THE PAPER TO DIGITAL MEDIA TRANSITION: DEFINING SUSTAINABILITY IN MEDIA SUPPLY CHAINS

by

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Abstract

The phrase, “please consider the environment before printing this email” has entered the common vernacular. It suggests that when I consider the environment, paper media is of particular concern, and by inference, digital media is not. This thesis tackles the legitimacy of this claim by examining how media sustainability operates from three critical perspectives: industry, consumers, and academia. To measure the paper industry’s perspective, a series of interviews with business executives along a supply chain were conducted. I found that collaboration between supply chain actors is a prerequisite for improving environmental performance. To gain insight on the consumer’s perspective, I surveyed 1,400 individuals in North America, investigating media habits and environmental values. I found that consumers are shifting from paper to digital media, but that environmental values have no influence over this shift. This suggests that consumers could be detached from the environmental impacts of their media choices. Finally, the academic perspective was analyzed through a comprehensive review of life cycle assessment (LCA) research that compares paper and digital media from an environmental perspective. The studies found that digital media is almost always preferable to paper, requiring less energy and materials. However, they did not assess the assumptions required in order to compare such different products. More worryingly, the context of media consumption – the industrial systems that produce paper and digital products – was never taken into account. I conclude that since a significant media shift is underway new methods are required to consider sustainability. The new methods should be anchored in two concepts that could improve considerations of the environmental performance of industrial systems. First, industrial ecology, the idea that industry might mimic nature, can strengthen initial assessments of environmental performance. Second, capability maturity models can assist in gauging the ability of industrial systems to manage and improve environmental performance over time.

Preface

While I completed all of the writing, research, and analysis present in this dissertation, credit must be given my collaborators. I designed the research program on my own, although the advice of my supervisory research committee – Drs. Robert A. Kozak, Paul McFarlane, and David H. Cohen – was sought. The analysis of my research results was conducted entirely by myself, unless noted otherwise. There are four components to my research where I had the privilege of collaborating with other researchers and benefitting from the scrutiny of peer-review.

The first is Chapter 1.1.1, "The Sustainability Shift." A lengthier version of this chapter has been peer-reviewed and is set to appear as "The meaning and means of environmental sustainability: Forestry in a more responsible world" in an untitled book published by the Value Chain Optimization Network, a research group supported by the National Sciences and Engineering Research Council (NSERC). I co-authored this chapter with Dr. Robert A. Kozak, but I was responsible for most of the work. I designed the research methodology, identified all relevant source material, conducted the analysis of research results, and was lead author on all drafts of the paper.

The second collaborative effort is Chapter 2, "The Case of Supply Chains: Carbon's Role in Paper Media." A version of this chapter was peer-reviewed and published in the Journal of Forest Products Business Research (Volume 8, Number 2) in 2011. While I was lead author, I collaborated with Graham Kissack, Dr. Christ Elliot, Dr. Robert A. Kozak and Dr. Gary Q. Bull on the preparation and publication of the paper. The design of the research program was a joint effort, although I was tasked with implementing the majority of proposed research. I conducted interviews over the phone and in person with corporate executives in North America. I wrote all drafts of the paper and incorporated any edits that were suggested by my co-authors. Mr. Kissack conducted the carbon footprint analysis, although I led the summation and write-up of his work. The research was conducted after receiving a certificate of approval from the Behavioural Research Ethics Board (BREB certificate #H08-02734).

The third collaborative effort is found in Chapter 3, "The Case of Consumers: Environmental Values and Media Consumption." I was lead author on this chapter, but worked closely with Dr. Robert A. Kozak on the design, implementation and analysis of the research program. I used a web-based survey to engage consumers in North America with the approval for the Behavioural Research Ethics Board (BREB certificate #H09-03036). I wrote every draft of the paper, including all feedback from my co-author. And

while I took the lead in designing the survey and collecting results, the advice of my co-author was invaluable. Most importantly, Dr. Kozak played an instrumental role in guiding statistical analysis. However, the write-up of all results, discussions, and conclusions were my own efforts.

The fourth and final collaborative effort is found in Chapter 4, "The Case of Academic Comparison: Efforts to Measure Paper and Digital Media." A version of this chapter was peer-reviewed and published in February of 2014 in the journal Environmental Impact Assessment Review under the title "Comparative life cycle assessments: The case of paper and digital media" and can be found on pages 10 through 18. My co-author for this paper was Dr. Robert A. Kozak. I was once again lead author, designing and implementing the proposed research program. I conducted the necessary literature review, gathered all relevant data, and wrote-up all results. Dr. Kozak provided input throughout the process, with particular focus on the discussion and conclusions of the paper.

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List of Abbreviations

British Columbia (B.C.)
Burlington Northern Santa Fe Railways (BNSF)
Business to business (B2B)
Capability maturity models (CMM)
Carbon Disclosure Project (CDP)
Cathode ray tube (CRT)
Corporate social responsibility (CSR)
Digital subscriber line (DSL)
Economic Input-Output (EIO)
End of life (EOL)
Environmental Defense Fund (EDF)
Environmental management systems (EMSs)
Environmental non-governmental organizations (ENGOs)
Environmental, social, and governance (ESG)
Information and communication technology (ICT)
Input-Output (IO)
International Panel on Climate Change (IPCC)
Global warming potential (GWP)
Life cycle assessment (LCA)
Life cycle inventory (LCI)
Megajoules (MJ)
New ecological paradigm (NEP)
Non-state market-driven (NSMD)
Original equipment manufacturer (OEM)
Personal computer (PC)
Personal digital assistant (PDA)
Reduced Emissions from Deforestation and Degradation (REDD)
Regional Greenhouse Gas Initiative (RGGI)
United Nations Environment Programme's (UNEP)
United States Climate Action Partnership (USCAP)
Washington Marine Group (WMG)
Waste Electrical and Electronic Equipment (WEEE)
Western Climate Initiative (WCI)

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I offer my gratitude to the faculty at UBC, who both permitted and inspired this far-reaching thesis. I offer particular thanks to Dr. Thomas Sullivan, for showing me value in the philosophy of science, not just science itself. I am indebted to my committee members, Dr. David Cohen and Dr. Paul McFarlane, for their patience and insights. My supervisor, Dr. Robert Kozak, invited me to take a long and unconventional path and tolerated my ever-evolving interests. His penetrating insights, high standards and incredible work ethic were a great gift and a tremendous inspiration.

I also need to thank NSERC, the Value Chain Optimization Network, and the UBC Faculty of Forestry for their generous support throughout my matriculation.

Special thanks are reserved for my parents. To my mother, for never letting me forget that I was expected to succeed. And to my father, Dr. Gary Bull, for providing the perspective and encouragement required to get things done.

Dedication

For Grandma.

For Sunny.

For Mom.

For Dad.

For Dulce.

(Oh, and Crowley too.)

Chapter 1: Introduction

"Please consider the environment before printing this email." We've all seen the phrase happily applied to the bottom of emails, reminding us to refrain from printing. It is an empowering eight words, letting the reader know that, if they do the right thing, the environment will thank them. It also suggests that printing is bad for the environment, but emails aren't something I should worry about. After reading the phrase countless times, I have finally decided to heed its advice.

This dissertation takes the phrase seriously, but rather than simply ask whether I ought to print an email or not, I have taken an academic approach. I want to explore the big questions the phrase, pondered closely, reveals. What does it mean to "consider the environment"? I need to define and understand sustainability. Why is printing on paper implicitly criticized? I need to understand the sustainability of paper. Why is paper being compared to an email? I need to describe the shift from one media type to another, and its environmental consequences.

If these questions sound too big for the scope of a PhD, it is because they are. But they have been winnowed down to research questions and scientific approaches that will strengthen an understanding of what sustainability means in the context of media consumption. The environment will be considered from the perspective of industry, consumers, and academic research. The research objective of this dissertation is to consider the environmental footprints of digital and paper media from three perspectives – industry, consumers, and academic comparisons – in order to elucidate the concept of sustainability.

1.1 Background and Literature Review

In order to properly assess the environmental impacts of media – either digital or printed – I need to begin with a thorough grounding in the literature and establish working definitions of the two major topics this thesis examines: sustainability and media. In this section, I set out to achieve two things: to explore definitions and manifestations of sustainability, and to identify and contextualize the changes in media consumption underway and potential environmental impacts. I call these two trends, "The Sustainability Shift" and the "The Media Shift", respectively, terms I employ throughout the dissertation.

1.1.1 The Sustainability Shift[1]

For such a common word, sustainability is a difficult concept to define. At its core, it implies doing something better (or at least less badly). For this dissertation, I need to define sustainability in light of my broad research objective – to understand the sustainability of media consumption. Due to the nature of media, I must ground an understanding of sustainability in the world of industry. It takes businesses, supply chains, and consumers all connecting together in order to produce, distribute, and consume media.

With the need to understand business and sustainability established, this section describes the origins, evolution, and future directions of business and sustainability. My focus is on environmental sustainability, not social or economic sustainability. While these latter two issues are important, economic sustainability is well understood and already considered thoroughly by business and its profit motive. Social sustainability – which considers human rights and the concept of inter-generational equity – is important, but sufficiently distinct from environmental sustainability to make its inclusion here inappropriate.

1.1.1.1 Definitions of Sustainability

In 1970, the economist Milton Friedman wrote (Friedman, 1970) a seminal article called "The Social Responsibility of Business is to Increase its Profits." The role of business has since changed. Business can no longer relentlessly pursue profits without considering the environmental and social implications. A confluence of drivers has shaped this evolution, including increasing population (and consumption) levels and the emergence of climate change as a global environmental issue have shaken the corporate sector and undermined public trust in private industry. In 2010, the Nobel Laureate Joseph Stiglitz revisited Friedman's narrow doctrine, and suggested, "We should think about how we can create a global economic architecture which works better, for more people, in a more sustainable way" (United Nations, 2009).

