opportunities and constraints. Humans are responsible for understanding their role in the larger system and managing it sustainably."* [8]

Ecological economists draw a key difference between growth and development. Economic growth is quantitative and cannot be sustained on a planet of finite limits. Economic development, however, does not necessitate increase in resource consumption but strives to improve the quality of life and hence, is sustainable [8,10]. Unlike conventional economics, ecological economics is cautious about technology's role in supporting sustainability [8]. It neither dismisses nor depends on technology's ability and focuses on how we can achieve ecological and economic sustainability.

CHAPTER 3: ALTERNATE ECONOMIES

The emergence of ecological economics encouraged ideas of economies that do not focus on growth. I discuss three types of movements that address this limits-to-growth predicament and they are - post growth, steady state, and degrowth.

3.1 Post growth, Steady State Economy and Degrowth

A post-growth approach believes Daly's assertion that infinite growth is not possible with finite limits [49]. This approach believes that beyond a certain level of economic growth, we need to turn to other ways for development [49]. It guarantees a minimum income per capita after which happiness and satisfaction is sought from living sustainable lives. A post-growth approach embraces parts of the current system that can work and delineates problematic parts of the system. It calls for prosperity, social and environmental justice, political and structural reorganization, diversity, and cooperation. According to this approach, solutions need to employ a systems perspective and be tailored to the place, time, culture, and resources available. In this regard, it can be considered as an asset-based approach since it seeks to leverage existing assets to build post-growth futures [49].

A steady state economy, according to Czech and Daly, is defined by stability [9] - it has neither growth nor recession. Ideally, it has a constant population, constant capital and constant throughput [9]. Here, constant does not and cannot indicate 'never changing'. It indicates that while there might be minute changes initially, stability will be established over the long-term. For example, birth rates and death rates will eventually maintain a stable population size. Czech and Daly also assert that environmental sustainability and ecological integrity is

the sole reason to strive for a steady state economy. This warrants that pollution levels do not exceed what this planet can take in a steady state economy.

Czech and Daly point out that goods should also follow similar models. Slow influx of high-quality, durable goods has considerable implications for production practices which in turn reduces energy and resource consumption, pollution, and paves way for sustainable consumption [9]. They use John Stuart Mill's work [25] to emphasize that once we shift our focus away from growth, we allow for developing the quality of life and improve our political, ethical, and spiritual considerations.

A steady state economy has a constant rate of employment [9]. Average amount of money earned by working people from one generation to the next remains constant. A stable income indicates a stable ecological footprint. The stock market can still exist in a steady state economy but it would not be as volatile, compared to the one in growth economy [9]. Economy functions are closely related to governance. Czech and Daly assert that a socialist democracy would be conducive to a steady state economy. In such a socialist democracy, the state would own the forests, oil fields, mineral lands, and fisheries. Important services such as healthcare, education, environmental protection, and wildlife conservation would also be owned by the state, instead of private industries that might prioritize profits.

Degrowth involves scaling down on production and consumption, protecting ecological systems, and promoting equity [50]. It envisions a world that has open, regional economies with equal share of resources for all. The central idea is to live frugally. Material possession

and consumption will no longer be part of people's lives, attitude or culture. Sufficiency trumps efficiency and new forms of democratic institutions would be required to oversee such economies [50].

These economies have different approaches to the limits-to-growth dilemma. The underlying idea that all three have in common is that limitless economic growth is neither sustainable nor does it help environmental sustainability and social justice.

3.2 Post growth thinking for the world

Gerber and Raina note how these approaches are considered Western-centric and very little about their applicability to the global South is discussed [14]. They point out that many ecological economists, including Georgescu-Roegen and Herman Daly, consider growth-critical approaches to be applicable only to the global North. Growth is generally considered required for developing countries to develop and address poverty. But this viewpoint is debatable. Gerber and Raina put forward several ways of thinking about post-growth in the global South, using India as a reference. I will use their arguments to discuss the relevance of such approaches in developing countries.

I also believe their ideas and arguments broaden the ideas of these approaches. Gerber and Raina consider post-growth as a 'combined application and theorization' of degrowth, agrowth, steady state economics, and post-development. Degrowth indicates a changed civilization with local, equitable economies. '*Sharing, simplicity, conviviality, care and the commons are central features of such a society*' [14]. Agrowth is agnostic about growth and

does not believe in limitless growth or growth as a solution. Steady state economics focuses on societies that do not grow, but have a stable, constant throughput. Post-development abandons practices of development since it believes they reflect capitalism and Western supremacy. All four movements reject GDP and focus on quality lives and ecological conditions [14]. Gerber and Raina argue that all four movements are appropriate in specific cases to both global North and South. Gerber and Raina's important point of contention is that 'serious post-growth thinking (as they define it) is world-systemic and rooted in class analyses' [14].