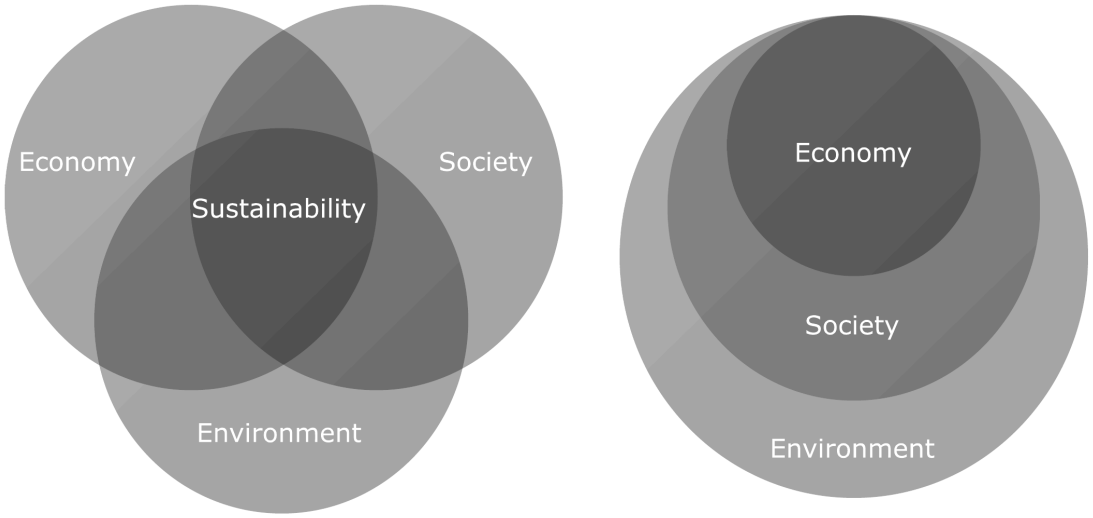
[1] [1] A longer version of this section (1.1.1.) appears in the following: J.G. Bull and R.A. Kozak. (In Press). The Means and Meaning of Sustainability: The Role of Forestry in a Responsible World. In: S. D'Amours, M. Ouhimmou, J. Audy and Y. Feng, ed., *Forest Value Chain Optimization and Sustainability*, 1st ed. Boca Raton: CRC Press/Taylor & Francis.

1.1.1.1.1 Academic Definitions of Sustainability

A founding definition of sustainability comes from the Brundtland Commission, which described sustainability – more specifically, sustainable development – as meeting "the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). This definition evolved, with the concept of sustainability as a 'three-legged stool' gaining popular adoption (Newport *et al.*, 2003). Here, an ideal outcome considers economic, social, and environmental concerns together, with sustainability occurring at the intersection of these three values. A modified version of this idea is the embedded circles approach (Lozano, 2008), which considers the economy a subset of society, which in turn is a subset of the natural environment. This approach offers the natural environment as the most important variable worth considering (see Figure 1).

A variation of this definition comes from the discipline of ecological economics. Ecological economics is an effort to promote understanding between ecologists and economists. It differs from neoclassical economic approaches in that neoclassical models are defined by achieving an equilibrium and final state that is independent of the path taken (Goodland and Ledec, 1987). Growth in the neoclassical sense is a function of accumulated savings, capital investment, and technological progress. Consequently, growth is theoretically exponential and limitless. By contrast, ecological economics models are subject to an exogenous limit: the carrying capacity of the planet. Economic models are embedded in the environment, and these models explicitly address the interdependence of human economies and natural ecosystems over time and space (Wackernagel and Rees, 1997). Thus, sustainability is conveyed as 'embedded circles' where social and economic concerns are bounded by the broader context of the environment. In this view, society and economic systems are subsets of the environment, limited by a finite amount of natural capital.

Figure 1: Schematic definitions of sustainability



While these definitions are conceptual, elegant, and inclusive, they do not necessarily offer the specificity required by different actors, such as governments, consumers, corporations, and civil society. The traditional academic approach of creating distinct and isolated disciplines and reducing questions to testable hypotheses is ill-suited to ask questions and provide answers about sustainability. What type of academic is best suited to address issues of sustainability –an engineer, an ecologist, an economist, a sociologist, or political scientist? Each would approach sustainability in very different ways, none more correct than the others.

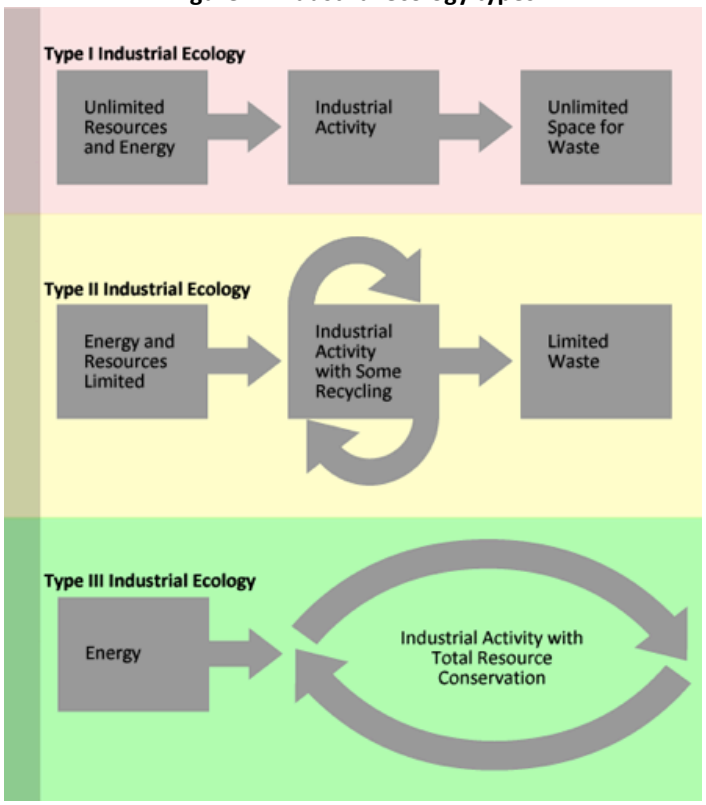
Seager (2008) suggests that academics are not unaware of this mismatch between traditional research structures and urgent research questions. To that end, two new academic disciplines are emerging as a means of grappling with the complex and multifaceted nature of sustainability: industrial ecology and ecosystem health. Seager, in identifying this mismatch between definitions and research capacity, follows upon the work of Mebratu (1998, p.493) who noted that definitions of sustainability "focus on specific elements while failing to capture the whole spectrum." Efforts to develop a theory of sustainability has led to concepts and definitions that benefit specific groups and interests, but do not reflect holistic thinking on the subject (Mebratu, 1998).

Industrial ecology is focused on the interactions between ecological and industrial systems (Graedel and Allenby, 1995). It is founded on the idea that much can be learned from natural systems to improve the environmental footprint of industrial systems (Erkman, 1997). Given that industrial systems have a

relatively brief history, at least compared to ecosystems, looking at the structures and successes of nature can provide insights into how to devise more effective and sustainable systems (Seager, 2008).

Figure 2 shows three types of systems commonly discussed in the discipline of industrial ecology. The first, Type I, is an open loop, with energy and materials flowing in, being processed, and flowing out. It assumes an unlimited availability of resources, and an unlimited ability for the planet to absorb the impacts of industrial activities. Early industrial systems were similar to this model. Type II describes most existing industrial systems as they occur today. There are limited supplies of materials and energy, and industry cannot pollute freely without incurring costs. Some industries might be a 'weak' Type II, with minimal resource conservation and waste reduction efforts, while others could be considered a 'strong' Type II, where both economic and environmental motives exist for managing resource use and waste streams. A completely closed loop Type III system is impossible for industry, as *total* resource conservation is unachievable. However, it is something that industry can aspire to. Ecological systems are Type III systems, as nature has only one input (solar energy), waste does not exist as every material is eventually reused by the system (Gradel and Allenby, 1995; Erkman, 1997).

Figure 2: Industrial ecology types



Industrial ecology is more than simply envying the extreme efficiency of nature. Kalundborg, Denmark is an example of industrial ecology that has garnered substantial academic inquiry (see Ehrenfeld and Gertler, 1997 for a detailed account). A variety of industrial actors evolved, without any master plan, to integrate their waste and energy flows to become more environmentally benign. A coal plant sells steam to a variety of users, including local households. A pharmaceutical factory installed a two-mile steam pipe rather than replacing their existing boilers, an investment that paid for itself in two years. The coal plant was also required by regulators to install sulfur dioxide scrubbers at a cost of $US 115 million. Fortunately, the coal plant was able to sell gypsum, a byproduct of the scrubbing process, to a local plasterboard plant. All of these connections between industrial actors minimize the waste of energy and materials. This symbiosis was not mandated by regulations, although some regulatory imperatives helped foster connections that would not have otherwise existed. Further, and perhaps more importantly, these decisions made a good deal of economic sense.

While industrial ecology is now emerging as a *bona fide* area of inquiry, ecosystem health is much less formalized and the most nascent of the academic disciplines focused on sustainability (Rapport *et al*., 1999). It advances the goal of assessing the health of an entire ecosystem, not just the health of individual organisms or species. Further, it suggests that human health is dependent on healthy ecosystems, and that the interaction between these two systems is vital. Like ecological economics, it considers a healthy ecosystem to be a necessary factor of production in a functioning society and economy. There are three key concepts that have shaped research in ecosystem health, and thus, a conception of sustainability: vigour –a measure of total activity; organization – a measure of the quality and diversity of interactions between different parts of the system; and resilience – the ability of the system to recover from injury (Seager, 2008; Costanza and Mageau, 1999).

1.1.1.1.2 Corporate Definitions of Sustainability

The corporate world offers its own versions of sustainability, with corporate social responsibility (CSR) being the most common tool for pursuing sustainability objectives. CSR requires a firm to think beyond legal and profit imperatives by considering its impacts on society and the environment (van Merrewijk, 2003). By no means is CSR a simple concept; the literature identifies nearly 40 competing and complimentary definitions (see Dahlsrud, 2008). CSR can be referred to by many names, with the terms triple bottom line accounting, stakeholder management, corporate citizenship, or corporate responsibility being used interchangeably. Auld *et al.* (2008a) describe CSR efforts as either 'win-win'

solutions or 'win-lose' solutions. Win-win solutions involve internal changes that are socially and/or environmentally beneficial, but also serve to increase profit. In other words, this is the 'low hanging fruit' of CSR. Win-lose solutions are more complex, as a change that provides environmental or social benefits may decrease profits. As a result, the structures that influence profits (such as government policy and consumer preferences) would need to be adapted to reward the new, but initially less profitable, solution. If no such changes take place, the win-lose solution eventually fails.

Firms can be proactive in trying to develop new markets that reward what are initially win-lose efforts, or they can anticipate changes in government, consumer, or civil society behaviour that will eventually result in win-lose solutions becoming profitable. However, when win-win or win-lose solutions fail to generate profits in the long-term, CSR efforts can result in a competitive disadvantage, and become marginalized rather than transformative in influencing firm behaviour (McWilliams and Siegel, 2001).

There is a danger that CSR efforts might bias a conception of sustainability. Does CSR mean that a company will transform to become truly more sustainable? Or does a company engage in CSR in the hopes that some of its industrial practices can be viewed – without much corporate effort – as being sustainable? Another important idea is that, 'you can't make an omelet without breaking eggs.' Businesses will always have an impact on the environment, and it is prudent to remember this when considering some of the more utopian ideals surrounding definitions of sustainability.

1.1.1.1.3 The Spectrum of Sustainability

Sustainability manifests differently within academic and corporate contexts. But in many ways, the multitudes of definitions complement one another, offering guidance at practical and abstract levels. A common element is that sustainability is a function of both time and space. For example, the time dimension of sustainability is revealed when describing the use of a reusable mug instead of a disposable cup, or altering an entire economy to rely on the production of services rather than goods, or reducing consumption as a means of achieving intergenerational equality. The space dimension refers to the fact that sustainability initiatives can occur at the scale of a single consumer or at the scale of a factory, supply chain, or country. When defining sustainability, we must embrace diversity, rather than struggle to find a unifying articulation. Seager (2008, p.447) grapples with this tension between inclusivity and specificity and arriving at a definition that allows different actors to consider sustainability relative to their own interests:

> "Sustainability might best be defined as an ethical concept that things should be better in the future than they are at present. Like other ethical concepts such as fairness or justice, sustainability is best interpreted conceptually rather than technically."

Seager (2008) takes this notion that sustainability is an ethical concept, and produces spectrum of sustainability that reflects the different dimensions of time and space over which sustainable outcomes can occur. On one side is a version of sustainability that is static. It is defined by the maintenance of the status quo, which to some actors (such as law enforcement) would be a sustainable outcome. Next is steady-state sustainability, which is defined by reliability. Here, the ability for a system to sustain the same function over the long-term is prioritized. Further along is dynamic sustainability, where the ability of a system to adapt, regrow, or evolve in light of changing circumstances is prioritized. To the far side is episodic sustainability, which is, in essence, a version of Schumpeter's 'creative destruction' (Schumpeter, 1942). In this view, sustainability is defined as an evolving system passing through multiple states.

1.1.1.2 Drivers of Sustainability

It is clear the sustainability has a range of meanings and interpretations. It should come as no surprise that a wide variety of factors motivate the adoption of sustainability practices. Each actor along any given supply chain is motivated by their own definition of sustainability and self-interests. That being said, many common themes are emerging within this burgeoning domain and, in the first part of this section, I consider the main 'drivers' of corporate sustainability: governments; investors; eco-efficiency; the marketplace; advocates; and climate change. These categories emerged from an extensive literature review. While other categories certainly exist, these provide a framework that captures both the breadth and the complexity of sustainability and its manifestations.

1.1.1.2.1 Sustainability Driver: Governments

Governments motivate sustainability by a variety of means and for a variety of reasons. Governments are 'stewards' of the environment; they are responsive to the demands of voters who, at times, prioritize environmental issues (Kraft, 2001). Governments are pressured by environmental advocates and corporations, and attempt to strike a policy balance between environmental conservation and the need for economic growth. How, when, and why a government pushes for corporate environmental sustainability is dependent on the definition of sustainability employed and the environmental issue at

hand. Graedel and Allenby (2003) provide a thorough accounting of how governments influence corporate sustainability. They suggest that government action rests on a spectrum. On one hand, governments can encourage specific behaviour, by setting standards, implementing bans, or mandating the use of best available technology. At the other end of the spectrum, governments can act by correcting a lack of information, using product labels, life cycle accounting, and awards and recognition to encourage sustainable outcomes. In the middle rests governmental actions which serve to change incentives, either by introducing or removing subsidies, taxes, or regulatory reform.

Governments have motivated environmental sustainability in the forest sector in a variety of ways. In British Columbia (B.C.), emitters are required to pay a tax on their carbon emissions (Schnoor, 2014). This can be a significant cost for major emitters, such as pulp and paper mills (Bumpus, 2014). The provincial government has committed to becoming carbon neutral, providing opportunities for forest companies to sell credits to the Pacific Carbon Trust.[2] B.C. is also part of the Western Climate Initiative, which could evolve into a major market for trading carbon emissions in North America. The federal government in Canada has subsidized the retrofitting of pulp and paper facilities to produce bioenergy and biochemicals as a means of participating in the new so-called 'green economy' (Laan *et al.*, 2009). In Europe, governments have implemented sustainable a variety of procurement policies, including policies to ensure that the government only buys forest products from legally verified suppliers (Commission of the European Communities, 2003).

1.1.1.2.2 Sustainability Driver: Investors

Investors – those who provide capital to companies or hold corporate stock – have been a key driver of corporate sustainability. But to characterize all investors as drivers of sustainability would be untrue. Many are focused on only profits and quarterly returns. However, large institutional investors, like pension funds, have taken a different approach, adopting ESG (environmental, social, and governance) metrics in their investment strategies (Flatz *et al.*, 2001).

The United Nations Environment Programme's (UNEP) Finance Initiative is a group of over seventy investors that have adopted Principles for Responsible Investing. The investors describe their motives for considering ESG issues as threefold (UNEP, 2006). First and foremost, ESG variables can help

[2] The Pacific Carbon Trust is currently being wound-down, with the provincial government folding its services back into the provincial Environmental Agency (Moore, 2014).

investors make more money. Their hypothesis is that, over time, integrating thorough and systematic reviews of ESG issues will result in better financial performance (Tang *et al.*, 2012). Second, some investors consider ethical values in their investment decisions, and are happy to ignore marginal impacts that ESG criteria might have on financial performance. Finally, channeling investment flows in accordance with ESG issues will support the long-term sustainable development of the global economy.

The authors of the UNEP report dismiss the notion that investors are unfamiliar with the financial impacts of environmental or social risk, offering as evidence the financial liabilities associated with asbestos in building materials in the 1980s and 1990s, or the costs faced by Union Carbide following the Bhopal explosion. Speaking to agnostic or skeptical investors who think ESG issues have a tenuous connection with financial performance, the authors suggest (UNEP, 2006, p.4):

> "Investors who are not sure what to do would do well to refer to Pascal's wager concerning the existence of God: make believe as if the hypothesis is true, thus at little or no cost avoiding the worst-case scenario."

Another example of investors encouraging environmental sustainability comes from the Carbon Disclosure Project (CDP). The CDP is a non-profit supported by 534 investors with assets totaling $US 64 trillion. The CDP administers an annual survey to over 4700 corporations, but focuses its efforts on the so-called 'Global 500', a group of companies that collectively accounts for 11% of annual greenhouse gas emissions (CDP, 2010). Of these top 500 companies, 82% responded to the survey in 2010, the highest rate since the inaugural survey in 2003. In their annual report for 2010, the CDP identifies several important trends. They see the demand for primary corporate climate change data to be growing, with platforms like Bloomberg Finance now offering carbon data alongside financial data. Previously unresponsive sectors, such as shipping and transportation, have now begun to share carbon data (CDP, 2010). CDP also sees a shift in corporate perceptions of climate change, with more respondents in 2010 identifying climate change as an opportunity (average of 9 out of 10 respondents) than a risk (average of 8 out of 10 respondents). While the CDP is not, by itself, a driver of sustainability, it is the result of pressure from investors to identify environmental risks in their investment portfolios, which is a strong driver of disclosure and transparency on environmental footprints.