Using India as a reference, the authors emphasize the importance of post-growth in both global North and South. I will briefly describe key points of their arguments here.

Economic growth has been detrimental in India, increasing levels of environmental damage, pollution, life-threating diseases, and debt [14]. How can economic growth address development if data shows us that it has created ecological, financial, and social instability? The authors assert that the causal relationship between growth and eradicating poverty is not clear. They question the impact of higher GDP on the lives of lower classes both materially and existentially, and stress that this relationship is not direct or causal. India has slipped by 12 places in the Human Development Index. 80 percent of India's population live on 20 Rupees a day (0.28 USD). India's growth rates have also failed to resolve job insecurity. They draw such evidences from research to demonstrate that India's growth has only helped the rich, spurred inequality, and damaged ecosystems [14].

The authors argue that post-growth thinking should consider world population as a whole instead of limiting it by geographical boundaries. They use Robinson's stance [31] that the world is ruled by a class of people who probably share similar lifestyles that are driven by growth. Irrespective of geographical location, global upper classes of rich people should embrace the degrowth perspective. The real issue then becomes about unequal distribution of resources and wealth rather than ensuring continuous economic growth to address issues of poverty. According to Gerber and Raina, post-growth thinking is hence, world-systemic and rooted in class analyses.

Such ideologies exist largely in theory right now and might be hard to implement. We need to create awareness about how continuous economic growth is not feasible and is detrimental to ecological systems. People don't always relate economic functions and ecology. One of UN's sustainable development goals is 'decent work and economic growth' [22] . They call for 'sustainable economic growth' to address poverty and unemployment. Can economic growth be sustainable? I believe by focusing on development, not growth, and equitable share of resources for all, we can address poverty and unemployment. We need to educate about the correlation between ecology and economic functions so that together we can push for integrating ecological concerns in economic activities.

CHAPTER 4: TECHNOLOGY AND ECONOMY

Technology use is widespread today and will probably increase in the years to come. While we can leverage its pervasiveness to implement ideas of a degrowth society, we also need to rethink how we should design, build, and use technology in a manner that complements these ideologies.

4.1 Technology and change

We require institutional level change, from local, national, to global levels. The kind of economies discussed previously need a top-down approach. We need to restructure our economies and governance based on the limits-to-growth predicament. Institutions and organizations need to have an open, ethical ethos that are accountable to ecological systems and drop pursuits of limitless growth and profits. We all need a change in our attitudes, culture, and perspectives towards growth. People might be ingrained to seek better lifestyles and material things. Can we possibly recalibrate ourselves to live frugal and sustainable lives?

Toyama discusses how technology acts as an amplifier of prevalent social and economic conditions [40]. For example, even though we design ICTs for development, there are other social, financial, and political factors at play that create barriers for use of that intervention. He uses Mark Warschauer's research on schools in America and other countries to explain this idea. Warschauer's research shows that technology improves education in better ranked schools with good teachers, while its introduction doesn't impact schools that lack resources

in the first place [41–43]. Toyama discusses how technology does not 'fix' barriers or digital divides. It doesn't substitute for human capacity and intent either. Humans can leverage technology only to increase their capacity and fulfill intent.

Fogg's Behavior model of Persuasion [11] explains how behavior is an outcome that results from three factors – ability, motivation, and trigger. Levels of motivation and ability have a direct effect on the behavior. For example, consider the following cases: People have high motivation towards sustainable behavior. However, they do not have the ability to take action. Despite high levels of motivation, inability prevents sustainable behavior. The other case when people have low levels of motivation; but they require very little ability, in the sense it is easy for them to take that particular action. Despite low levels of motivation, people might act because of high ability.

Fogg talks about these factors specifically in the case of persuasive technology where designers are trying to get people to enter email addresses in a website or for similar trivial actions. However, I believe these factors of motivation and ability also apply, at a high level, to people's views and actions regarding sustainability. It is similar to Toyama's position of technology failing to create intent or motivation but in addition, also discusses ability. Both Fogg's and Toyama's research provides interesting insight on people's behavior.