1.1.1.2.3 Sustainability Driver: Eco-Efficiency

Eco-efficiency is the most obvious reason for a corporation to consider sustainability. At its core, eco-efficiency involves "producing and delivering goods while simultaneously reducing the ecological impact and use of resources." (Molina-Azorín *et al.*, 2009, p.1082). From this perspective, the generation of pollution is seen as inefficient. However, the financial benefits of eco-efficiency are not always immediate or evident, and its pursuit could render a firm temporarily or permanently uncompetitive. Ambec and Lanoie (2008) identify ways in which eco-efficiency can help businesses to improve their bottom lines, for instance, by increasing their levels of risk management and external stakeholder engagement or by decreasing their costs of materials, energy, and services. They also identify three opportunities afforded by eco-efficiency to directly increase revenue streams: through better access to certain markets; through product differentiation; and through selling pollution-control technology. This variety of opportunities is demonstrative of how eco-efficiency can be implemented in a manner that makes good fiscal sense to businesses. Eco-efficiency can also involve attempts to reduce the transportation infrastructure required to deliver a product to market. This is most prevalent in the food industry where 'food miles' are used to measure the environmental impact of delivering food to market (Engelhaupt, 2008).

Based on a review of 32 case studies, Molina-Azorín *et al.* (2009) present a three-stage process that relates environmental management to financial performance. Functional specialization is the first stage, and involves a company reacting to the pressures of environmental regulation. Internal integration, the second stage, involves management developing and monitoring corporate objectives on environmental management. The third stage is external integration. Here, a firm incorporates environmental performance into its overall business strategy. Many of the opportunities identified above by Ambec and Lanoie (2008) result from this three-stage process. In pursuing environmental goals, new markets of consumers who prioritize ecological issues open up and firms can become leaders in their sector. As a result, they may develop technologies or processes that put them in an advantageous position, or they may be able to patent and resell their innovations, thereby gaining first mover advantage. Molina-Azorín *et al.* (2009) find that firms who achieve a positive relationship between environmental management and financial performance are able to invest more in their environmental strategies, resulting in a positive feedback loop.

1.1.1.2.4 Sustainability Driver: Marketplace

There are primarily two market forces that can drive corporate sustainability: business-to-business (B2B) markets and consumer markets. B2B markets influence corporate sustainability when one company seeks suppliers who have integrated environmental thinking into their business model (Mariadoss *et al.*, 2011). For example, the Home Depot implemented a policy where the purchase of certified wood is prioritized (Home Depot, 2011). Wal-Mart has undertaken similar responsible purchasing policies. Wal-Mart has developed a widely praised supplier assessment mandatory for anyone who intends to sell goods at a Wal-Mart store (Wal-Mart, 2011). Providing information on carbon emissions, water usage, and plans to increase eco-efficiency, amongst other things, is required. Wal-Mart is in the process of requiring its largest suppliers to also conduct the same assessment of their own suppliers. As a result, Wal-Mart's environmental priorities are trickling up the supply chain, influencing companies who might not even sell directly to Wal-Mart. Given the purchasing power of Wal-Mart these efforts hold enormous potential.

Consumers can also drive corporate sustainability. Price being equal, consumers generally prefer to purchase a 'green' product (Wilk, 2001)), and some are willing to pay a premium for more sustainable products (Ottman, 2011). The rapid rise of organic food reflects an increasing consumer awareness of environmental issues. Major consumer products manufacturers, such as Coca-Cola, are beginning to promote their green initiatives, in this case, promising to make bottles that contain at least 30% plant-based materials (Houpt, 2011). Information and communications technology companies are offering mobile phones with plastic casing made from recycled water bottles (German, 2009). Hygienic paper products with only recycled content have been developed and are capturing market share (Tissue World, 2010). There are similar examples from almost every sector and product type.

But there is a risk that corporate efforts to increase demand for green products offer little environmental benefit or, even worse, are misleading (Athanasiou, 1996). This 'greenwashing' is not surprising given the relative immaturity of markets for environmentally responsible goods. In the future, however, it will be harder for companies to mislead consumers (Parguel *et al.*, 2011). The Internet and social media are creating savvy consumers who facilitate the rapid dissemination of embarrassing information on corporate practices. Green marketing experts suggest that, in this transparent information age, CSR should be authentic or not attempted at all (Ottman, 2011).

1.1.1.2.5 Sustainability Driver: Advocates

Advocates are individuals or organizations who attempt to influence corporate behaviour, with environmental non-governmental organizations (ENGOs) serving as the most prominent example. Other advocates might include local communities that are impacted by a firm's activities or academics whose research leads them to believe that a firm's behaviour should be improved. Advocates will exert influence by different means at various levels on a variety environmental issues (Stevis and Assetto, 2001).

If there is a corporation creating an environmental impact, there is likely an ENGO advocating for its amelioration (Jad, 2007). They do so by a variety of means (Obar *et al.*, 2012): connecting directly with a firm to express their concerns and perhaps offer solutions; lobbying relevant government agencies to suggest regulatory changes that address the situation; or communicating with the public to raise awareness. Some ENGOs have a more adversarial and combative relationship with the corporate world, publicly shaming a company by releasing details of an environmental harm. Other ENGOs, in contrast, work directly with corporations to help improve their environmental performance, lending authenticity and credibility to CSR efforts. ENGOs themselves admit that working with the private sector is a potent opportunity to promote sustainability. Speaking about his relationship with the CocaCola Company, the CEO of WWF Canada stated the following (Houpt, 2011, para. 8):

> "Coke is the No. 1 purchaser of aluminum on the face of the earth - which is one of the most carbon-intensive commodities. The No. 1 purchaser of sugar cane. The No. 3 purchaser of citrus. The second-largest purchaser of glass, and the fifth-largest purchaser of coffee. We could spend 50 years lobbying 75 national governments to change the regulatory framework for the way these commodities are grown and produced. Or these folks at Coke could make a decision that they're not going to purchase anything that isn't grown or produced in a certain way – and the whole global supply chain changes overnight. And that in a nutshell is why we're in a partnership."

Local communities affected by a company's environmental footprint can similarly advocate for change. How and where they advocate will depend on the particular issue, their capacity, and the responsiveness of government to community concerns. Like ENGOs, what is important from the perspective of CSR is that advocacy is likely to occur for any number of issues, at many levels, and can be combative or cooperative (Lund-Thomsen and Wad, 2014). How a corporation responds to advocacy is

perhaps indicative of how seriously it has integrated CSR practices into its business strategy. Those that have taken the steps to measure and manage their environmental footprint, and have done so in a methodologically rigorous and transparent way, will be better positioned to engage with advocates (Doh and Guay, 2004).

1.1.1.2.6 Sustainability Driver: Climate Change

Climate change and, by extension, carbon, deserve particular attention as a driver of sustainability. Climate change is a unique environmental issue because it is global in scale and has dire implications (IPCC, 2007). It is unique politically because so many government bodies at the international, national, provincial, and municipal levels have put forth regulations and set targets with the goal of reducing carbon emissions. Corporations, perhaps seeing the writing on the wall, have embraced carbon as a major environmental issue (SwissRe, 2007). Given that carbon emissions are somewhat analogous with energy use, reducing carbon often equates with reducing energy costs. Reducing emissions can, therefore, be a classic 'win-win' CSR initiative (Stanny and Ely, 2008).

Carbon simply being ubiquitous does not make it a driver of environmental sustainability. The real driver is the likelihood of carbon as a priced commodity. Governments, advised by scientists and advocates that carbon emissions should be reduced, have devised schemes to put a price on carbon (Garnaut, 2008). In the European Union, the European Trading System governs the buying and selling of emission allowances (Europa, 2005). International agreements have tried, thus far failing, to emulate this system. Regional approaches, such as the Western Climate Initiative or the Regional Greenhouse Gas Initiative, have taken steps to price carbon (Western Climate Initiative, 2009; RGGI, 2009). Some jurisdictions, like British Columbia, have imposed a carbon tax. All of these efforts result in one obvious conclusion: corporations anticipate having to pay for carbon (Kolk *et al.*, 2008). The prospect of a new expense embedded in all business transactions has been remarkably effective in driving businesses to consider their environmental footprints.

The monetization of carbon is what economists consider internalizing a cost. Economic systems often fail at internalizing environmental costs, and carbon is the first attempt at a global scale (Lohmann, 2009). It should not be a surprise that reaching an international consensus on how to price carbon is an elusive goal. The lack of action at the international level has not stopped corporations from learning how to measure, manage, and reduce their emissions, and these efforts are reaping benefits (Lee, 2011).

Measuring the carbon footprint of a large multinational corporation is a technical feat, requiring expertise, scientific knowledge, and an evolved corporate culture (Halldórsson *et al.*, 2009). However, now more than ever, companies have an increased capacity and willingness to begin measuring this aspect of their environmental footprints (CDP, 2010). Furthermore, lessons learned here could be used in measuring the environmental impacts of using other public goods, like water.

1.1.1.3 Responses to Sustainability

Here I consider responses to sustainability in the form of CSR practices, basing the analysis on a framework developed by Auld *et al*. (2008a) that categorizes CSR innovations. These seven categories capture how a corporation might respond to the sustainability imperative: individual firm efforts; individual firm and NGO agreements; public-private partnerships; information-based approaches; environmental management systems (EMSs); industry association codes of conduct; and non-state market-driven (NSMD) governance in the form of private-sector hard laws.

1.1.1.3.1 Sustainability Response: Individual Firm Efforts

Individual firm efforts occur when a firm independently makes a decision to become more environmentally responsible. Such efforts are not responses to regulations, but may be attempts to preempt government. Firms may uncover win-win CSR opportunities or adopt win-lose strategies that hold long-term financial potential. In general, internal firm efforts are not subject to externally imposed prescriptive requirements, and firms control the processes and policies developed. This flexibility and the fact that win-win solutions tend to be the focus of corporate attention, explain why individual firm efforts represent the most prevalent and widespread manifestation of CSR (Hill *et al.*, 2003).