We need to think about a suite of measures that would cater to people with different beliefs and different levels of motivation and ability, instead of a 'one-size-fits-all' solution for everyone to adopt sustainable behavior. For example, education is a useful area of

intervention for students and children. Integrating issues of sustainability in education can enable future generations to think through these issues early on [29,39], which is better than attempting to change set mindsets later on. For people who already strongly believe in notions of sustainability and degrowth, technologies must support mass activist movements [17,18]. We must leverage information and communication technologies to support visibility of such movements and increase its reach [18]. More effective means of collaboration and engagement should also be built as opposed to 'clicktivism' [18]. For disbelievers or people who remain largely unaware of such issues, ICT media be leveraged to increase awareness about how our economies and societies have a direct effect on these issues. We also need to suppress the spread of disinformation (for example – the climate change conspiracy) by giving people tools to evaluate the authenticity and context of information they encounter online.

Transition to a degrowth economy is hard to achieve. These changes are small steps that can bridge the way societies and economies function now and the way it would rather work in a degrowth society.

'Planned obsolescence' describes the industry practice of deliberately manufacturing products to have short lives so that consumers are forced to make more purchases [7]. Vance Packard coined the term, 'planned obsolescence' in his book 'The Waste Makers', 1963 [28]. He describes how industries create a consumeristic culture, making people indulge in products that they did not need. These products were also planned to be frequently replaced.

Such production and consumption habits are detrimental to our environment. Almost fifty years later, nothing has changed.

Planned obsolescence can be observed in the case of our digital devices. Apple and Samsung have released software upgrades that slowed down older models [20]. 'Perceived obsolescence' is when people believe that their current products are obsolete simply because newer models have released. They attach importance to form over functionality. The industry also drives this behavior by releasing newer models and extensively advertising them. This ties with our own desires to own the latest product, be part of the trend, and hold social status. Such practices of obsolescence can also be observed in the automobile and fashion industry as well. These practices increase material consumption and material waste. Electronic wastes in landfills are harmful because of the chemicals used to manufacture them.

Such practices drive consumerism, growth and connects back to our attitude towards life and material possessions. If the way technology is developed can squash practices of obsolescence, people can also scale back on their consumerism. Current patterns of manufacture and consumption reflect a linear economy where we take, make, use and dispose. The Ellen MacArthur foundation calls for a circular economy instead, where we restore and regenerate by design [51]. In a circular economy, reuse, refurbishment, remanufacture, and recycle are important cycles to design for, in order to close the loop. Korhonen et al. point out disadvantages of the circular economy [19]. Complete recycling is not possible because of the second law of thermodynamics. Recycling requires energy and

will always generate by-products or wastes. Processes in the circular economy are also subject to the rebound effect and Jevons paradox.

Industries relentlessly pursue growth and profits. But they can aim to achieve business models that are considerate of ecological issues. For example, Blevis introduced the idea of 'Sustainable Interaction Design' [3] and proposed ways in which sustainability can be integrated as a core value for interaction design practitioners. Thinking through the outcomes for obsolete technology and considering possibilities to reuse and renew current technologies are two important goals for sustainable interaction design [3]. Blevis also outlines a rubric that lists factors to account for in interaction design, ranging from disposal, salvage, recycle, and reuse to prolonged life and use, quality, heirloom status, and sharing. For example, if a device was hand-made or was passed down, we would probably hold onto it longer because of the value we associate with it.

4.2 Other considerations for technologists

Even if we are not using technological innovations for increasing energy efficiencies, we can observe a kind of rebound effect in technological interventions. Consider the example of ride-sharing apps such as Uber or Lyft in the context of sustainable transportation. Ride-hailing services might reduce dependencies on personal transportation and ride-sharing might seemingly be eco-friendly. However, data indicates that use of such services has led to more traffic and congestion [52]. They also pull off people from public modes of transportation. While such services could have had positive effects, the consequences were adverse. These adverse consequences counteracted any benefits that could have been

gained. It is hard to predict such effects; however, we can question the impact if such measures are adopted at a large scale (city wide). Thinking through a series of 'what if's and brainstorming how rebound effects can play out can provide some insight.

Remy et al. recently discussed the importance of evaluating sustainable HCI research beyond usability [30]. Remarking on how work so far has not produced tangible solutions or methods of evaluating real-world impact, the authors have gone a step further to elaborate on five important constituents for evaluation – goals, mechanism, metrics, methods and scope. They define mechanisms as factors "*...that need to be considered to understand and assess the holistic impact of the research artefact in the context of external influencing factors*" and point out how economic and political mechanisms should be considered by researchers. They acknowledge the difficulty in doing so and suggest working out societal, political, and economic implications of design to bring out the small-scale effects [30]. Including considerations of the rebound effect in such evaluations would prevent us from being misguided about the technology's potential in addressing sustainability.