1.1.1.3.2 Sustainability Response: Individual Firm and Individual NGO Agreements

Agreements refer to CSR efforts in which a firm engages with an ENGO or other stakeholders to address the environmental impact associated of a firm's operations (Hartman and Stafford, 1997; Dauvergne and Lister, 2012). In general, an ENGO will come to view an environmental issue from a different perspective than a firm. Firms benefit from these partnerships by adding legitimacy to their CSR efforts by collaborating with traditional adversaries (Yaziji and Doh, 2009).

An example of firm-ENGO collaboration comes from the Environmental Defense Fund (EDF) and Wal-Mart. Wal-Mart, the epitome of a big box American retailer, has integrated environmental variables into

its practices for a variety of reasons. EDF decided to leverage this opportunity, seeing collaboration with Wal-Mart as a chance to highlight what they perceive to be a sincere CSR effort, but also to promote best practices among retailers and along Wal-Mart's massive supply chain (EDF, n.d.).

1.1.1.3.3 Sustainability Response: Public-private Partnerships

Public-private partnerships are similar to firm-ENGO agreements, but involve other interests, such as governments, or are made up of several firms and ENGOs acting in concert. These partnerships can emerge as efforts to address standards development, to implement self-regulation, or to develop collaborative co-regulation schemes (Andonova, 2010). These partnerships are grounded in the idea that private-public collaboration can provide an efficient means of enforcing costly legislation.

An early example of public-private partnerships comes from the United States and the Environmental Protection Agency (EPA), which developed the 33/50 program. Implemented in 1991, the goal of the program was to reduce emissions of 17 toxic chemicals by 33% in 1993, and 50% by 1995 (EPA, 1994). Rather than set strict prescriptive requirements, the EPA gave industry flexibility in meeting these goals. The program managed to achieve its targets one year ahead of schedule (Khanna and Damon, 1999). Forestry has similar examples. The Great Bear Rainforest Agreement and the Canadian Boreal Forest Agreement both demonstrate the potency of partnerships between ENGOs, industry, and government. The former protected a large area of rainforest on the coast of British Columbia, allowing ENGOs to claim victory while providing industry with a degree of security from ENGO criticism ((Howlett *et al.*, 2009). In the latter, ENGOs and industry (including traditional adversaries like Greenpeace and Weyerhaeuser) agreed on environmental conservational goals and the need to pursue sustainable forest management and provide jobs for forest-dependent communities (FPAC, 2010). This provided a détente of sorts, allowing industry to focus on economic issues without the constant risk of negative attention from ENGOs.

1.1.1.3.4 Sustainability Response: Information-based Approaches

Many CSR efforts revolve around the provision of information related to a firm's behaviour (Kharrazi *et al*. 2014). Some efforts are voluntary, while others are mandatory. Government sponsored systems, such as the EPA's Toxic Release Inventory (Khanna *et al.*, 1998), require companies to disclose information on an extensive list of chemicals that their activities produce. This was brought about by advocates who argued that communities have the 'right to know' about what corporations are doing. In

Canada and the United States, like most other developed economics, major emitters of carbon are required to report on their emissions to the federal government (Jones and Ratnatunga, 2012). Similarly, food producers must report on the nutritional requirements of their products. Wal-Mart, while describing the future of its Supplier Sustainability Index has suggested that a carbon label might be required for all of the goods that it sells (Wal-Mart, 2011), which could potentially impact sustainability reporting and information based approaches across the globe (Gereffi and Christian, 2009).

These examples speak to an increasing emphasis on transparency. By requiring the disclosure of information or by advocating for voluntary disclosure, transparency becomes the norm rather than the exception. Firms that do not participate risk losing market access. Other forms of information sharing also revolve around this notion of transparency. In the United States, the Lacey Act mandates that importers of forest products trace the origin of their imports. This has forced the development of sophisticated supply chain practices, such as radio-tags that get attached to felled trees at harvest sites (USDA, 2011). Non-compliance with the Lacey Act can lead to embarrassment. Gibson Guitars, a high-end luthier in the United States, experienced public scrutiny when its operations were shut down by government officials for violating the Lacey Act. An investigation by the World Resources Institute purchased 32 books randomly from a retailer and found that three of them used illegal fibre in the paper (Nogueron and Hanson, 2010). A continued need for transparency and measurement along the supply chain remains. Similar legislation for conflict minerals (minerals from the Congo Basin whose sale funds armed conflict) are being implemented in the United States which would require manufactures to trace the source of certain metals in their products (OpenCongress ,2010).

The Global Reporting Initiative (GRI) is an example of information sharing that deserves particular attention. The GRI has become the *de facto* standard (it is technically a guideline rather than standard, as it is free to use and does not mandate verification or auditing) for corporate sustainability reporting, and is perceived by executives as second only to the ISO 14001 standard in influencing their CSR practices (Brown *et al*. 2009). The GRI is a multi-stakeholder process, involving industry, governments, scientists, and civil society. Various working groups develop specific guidelines for different sectors. Additionally, the guidelines evolve relatively quickly; the third version of GRI is in place after only 9 years. The GRI has gained widespread support for a variety of reasons. It is a 'win-win' solution as corporations adopt a reporting framework that meets the requirements of many social actors (notably,

advocates and investors). The GRI also carries with it a strong sense of legitimacy and inclusivity and is a partner institution of the UNEP.

At the opposite end of the scale from enterprise-level GRI reporting is another information-based approach: Environmental Product Declarations (EPDs.) These statements are equivalent to food nutrition labels, disclosing the energy, materials, water impacts and waste emissions associated with a particular product. EPDs are based off ISO standards (ISO 14025, 2006) and can only be prepared once Product Category Rules (PCRs) have been developed using a multi-stakeholder process. The forestry sector has embraced EPDs, as they are increasingly being required of products used in the construction industry (Zackrisson *et al*. 2008). EPD's have been developed for highly specific products, like Western Red Cedar Decking, Western Red Cedar Bevel Siding, Glue Laminated Timbers and Softwood Timber, to name a few (FII, 2013).

1.1.1.3.5 Sustainability Response: Environmental Management Systems

Environmental management systems (EMS) are externally defined and imposed criteria about how a firm should approach its environmental footprint (Melnyk, 2003). The ISO 14001 standard, and more recently the 26001 standard, are examples of widely adopted EMSs that organizations adopt in order to standardize their internal processes for handling environmental issues. Firms use these systems to measure and monitor their footprint with the goal of reducing inefficiencies and identifying risk. They carry with them credibility, and the opportunity to attach a recognized logo to a product, but there are costs associated with implementation and third-party verification of EMS standards.

Firms can also employ other systems to measure their environmental footprint. A common tool, in both academia and the corporate world, is life-cycle assessment (LCA) (Gauthier, 2005). While ISO standards are used to define protocols on how to conduct an LCA, LCAs are rarely verified by a third party. Increasingly, LCAs are utilizing data from life cycle inventory (LCI) databases that are privately owned and not subject to peer-review. While these databases make the conduct of an LCA cost effective, they may also hide uncertainties or gaps in data (Auld *et al*., 2008a).

1.1.1.3.6 Sustainability Response: Industry Association Codes of Conduct

Industry codes of conduct are typically found in sectors where companies tend to share a collective reputation. This can happen when the behaviour of one firm can impact an entire industry, regardless of

individual firm performance (Bondy *et al.*, 2004). Most often these are sectors that produce primary or intermediary goods, like forestry, mining, or petrochemicals (Jenkins and Yakovleva, 2006). Recently, other sectors have adopted codes of conduct: the coffee industry, which sells directly to consumers, has several schemes in place (Giovannucci and Ponte, 2005); and the textile industry in the United States has created a Sustainable Apparel Coalition (Sustainable Apparel Coalition, 2014) with the backing of ENGOs (EDF), government bodies (EPA), and major clothing manufacturers (Levi Strauss, Nike, and Mountain Equipment Co-op, to name a few). These codes of conduct are often principles-driven and administered by industry associations; they do not provide specific, prescriptive guidance on how firms should behave. Rather, concepts are defined and adherents promise to meet them, although verification and enforcement may not be as stringent as in other types of CSR innovations.

1.1.1.3.7 Sustainability Response: Nonstate Market-driven Governance

Nonstate market-driven (NSMD) governance is a type of CSR innovation defined by Auld *et al*. (2008a, 2008b). It differs from all of the above CSR tools in that it requires mandatory and enduring behaviour (so-called 'hard law'), but is not enforced by the state. Further, it differs from traditional hard law by continually adapting over time with the input of various stakeholders (Bernstein and Cashore, 2007). NSMD governance also differs from other CSR innovations in that it is rooted in the supply chain. NSMD governance requires a firm to understand and manage the upstream implications of its activities, but also requires a firm to look downstream to understand that it is ultimately the market that drives NSMD schemes to be adopted. Finally, NSMD governance, unlike most CSR efforts, requires third-party verification (Cashore *et al.,* 2007). This imposes a significant cost on firms, but also ensures that NSMD schemes remain something akin to hard law.

The most obvious example of NSMD is certification. Certification schemes exist in several industries (seafood, for example, has seen recent growth in a variety of schemes). But forestry has led the way in the development of certification systems. Perhaps the most widely known scheme is the Forest Stewardship Council (FSC). Borne out of dialogue around sustainability at the Rio Environmental Summit in 1992, FSC is an independent body jointly controlled by an environmental committee and an industry committee (see Rametsteiner and Simula, 2003 for a more thorough discussion of forest certification schemes). Other prominent schemes are the Sustainable Forestry Initiative (SFI, an industry-backed scheme in North America) and the Programme for the Endorsement of Forest Certification (PEFC,

dominant in Europe with a significant Canadian presence and composed of a central body that allows for country-level definitions of certification).