CHAPTER 5: CASE STUDIES

Despite obvious and inherent issues associated with the development of technological devices and applications, I believe we can still leverage and reorient them to cater to ideologies of degrowth. In this section, I present descriptive case studies of technical systems that have societal and environmental impacts. They address issues related to sustainability, such as circular flows, reuse and recycle of devices, at a smaller scale (for example, city-wide). Such systems are working models that can be adapted to other places and scaled up to have higher impacts. Through an analysis of research published in relevant areas and work of organizations that are considerate of our ecological systems, I present how important themes of degrowth have been realized and supported through technological applications.

These case studies have been selected primarily on the basis of relevance in a post-growth and/or degrowth society. For example, efforts that employ use of technology to implement relevant ideas that exist in theory and fundamental changes in the way technical devices are designed, and used or appropriated by people, were valid and valuable. They inform how design, development, and use of technology can intertwine with degrowth principles. I also examined if the application presents a proof-of-concept demonstrating its feasibility and real-world use, or if multiple sites realized the need for similar kind of applications that support degrowth values and used them as criteria to select particular case studies over others.

5.1 The Case for Commons

Franquesa and Navarro implemented a commons approach to device use and recycling through the site eReuse.org. They supported a model in which device repair, reuse, and recycle can be collectively owned and managed [13]. This model is possible through a commons-based cooperative platform, a circular product license, and an algorithm that estimates the use value of the devices and supports decision-making.

> *"These open-source tools that are part of the eReuse.org platform bring automation, cost reduction, traceability, and auditability to all the steps in the lifetime of any device included in the commons, across manufacturing, use, reuse, repair, refurbishment, and final recycling."* [13]

Franquesa and Navarro point out how it is not easy for users to find scenarios for their devices to be reused when they want to give them up. They might simply discard their devices and such practices leads to *premature recycling*.

The authors, in view of the rising amount of e-waste generated and the toxic landfills they lead to, sought to address the issue. Their primary goal is to extend the lifetime of digital devices to the maximum extent possible by repairing, updating, refurbishing, and reusing them. Through this measure, they hope to ensure that only devices that have almost no use value are recycled.

The authors elucidate why and how their objectives fit with the circular economy. Ideas and definitions of circular economy are appropriated by different people [13]. For example, burning waste to generate energy is considered circular [13]. However, Franquesa and Navarro stress that the order of reduce, reuse, and recycle is important to a circular economy. The waste that was burnt could have been avoided in the first place through reduce or reuse applications [13].

It is important to maintain the value of products and devices for as long as possible. But most of that responsibility and decision-making rests with people themselves. The authors strive to implement circularity in its true sense by shifting the ownership of devices from an individual to a community.

The common-pool resource (CPR) governance is a model for shared resource systems that includes policies to regulate their maintenance and consumption [27]. eReuse represents a "global federation of local groups, organizations, and communities that deal with the circular life of digital devices in their target communities under specific business models" [13]. By sharing information, methods, and services through eReuse, the platform provides a common governance digitally. Franquesa and Navarro assert that this governance through principles and protocols are supported by a set of software tools and applications.

The authors argue that eReuse commons generates more local impact and an equitable local economy compared to corporate structures. Corporate platforms are aimed only at extracting market value and recycling, and do not help with environment preservation.

The stakeholders of this system are volunteers, who are concerned about a range of issues from environmental sustainability to consumer rights, professionals who refurbish, repair, and recycle devices, customers who are conscious about using reused devices, either to be environment-friendly or cost effective, and public administrations. Devices enter the CPR through collective purchase of new devices, donations from public administrations and companies, and donations from other members in the community. Devices can be donated based on a preferred license and the receivers must accept a particular license to obtain them.

The eReuse commons has both environmental and social benefits. Extending the lifetime of devices both prevents new manufacture and avoids waste [13]. Social benefits arise from providing computing to socially excluded populations and voluntary services [13]. For example, students learn how to repair devices in service-learning centers.

The internal model of CPR relating to governance aspects is realized through good practices, procedures and internal regulations, agreements, ground rules and local socio-legal framework, and each layer and their elements are elaborated in [13]. The importance of a socio-legal framework is recognized, and its values emphasized in this effort. The rules around reuse, refurbishing, recycling draw on legislations about manufacture, e-waste, data, and environment. Social values of local governance, volunteering, corporate social responsibility, environment and politics also shape efforts in CPR.