Whether a firm choses to participate in a forest certification scheme relates to the character of the firm (publicly or privately owned), the product they are manufacturing (magazine paper, dimensional lumber, pulp, etc.), trade dependence (major exporter or domestically oriented), ENGO pressure, supply chain procurement policies, and government support. Small operations may find compliance too costly and not worth the effort (Crals and Vereeck, 2005). Large forestry firms, in contrast, are more vulnerable to pressure from advocates and can better bear the costs of compliance. In fact, in many instances, certification among larger supply chain actors is fast becoming the norm in the marketplace (Cashore *et al.,* 2005). Other firms, such as those that sell intermediary products, must comply with more than one scheme in order to meet various customers' demands (Mikkilä and Toppinen, 2008). For example, a paper company might have to be SFI-certified to sell to an American client, FSC-certified to sell to a Canadian client, and PEFC-certified to sell to a European client.

1.1.2 The Media Shift

We've described and defined sustainability and its facets, possibilities, and contexts. With these drivers, definitions, and responses in mind, in this section I set out to characterize the media shift that is underway. Describing the paper to pixel transition is not simple. There is such variety in the many transitions that no single metric that can capture the diversity in the scope, volume, or intensity of the transition. My goal is not to describe specific transition, but instead to consider the types of transitions. Given the diversity of media that can be consumed either on paper or digitally, this approach was necessary.

The complexity of the transition is simple to illustrate: media that previously could be consumed only on paper is now available on a vast array of digital devices. Paper media can be a newspaper, magazine, book, catalogue, flyer insert, directory, printing or writing paper, invoices, and bills, etc. All of these serve as a basis for communicating information. Digital media is similarly equipped to communicate over a wide variety of platforms including desktop computers, laptops, internet-enabled cell phones, tablet computers, or E-Readers. With this many products and types of information, the scope for different transitions is vast (Hetemäki and Nilsson, 2005).

There are other characteristics of media that need to be considered when describing the paper to pixel transition. Media consumption is not necessarily a zero-sum game. If the marketplace consumes more digital media, it does not necessarily to come at the expense of paper media. This is not to suggest that increased digital consumption does not impact paper consumption, it's just not a direct trade-off.

Nor is the transition towards digital media the result of consumers becoming tired of the offerings provided on paper media (Hujala, 2011). Digital devices are capable of providing a broad range of services, far beyond the ability to communicate information previously on paper. For example, digital devices can email, bank, shop, play videos, take pictures, and act as GPS devices – this multi-functionality is a large part of their attraction to consumers. And, most importantly, it also implies that the environmental impacts of digital devices are spread over multiple uses.

In this section, I review digital and paper media, their lifecycles, and the range of environmental issues associated with media production, distribution, consumption, and end-of-life. The objective is to bring into focus the characteristics of each sector, and to identify key trends that indicate a shift is underway. By combining this review with definitions of sustainability (see section 1.1.1 The Sustainability Shift) I can define research questions that will add depth and context to our understanding of the sustainability of media.

1.1.2.1 Digital Media

I discuss trends in the digital media according to various lifecycle stages. The goal is to better understand the diffuse, complex and rapidly changing digital media landscape. I organize the review in four parts – media production, distribution, consumption, and end-of-life. In each category, I examine recent trends and the environmental context of each. Digital media is employed as a holistic term; it incorporates both the virtual, final product (the digital content viewed on a screen), as well as all of the necessary Information and Communication Technology (ICT) that supports the product, delivery, and consumption of digital media. This includes hardware and networking devices, consumer devices like computers and smartphones, as well as the factories required to manufacture all of this equipment.

1.1.2.1.1 Digital Media Production

To actually produce digital media requires a global and complex supply chain of ICT. To deliver digital media requires a complex supply chain, from raw materials to material processing to manufacturing

facilities, to computer hardware and networking equipment. Over its lifespan ICT equipment hosts a massive variety of products, dispersing its footprint across a range of digital media. But the key point is that digital media is not virtual media: it depends on a physical, tangible, and complex network of material goods.

Digital media begins making hardware, involving a variety of raw materials, including chemicals, metals and minerals. Paul and Campbell (2011) investigate the environmental footprints of rare earth minerals[3], substances that are present in in almost all ICTs. In all stages of mining and refining rare earth minerals, there are adverse impacts on the environment. After sourcing and refining raw materials, complex industrial processes are required to produce ICT equipment. Lau *et al.* (2002) investigate the footprints associated with electronics manufacturing, finding that a host of environmental problems arise in the production and then eventual disposal of computer material components. Adamon *et al.* (2005) find the range of environmental impacts from ICT is difficult to manage: impacts are dispersed along the supply chain, and ICT users are limited in their ability to mitigate footprints.

1.1.2.1.2 Digital Media Distribution

Once ICT hardware and networks are in place, digital media needs to be distributed. This means data flowing over wired and wireless networks, being processed by data centers, and finally arriving at the various devices that can be used to access digital media. Over the past two decades, there has been an almost exponential increase in the volume of data being delivered worldwide, and the trend is accelerating. According to Cisco (2014), devices like smartphones, tablets, and laptops are expected to increase in number from 7 billion in 2013 to 10.3 billion in 2018. Over the same period, the amount of data consumed over mobile networks is expected to increase by 15.9 exabytes per month[4]. Mobile networks are also evolving away from 3G (third generation) to 4G (fourth generation) networks. This requires a massive build-out of switches, relays, and transmission towers in order to support the new, faster mobile frequencies (Suk Yu Hui and Kai Hau Yeung, 2003).

As the volume of data and digital networks grow, more and more data centers are required. Terms like "the cloud" and "big data" have become ubiquitous as firms like Google, Apple, Facebook, Microsoft, and Amazon measure and collect more data, while finding ways to profit from the process. Koomey

[3] Rare earth minerals are used in a variety of applications, and have nuclear, metallurgical, chemical, catalytic, electrical, magnetic, and optical properties that are sought-after by industrial users. (Koltun and Tharumarajah, 2014)

[4] To put that figure in perspective, an exabyte is one million terabytes, and one terabyte (a thousand gigabytes) is about the size of large hard drive in a desktop computer.

(2008) reviews the explosive growth in data centers that started in the early 2000s. Early in the growth curve, data centers were smaller and their operators paid little attention to energy consumption. But as the number and size of data centers grew, they began to consume almost 2% of total electricity produced in the United States. Operators have now begun to manage for energy consumption, attempting to reduce both environmental and financial costs (Koomey, 2008). But not all companies share a concern for reducing the environmental footprint of their data centers. A recent investigation (BBC, 2014) found that not all data centers are created equally. While some providers publicly disclose their environmental footprints and set targets for absolute reductions in emissions, others are more sanguine about their facilities impacts and energy use (Greenpeace, 2010).

1.1.2.1.3 Digital Media Consumption

The production and distribution of digital media has experienced explosive growth. Unsurprisingly, the consumption of digital media – both digital hardware and virtual media – has undergone a similar experience. Between 2009 and 2012, global shipments of smart phones and tablets per quarter rose from 15 million to almost 190 million today (Business Insider, 2014). Over the same period shipments of traditional personal computers (PCs), like desktops and laptops, experienced little growth (AVC, 2014).

In mature markets like North America and Europe, people have long consumed digital media, first on desktops with dial-up modems, shifting to laptops with broadband connections, and now dominated by mobile devices with wireless connections. According to the MIT Technology Review (2010), developing countries like India are experiencing growth that skips the wired, stationary ICT devices and are moving straight towards cheap, mobile devices. While mature markets still dominate the total consumption of mobile data, the fastest growth is occurring in regional markets like Latin America, Africa, and Eastern Europe.

Smartphones, laptops, and tablets have been steadily declining in price for years, facilitating the massive growth in data consumption (Zuberbühler Associates, 2013). ICT companies know that not all consumers can afford $700 smart phones and are creating cheaper devices for developing markets. But this trend means that devices tend to last for only a few years and companies may in fact been engaged in so-called ‘planned obsolescence’ where devices are deliberately designed to have a limited lifespan (CBC News, 2013b). Why make a device intended to last a long time, when after just 12 or 24 months a new device with better performance is available? Unfortunately, this approach results in manufacturing

complex devices with embedded environmental impacts that have relatively short lifespans, clearly suboptimal from the perspective of environmental sustainability.

1.1.2.1.4 Digital Media End-of-Life

Given these trends in production, distribution, and consumption, it is no surprise that the end-of-life (EOL) of digital media is problematic. Ongondo *et al.* (2011) provide a thorough review of the management of electrical and electronic waste flows worldwide. Digital media relies on ICT that is composed of abiotic, non-renewable resources that are difficult and expensive to process. Processing ICT at EOL is further complicated by the fact that dozens, if not hundreds, of different metals, chemicals, and plastics are present in small quantities. This makes it difficult to retrieve any particular substance at a large scale, removing any economic imperative to manage EOL. As a result, large volumes – between 20 and 25 million tonnes per year, by some estimates (Robinson, 2009) – of ICT waste ends up in landfills or exported to countries, like China, India, or Ghana, where the environmental and social impacts of processing ICT waste are often severe (Ni and Zeng, 2009). Some jurisdictions have tried to improve handling of ICT waste. Europe passed the WEEE (Waste Electrical and Electronic Equipment) Directive, requiring the handling of ICT waste domestically. In North America, the province of British Columbia charges consumers an up-front waste handling fee, and processes all ICT waste at a domestic facility operated with funds from the up-front fees (Driedger, 2001). But these initiatives are the exception, not the norm (Kahhat et al., 2008). In the face of explosive growth in ICT hardware production, ICT device consumption and digital media production, the EOL impacts of ICT and digital media remain a pressing environmental concern (Yu *et al.*, 2010).