Their circular product licenses, comprising of three parts, guides the correct flow of circular devices. The first part is aimed at commons itself, guiding organizations on how to prevent premature recycling and enable reuse and traceability of products. The second part is aimed at organizations that collect, refurbish, distribute, and recycle digital devices. The third part is for end-users or consumers who use these devices. In addition, the authors developed an algorithm to estimate the use value of devices (to determine if they are up for recycling) which has cut down processing costs and increased efficiency. The commons also hope to support transparent and traceable transactions of these devices through smart contracts.

Franquesa and Navarro also put forward a higher agenda for commons as a resource management alternative for digital systems [12].

Digital interactions depend heavily on networking infrastructure. The authors point out that there are populations that get very less or zero connectivity and Internet access [12]. For example, they could be low-income users living in resource constrained areas. Lack of access transpires to lack of services, development opportunities, and participation in online movements [12]. Increased use of digital devices also leads to problems of e-waste, landfills, pollution and push environmental limits.

To address both the digital divide and environmental threat, Franquesa and Navarro suggest that people should collectively govern networking infrastructure as a commons property. A collective inclusive management will enable everyone to be more than just end users of digital interactions. It democratizes infrastructure for everyone, across all classes. The

eReuse.org is a realization of these principles and ideas for the use case of reusing and recycling mobile phones.

In people's cycle of device use, Franquesa and Navarro found the right point of intervention by offloading the consumer effort of finding out what to do with old phones and taking the right steps to dispose it. They identify the need to reuse before recycling, to achieve longevity of digital devices. The eReuse.org effort embraces values of a degrowth society and hence, would fit well in it. The digital platform eReuse.org enables redistribution of resources, attempts to equalize resource use, and protects ecological systems by scaling down on material waste. It also supports alternate regional economies, such as a commons model of resource use and sharing that is more equitable.

5.2 The Case for Transparency

Some applications have been developed with a deliberate focus on engendering fairness and accountability through transparency.

Sourcemap is a web-based tool that enables small businesses to evaluate the carbon impact of their supply chains [5]. It also provides maps of the supply chains for their users to visualize how local, or not local their sourcing is. For example, Figure 5.1 shows a map of how ingredients that are used to make Reese's Peanut Butter Cups, are sourced from different parts of the world [53]. Users calculate carbon impact of their own businesses, using carbon footprint data that is available from an open, crowdsourced database. Upon calculation, they add it back to the database. This disclosure of supply chain information is

useful for distributors, suppliers, and consumers for sustainable decision-making. It also allows for verification of environmental impact by sustainability experts and researchers.

Figure 5.1 A map of the supply chain for Reese's Peanut Butter Cups [53]

The key motivation behind developing Sourcemap was to develop a tool targeted at guiding professionals and business owners to make sustainable decisions in terms of their supply chain. Bonanni et al. engaged in participatory design processes with different people (caterer, butcher, hotelier, brewer etc.) to iterate on their initial prototype. It was soon released as an open source project, thus making the tools and information required to build sustainable supply chains available and free to use.

Provenance is another organization that focuses on fostering supply chain transparency through the potential of blockchain [54]. When we buy products without knowing how ingredients are sourced, we might support businesses that push environmental limits of the

planet. Provenance addresses this knowledge gap by tracing information about a product in all stages of the supply chain and making it available to consumers. Data reports that 30% of UK consumers are mindful of social and environmental issues but are unable to translate them into shopping decisions and purchases [55]. Building mobile applications for consumers that enable them to scan stickers on food items (Figure 5.2) and trace its journey supports them in decision-making.

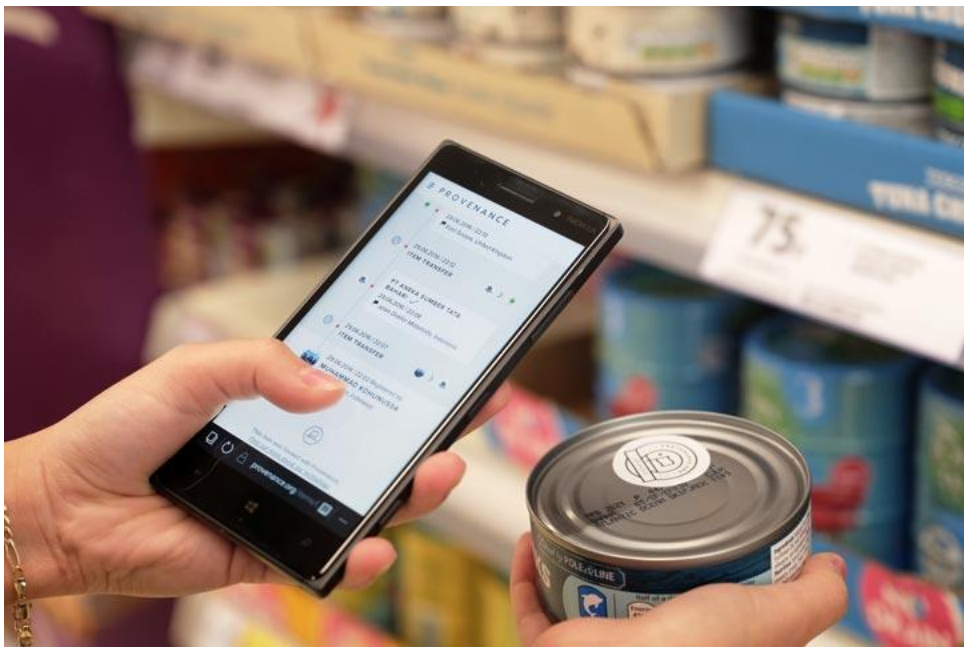

Figure 5.2 Provenance mobile application [55]

Fairphone is a company based in Netherlands that manufactures 'ethical and modular' smartphones [56]. A modular smartphone means different components can be replaced independently. Fairphone believes in long-lasting design, responsible sourcing, ensuring good labor conditions, reusing, and recycling. The smartphones are built in way to imbibe and encourage these values. Through modular design, different parts of the phone can be

easily replaced or upgraded instead of giving up the phone itself when something breaks or is problematic. The company also stresses that they take initiatives to ensure that minerals and materials that are used for manufacture are responsibly sourced. For example, they partner with NGOs, researchers, and labor rights experts to negotiate better working conditions in terms of hours, wages, and exposure to toxins and chemicals for the workers.

Here are some snippets from the goals and mission statements of Provenance and Fairphone.

> *"Every product has a story. We help brands and retailers build customer trust through transparency. Using blockchain technology Provenance empowers shoppers to choose your product."* – Provenance

> "*Our phones hold a complex story of the hundreds of people who helped make it. We want to open up that story, so we can make a positive impact in how phones are made, used and recycled."* – Fairphone

Something that is common in both these statements is the focus on openness, transparency, and weaving a narrative around the products targeting the consumers. People inclined towards making sustainable life choices would benefit from such products and services. This practice can also make others aware about these issues and motivate them to adopt such products. New, in his article in the Harvard Business Review, discusses how claims of sustainability by organizations are not substantiated [26]. With growing interest in the provenance data of products and technologies that support collection of such data, revealing

such information could become an expectation. If more consumers demand provenance data, marketing and perceptions of brand value could depend on how the organizations provides or supports tools for sharing this information.

Fairphone's efforts address issues of planned and perceived obsolescence in digital devices, changing the way technology can be designed and developed. On the other hand, technology is leveraged by Sourcemap and Provenance to build tools that can promote transparency of supply chains. This is to ensure that the supply chains are both environmentally responsible and socially just.

Costanza et al. point out that most institutions are built on the idea of continuous economic growth, do not consider ecological impacts, and lack awareness about environmental sustainability [8]. Prioritizing environmental sustainability and equality over monetary profits and growth is both ethical and practical given our current situation. If these institutions can acknowledge the severity of limits we are currently facing, and how they play a big role in it, we can work towards a change.

Costanza et al. use the World Bank, a financial institution that affects both economy and environment, as an example to illustrate how this can be realized [8]. For instance, while deciding projects, evaluating if the project uses up renewable resources at a rate more than the regeneration rate should be mandatory and take precedence over economic criteria such as return on investment.

The bureaucratic structure of these institutions makes it more difficult to bring about such changes. They are typically inflexible, do not provide information to public, close off decision-making to a few people who do not consider the ecological aspects of sustainability either by choice or because of lack of awareness [8]. The authors recommend that peer-to-peer institutions that are more flexible and less bureaucratic would be more effective in addressing issues of sustainability. Corporate organizations are also profit-driven and are not held accountable for actions that impact ecological systems. There is a pressing need for transparency and accountability in such institutions and organizations, and digital platforms can be built to enable such practices.