1.1.2.1.5 Summary: Digital Media Shift

Digital media is intrinsically connected to ICT hardware, devices and networks, all of which are undergoing significant growth in production, distribution, and delivery. The digital media shift can be characterized as accelerating quickly and increasingly global. It is complex and involves hundreds of industrial sectors and actors. This interconnected web of networks, data centers, and devices is the platform that hosts all digital media. And this platform is growing globally, evolving as new technologies emerge. In light of all the drivers and responses to sustainability identified earlier, the digital media shift is a challenge to environmental sustainability. The diffuse and rapid change makes it difficult to measure and manage environmental impacts, both negative and positive.

1.1.2.2 Paper Media

In this section, I explore four stages of the paper media lifecycle – production, distribution, consumption, and end-of-life. For each stage, I identify the most important trends and environmental issues. Clearly, paper is a very different media form than digital. Humans have been producing paper for thousands of years, and the printing press, pioneered in the 1430s, portended the almost universal adoption of paper media across the world. Paper media, much like digital, depends on expansive industrial system – in this case forestry – in order to be produced. Again, the goal here is not to define every environmental impact or sustainability issue in forestry. Instead, I review the production, distribution, and consumption of paper and the environmental impacts that arise.

An important factor to consider is that not all paper is created equally. Trees used to make paper could come from a sustainably managed forest or from an illegal harvest site in an area of high conservation value. A paper mill could be run at a world-class level, with all environmental impacts measured and managed, or it could originate from an old mill in a jurisdiction with weak environmental controls. Paper products also vary widely, from an enduring product like a classic novel or a passport, to something transient like junk mail or shopping catalogue. The Environmental Paper Network (EPN) produces a paper utility matrix that identifies four classes of paper (EPN, 2013):

- High Utility / Low Volume:
  passports, birth Certificates, letters, photographs, important documents
- High Utility / High Volume:
  books, newspapers, hygienic papers
- Low Utility / Low Volume:
  local advertising, advertising posters
- Low Utility / High Volume:
  junk mail, catalogues, over-prints of books and magazines, over-packaging

These four categories demonstrate the wide variety of paper media that exists. And in each category, digital media is playing a disruptive role, either augmenting or replacing a paper product.

1.1.2.2.1 Paper Production

The impacts of paper production begin in the forest, where logging takes place. Berg and Lindholm (2005) review the energy impacts of logging, finding that removal and haulage contribute significantly to the footprint of harvesting. Boltz *et al.* (2003) compare various logging methods, finding that reduced-impact logging can significantly decrease the footprint of harvesting. After a log is removed from the forest, it must be processed (typically at a sawmill) and chips moved from the sawmill to a paper mill.

Here another host of environmental challenges emerge. Carlberg and Stuthridge (1996) review the scope of environmental impacts of paper making, from the origin of fibre to the long-term impact of paper mills on the surrounding environment. Bajpai (2011) offers a more recent perspective, identifying how paper mills have improved their chemical, effluent, and waste handling procedures to minimize environmental impacts. Galloway *et al.* (2004) consider how paper mills and their effluents can adversely impact wildlife, including fish, with a commensurate impact on ecosystem health and biodiversity. This reinforces a core truth about forestry and papermaking: it involves harvesting and processing trees (with the exception of recycling various forest products), thereby disrupting natural environments at a large scale. The impacts of this disruption can be managed sustainably, through adequate planning and site-level remediation, or they can be ignored, resulting in deforestation and/or the degradation of the natural environment.

In the production of paper, there is significant scope for variation. In some instances, forest certification schemes may be used to encourage sustainable forest management. These schemes, either industry sponsored or a collaborative approach involving non-state actors and industry, have varying levels of effectiveness. Beyond a scheme and the standards it sets, the role of governance and transparency is important (Overdevest, 2010). Recent studies (Visseren-Hamakers and Pattberg, 2013) have suggested that it is inconclusive whether certification meaningfully and consistently improves environmental performance.

1.1.2.2.2 Paper Distribution

Distributing paper media has its own set of environmental impacts. There is an inevitable reliance on transportation networks, including sea shipping, railways, trucks, as well as the vehicles of consumers who drive to retailers to purchase paper media. Borggren *et al.* (2011) suggest that the distribution impacts of paper media can vary widely. Some paper media, like books, are easily shared and can last for decades. How a consumer actually receives a book matters too: do they drive a significant distance for the express purpose of purchasing a book? Or do they take public transit, and walk to a bookstore as part of their daily routine? Or perhaps the book is delivered, part of a network of trucks and distribution centres that deliver a wide variety of goods.

To understand the footprint of distributing paper media, there is no better case study than that of mail. The delivery of mail has been disrupted by the advent of digital media. SLS Consultants (2008) conducted a study of the evolving mail industry in the United States. Personal correspondence, as well as invoices and statements, used to dominate the mail system. Now people rely on emails and electronic invoices to correspond. Mail volumes have declined, but have also evolved. Unsolicited mail, or junk mail, now makes up the majority of mail delivered. The type of vehicle used for delivery can influence environmental impacts: older, less efficient vehicles can potentially double the footprint of delivering mail. The density of a mail system also matters. Delivering paper media in remote areas often requires driving significant distances. Postal workers operating in urban areas, in contrast, can easily do so on foot.

1.1.2.2.3 Paper Consumption

The impacts of paper consumption are best understood through the concept of 'paper utility' introduced at the beginning of this section. Different paper types are of high or low utility and are consumed in high or low volumes. A paper product like a book can be shared and stored for a significant period of time. Some have suggested (Skog and Nicholson, 2000) that paper products can even act as a carbon sink, thereby assisting in efforts to mitigate and abate climate change. In contrast, high volume low utility products – junk mail being the obvious example – can have a significant and adverse impact on the environment. Consumers often immediately discard some forms of paper, gaining no utility from its production and distribution.

1.1.2.2.4 Paper End-of-Life

At the end-of-life (EOL), paper media faces two options: it can be recycled or it can be discarded. Recycling paper itself has an impact: it takes energy and water to break paper down to its constituent fibres and recycle these into a new product. Virtaten and Nilsson (1993) offer a broad view of all the environmental impacts of paper recycling. They find that recycling has the potential to actually use more energy and water than virgin fibre, although specific energy sources and processes employed matter as well. If a paper product is not recycled at its EOL, chances are it ends up in a landfill. Research has suggested (Agriculture Today, 2010) that paper in a landfill can decompose in an oxygen starved environment, thereby resulting in methane emissions, a potent source of greenhouse gases. Some estimates (Micales and Skog, 1997; Wang *et al.*, 2013) suggest that decomposition in a landfill and the

associated methane can actually produce the most greenhouse gas emissions of any stage in the paper lifecycle.

1.1.2.2.5 Paper Media Shift

I have briefly reviewed the various lifecycle stages – from forest floor to delivery truck to landfill – where paper has the potential to impact the environment. But for the purposes of this thesis, I need to also review how paper media is changing. As digital media has emerged, it has clearly impacted the consumption of paper media. I want to contextualize and deepen the understanding of this impact.

A big change in paper media has been the decline of traditional paper media outlets. The best example of the paper-to-digital media shift is that of newspapers. For well over a century, newspapers dominated the media landscape, generating revenue by selling physical copies, advertisements as well as classifieds. But with the advent of digital media, this revenue model faced an existential threat. Websites like Craigslist offered a platform for posting employment advertisements, real estate listings, and various other products. The monopoly of newspapers on distributing targeted and local advertising was suddenly broken. Between 2003 and 2012, newspapers in the United States lost $11 billion in classified revenue (Edmonds, 2013). This amplified a downward spiral of declining readership and advertising revenue brought about by changing consumer preferences. Industry believes that the transition has stabilized (Newspaper Association of America, 2013), but big brands like the Wall Street Journal and the New York Times are now relying on digital subscriptions to augment their revenue streams.

Newspapers are not the only paper medium to be impacted: magazines have suffered too. Prominent brands like Life Magazine and Newsweek have ceased paper publications, unable to sell enough magazines or advertising to remain profitable (Media Life Magazine, 2014). While niche magazines endure, it is only prominent brands (e.g. The Economist) or publications with generous corporate backing (e.g. Time Magazine) that have survived the media shift (Pew Research Journalism Project, 2013). Experts predict that the future of media is both paper and digital (Ferguson, 2009). Consumers vary in their preferences, and the advent of cheap and accessible digital technology has, by no means, eradicated all print media. Established paper media brands (like, as mentioned previously, the New York Times) are able to leverage their editorial staff and reputation to generate significant digital revenues.

I have already discussed the decline in mail volumes that the digital to paper media shift has induced, but is worth revisiting. Between 1980 and 2013, mail volume went from around 60 billion pieces mailed per year to a peak of 103 billion in 2002 and back to 65 billion (United States Postal Service, 2014). With current mail volumes similar to levels in the 1980s, it is no surprise that postal services worldwide have had to aggressively curtail services and cut costs in order to operate without losing large sums of money.