Values of transparency pertain to both products and services. Bates and Friday elucidate how e-commerce websites lack transparency in of processes and services, drive growth and consumption, and create poor working conditions for delivery workers [2]. Such websites offer next day delivery options, forcing workers to push harder and deliver more. Consumers who are largely unaware of underlying logistics are tuned to this 'instant gratification' and indulge in consumeristic behavior by ordering more products online with quicker delivery options. Bates and Friday point to data that reports on the horrifying conditions of such workers who are pushed to make 150-200 deliveries in a day since pay depends on performance [2]. The authors call for the importance of interfaces or other digital tools that focuses on social justice by making these stories transparent. Providing Turkopticon as an example, the authors stress the importance of intervening and creating tools that can make human capital visible. E-commerce websites are designed to have endless cues or recommendations to encourage users to buy more products for extreme profit or growth

conditions. Design patterns can rather be developed to discourage consumerism and embed values of sustainability by applying the concept of a 'self-obviating system' as proposed by Tomlinson et al. [38].

5.3 The Case for Making and Do-It-Yourself (DIY) culture

As a contribution to the 'Visual Thinking Gallery' section in Interactions magazine, Eli Blevis added an image titled 'DIY Repair' [4]. It is a picture of a person using a hair dryer on an Apple MacBook charger, along with the caption, '*A quick Google search yields sound advice about what to do if your AC adapter/charger stops working*.' This image provokes thoughts on how majority of us are dependent on our device manufacturers to repair or replace devices when something stops working. Not only do we spend more on devices or accessories, we do not know where our discarded or abandoned devices end up.

However, making and hacking has become more commonplace in recent times, leading to a shift in how people interface with technology and its parts. Roedl et al. present their discourse analysis on research papers about the maker movement and elaborate on the implications of the maker movement for Human-Computer Interaction (HCI) research, especially Sustainable HCI research [32]. They highlight how the term 'user' implies a consumeristic relationship between people and technology. Recognized through their discourse analysis, they elaborate on the activities and ideas that constitutes this maker culture, which includes user appropriation, art, craft culture, open source, Ikea hacking, steampunk culture, and modding. Online DIY tutorials, open hardware tools such as Arduino,

and digital fabrication tools such as 3D printers have also supported and given rise to the maker movement [32]. As the authors note, the term maker represents people who tinker and play as well as those who are hobbyists and make it a part of their identity.

Tanenbaum et al. analyze and reflect from participatory observation in maker and DIY communities, on the underlying cultural changes that these communities bring about [36]. They prefer making personalized products over buying mass produced products and believe in knowledge sharing. Tanenbaum et al. note how DIY culture is growing among average-income people and how through making, they are changing norms in the way technology is developed and utilized. The authors frame these practices as 'democratized technological practices' and assert that they bind playfulness, creativity, and usefulness together.

Mellis and Buechley remark on how the maker movement deviates from capitalist methods of mass production and manufacturing [24]. But they also recognize how access to makerspaces does not necessarily mean that people are making devices for daily use. To investigate this gap, the authors organized a DIY workshop for mobile phones, and they call it "high-tech DIY". They dig into the difference between prototyping and production and investigate how high-tech DIY practices would benefit from transparency (for example, in terms of source code) and components from industries.

'Bike Kitchens – Spaces for convivial tools' by Karin Bradley reports on a do-it-yourself (DIY) bike studio in Sweden and its role in relation to the degrowth movement [6]. A wordplay on the idea of soup kitchen, bike kitchens refers to a DIY bike repair workshop where people can come repair their bikes or give them up for recycling. Though Bradley analyses the bike

kitchens and what this space affords through the lens of degrowth movement, the analysis could be extended to other makerspaces as well.

The bike kitchen offers a collaborative space for helping and learning as a community. Bradley analyses the importance of such spaces and culture through two theoretical perspectives. One is Illich's notion of tools for conviviality [15], where convivial tools "*enable citizens to reconquer practical knowledge for autonomy and creativity, rather than being confined to commercial relations".* The other one is based on cultivating non-capitalist relations, an idea central to degrowth movement. One method of realizing it is actually through a commons-based peer economy.

Bradley asserts that these workshops offers a convivial, non-commercial, and open space that reduces dependency on the consumeristic and industrial system [6]. The peer-to-peer relations also ensure that it's a commons-based economy. Tools, skills, and spaces are commonly shared to create use value. Bradley stresses how degrowth involves less material consumption, more reuse and repair of resources, local commons-based economy, democratization, and non-capitalist relations, and further elucidates how bike kitchens realize these values. These values are also realized by almost all DIY practices and maker activities.

CHAPTER 6: DISCUSSION & CONCLUSION

The case studies presented embrace different values of a degrowth society. Regardless of their focus areas, these efforts are similar in a few aspects and contribute to transitions to a degrowth society. It is important examine how technology can still play a role in a degrowth society without the pitfalls of techno-solutionism.

Problems of environmental exploitation and unequal share of resources are closely related to social injustice and inequality. When systems target to tackle environmental issues, it is encouraging if they can also impact related issues of social inequality. In the case of eReuse.org, the primary goal was to avoid premature recycling that fills up our landfills with unnecessary toxic waste. The organization, however, found use value for the collected mobile phones by distributing them among marginalized populations that otherwise do not have access to such computing devices. This attempt was a deliberate one to address digital divide.

In the case of Provenance, the goals of building transparent supply chains are to make all actors in the supply chain accountable for the choices they make and to communicate information about how food items were sourced and manufactured to the consumer. But Provenance was also concerned about the farmers and workers in the supply chain. While tracking and tracing tuna fish, they were careful to not promote fish that had been sourced through illegal practices and slavery. Increasing representation and creating awareness about practices of food production and distribution is the first step towards ensuring food sovereignty.

Fairphone's mission focuses on long-lasting modular phones that were made of sustainably sourced materials. But they were also taking care to ensure good working conditions for people who were dealing with these materials, in terms of wages, hours, and non-toxic environments.

To reiterate on Gerber and Raina's argument [14], post-growth is world systemic and rooted in class analyses. Efforts that identify disadvantaged and marginalized populations, reach out to them, give them a voice or create benefits for them are more encouraging and successful from a sustainability perspective. It is important to support both environmentally just practices and social equality.

An important common thread across these case studies is to question and change the status quo around the ways in which privately owned corporates might endanger ecological systems and cultivate consumeristic market relations for purposes of profit and growth. Franquesa and Navarro note how commercial organizations are focused primarily on extracting market value, in comparison to CPRs that create societal and environmental benefit. Sourcemap and Provenance built tools that assisted actors in the supply chain in sustainable decision-making. Organizations also need to be mindful of the supplies and materials they receive from other distributors, thus tracing products upstream in the supply chain. Provenance was also keen on conveying information to the consumer so that they do not encourage businesses that push our environmental limits. Makerspaces foster sharing, learning as a community, and convivial relations, and hence, are a clear step away from consumeristic, commercial relations.

Supporting organization and coordination of local economies or alternative decentralized infrastructures [37] is another sure step in the right direction. The state of current ICTs can provide such capabilities easily. Organizing CPRs such as in eReuse.org supports alternate regional economies and tools like Sourcemap provide carbon footprint information to encourage shorter and local food supply chains.

The work of Ostrom in investigating how common pool resource groups can manage their resources and avoid the problem of tragedy of commons is well established. This idea is extended and supported digitally by eReuse.org. It is important to remember that any intervention to realize degrowth values might require minimal or no technological features. In some cases, minimalism is desirable to address sustainability challenges, as outlined in the agenda for frugal innovation [1]. Careful considerations if technological solutions are required, and if it seems so, being clear about the capabilities and potential it provides and exactly what drawback it is solving, are crucial. Empirical studies post deployment that analyze what these systems afford different populations or classes and whether it inadvertently creates adverse effects are also important. Solutions that work in one place cannot be exactly replicated in another place. Implementing a CPR for device reuse and recycling in other regions might require changes compared to what eReuse.org implemented. As post-growth approaches advocate, a systems perspective tailored to the place, culture, and assets available will be necessary. Ultimately, values of post-growth and degrowth should be realized. Does it lessen material consumption and material waste? Does it support self-sufficiency and democratization of resources? How does it realize such values and integrates them in the fabric of everyday life?

Implementing a commons resource model, pushing for transparency in institutions, and makerspaces are not completely independent of each other. They are interdependent themes. For example, bike kitchens can also be considered a peer-based commons model for bicycle use, repair, and sharing. Maker and DIY activities depend on open, transparent practices of knowledge sharing and learning as a community. By identifying technological practices that already bolster ideas of degrowth, we can work towards supporting them and/or replicating them.

Though such technological practices might not bring about transition to a degrowth society by itself, it is nevertheless beneficial and important to understand the role of technology in it. Creating awareness about the interrelation between economic and ecological systems and educating about the limits-to-growth predicament is pivotal to change. It is also imperative for governments, world organizations, and institutions of power to realize it and work towards protecting our ecosystems. Post-growth thinking is world systemic and different countries might have to adapt different ways of developing beyond growth. Developing countries would need to radically reorient their political and economic system, while developed countries need to consider how they might scale down or maintain a steady state. The pervasive use of technology and the attention it receives, gives us leverage to reorient it towards creating this awareness. In this sense, it is merely a calling card, but it could be more if we are mindful of how it is designed and developed.

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