One final shift worth considering is that of the office place. In the workplace, paper and digital media form a complex, and at times symbiotic, relationship. Digital tools are used to produce paper products (like a printed email). And while the use of digital media has exploded, the decline of paper media has not experienced an equal and inverse implosion. York (2006) sees the concept of the 'paperless office' as a quintessential example of Jevon's paradox, which posits that any increase in efficiency is often offset by an increase in use. In the office environment, this paradox manifests in increased digital media consumption along with only modest declines in paper consumption. While digital media may be more efficient at delivering memos, emails, or reports, paper media is still being consumed. As a result, the aggregate environmental footprint of office workers may have increased. Researchers who study the effectiveness of media types suggest that a mix of paper and digital media is likely to persist, as each format has its own attributes and strengths (Ashby, 2011).

1.2 RESEARCH QUESTIONS

I have demonstrated that there has been a shift in media consumption, and that concurrent to that shift has been the emergent priority of sustainability. To probe these trends further, and to take the time to "consider the environment", I have arrived at three research questions that seek to unpack the relationship between sustainability and media. These questions look at the same issue – media sustainability – from three distinct perspectives: the consumer, industry, and academic comparisons of media choices. Given what I have learned about the sustainability shift and the media shift, it is clear that multiple perspectives are required. I have identified three research questions that will deepen an understanding of why I should consider the environment when printing an email. As already mentioned, clearly the paper sector deserves particular attention, having been classified as the product requiring environmental consideration. I have also seen that media consumption is shifting, and want to find out whether a survey of consumers provides further evidence of this transition. Finally, I have identified the need to compare paper and digital. To that end, I need to conduct a thorough analysis of the research that has compared both paper and pixels.

Influencing and motivating this line of inquiry are the two shifts I discussed in detail above. As the world responds to environmental challenges by pursuing sustainability, and as the media landscape evolves in light of new technologies, I need to better understand what this means for the environment. Given the breadth and depth of the trends that motivate this dissertation, I cannot focus simply on a discrete trade-off between digital and paper media. A discrete trade-off, say a consumer reading a book digitally instead of in print, is an important question. But it does not capture the systemic shifts in sustainability and media. It might say something about the impacts of a single consumptive choice, yet reveals very little about the impacts of entire industries across the planet and across decades of time. This dissertation seeks to elucidate the broad and deep questions that a comparative analysis of two industrial sectors requires. The uncertainties and assumptions that shape an understanding of paper and digital media need to be identified so that I might better understand the ecology of the industries involved, and contribute to a theory of sustainability that is both nuanced and evolved.

But scientific inquiry and academic research needs to be grounded in testable hypotheses, sound methods, and clear reasoning. While a long and philosophical exploration of sustainability is tempting, grounding this dissertation in sound research will ensure that results and findings are theoretically robust and relevant. Reflecting these trends and objectives, the three research questions are as follows:

1. Given the focus of environmental concern on paper media, how does sustainability operate along a paper media supply chain?
2. Given the shift of consumers from paper to digital media sources, has sustainability impacted consumers' media consumption habits?
3. Given the proliferation of media choices, have life cycle comparisons been made? And if so, what are their findings?

I start with an inquiry into paper media supply chains. Because paper is seen as an environmental pariah, I want to investigate how that sector is managing sustainability issues. Rather than focus on one company or facility, I want to investigate a media supply chain to learn more about how sustainability impacts the way business is done. I identify a specific environmental variable in order to fully understand how supply chains are coping with sustainability. Sustainability itself is a broad concept, and focus is needed. I use carbon as an environmental variable to explore for a variety of reasons: it is intrinsically connected to climate change, the pressing environmental issue of our age; it is a widely

understood and managed concept; and it is a proxy for cost, as carbon represents energy which is an economic cost faced by all businesses. In short, I am using carbon as a proxy for environmental sustainability. In selecting carbon as a vehicle for studying sustainable supply chain management, I utilize a variable that has traction and a shared understanding in the business community. I hypothesize that supply chains play an important role in managing environmental variables, as they capture a large part of the lifecycle of a media product. To conduct this portion of research, I use expert interviews, grounded theory methods, and a quantitative analysis of the carbon footprint of a magazine.

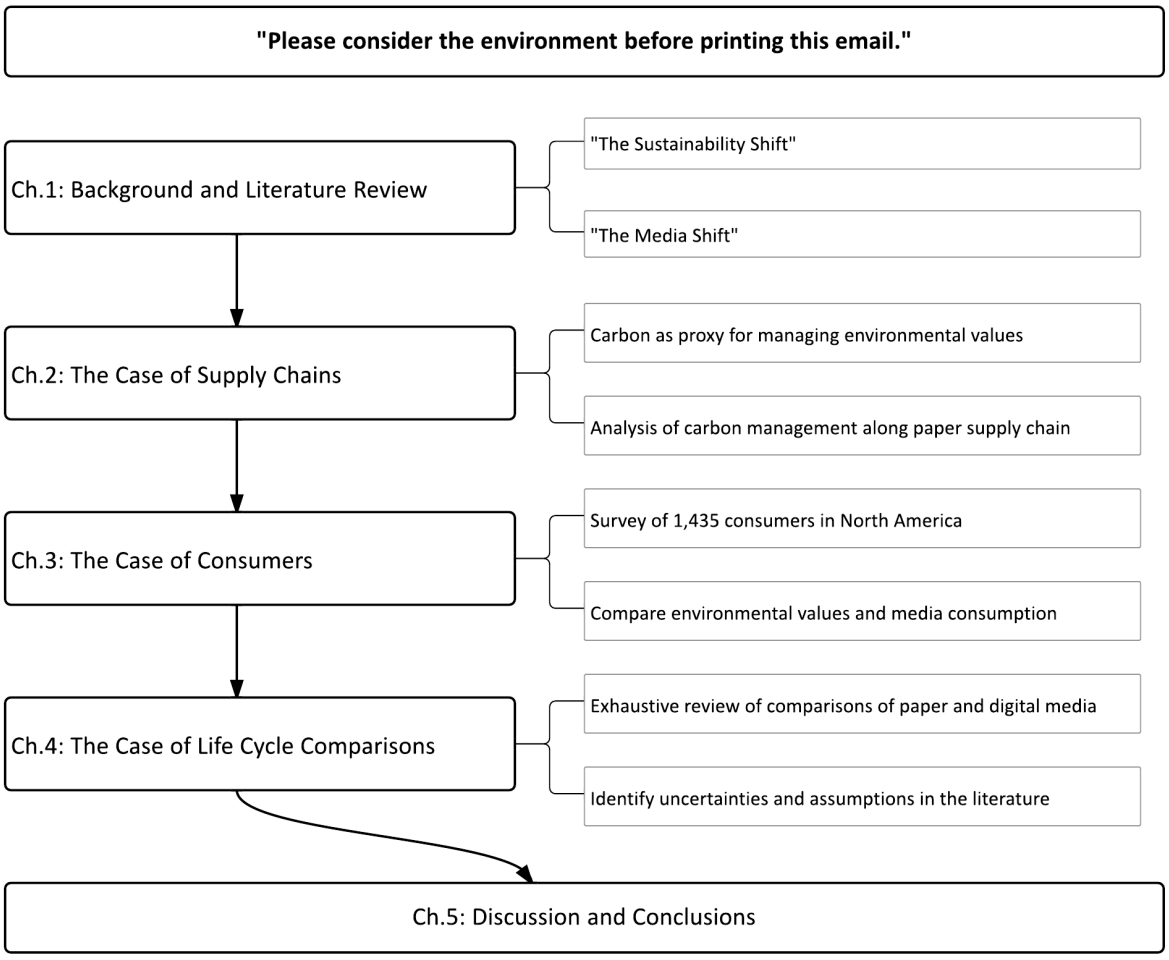
I then follow with an examination of the environmental values of media consumers. I want to evaluate whether consumers are shifting in their media consumption habits, and whether environmental values have any role to play in that shift. I hypothesize that consumers who care more about the environment consume less media, thereby reducing their environmental footprint. I also hypothesize that consumers are shifting in their media consumption habits, with digital media playing an increasingly large role. While I did present evidence of this shift earlier in Chapter 1, I want to validate and add nuance to my understanding of changing consumer habits. I survey consumers in North America using an online survey tool, asking a series of questions on environmental values and media consumption habits. Where appropriate, I apply statistical methods to strengthen and validate my results. I employ the New Ecological Paradigm (NEP) Dunlap *et al.* (2000) in order to segment my survey sample, while also connecting my research with a broader academic discourse.

Finally, I evaluate the findings of academic research that compares the environmental footprint of paper and media products. Beyond a simple literature review, however, I construct an analytical framework so that I can better understand the limitations of academic research, and what gaps in the environmental lifecycle of media products traditional methodologies might miss. I hypothesize that the standard academic method of comparing environmental footprints, the life cycle assessment (LCA) has limitations when assessing the footprint of digital media. I use an analytical framework developed by Reap *et al.* (2008) to structure my research. The framework identifies the key areas of concern, as well as opportunities for improvement, in the conduct of LCAs. This approach allows us to compare LCAs using a common framework.

Our results are presented in three chapters, organized according to Figure 3 on the subsequent page. The first, Chapter 2, presents the results of my investigation into a paper media supply chain. The second, Chapter 3, examines consumer's perceptions of media consumption and environmental values.

The third, Chapter 4, provides a framework for analyzing comparisons between paper and digital media products. Together, this research constructs a more nuanced definition of the sustainability of media. I then synthesize the findings into a broader discussion of media and sustainability. I identify patterns that connect my research chapters, looking for opportunities to strengthen and expand an understanding of sustainability. My goal is to move beyond results towards new ideas that might help us better understand what it is to "consider the environment", contributing to the existing literature while offering guidance for further research.

Figure 3: Summary of research chapters and objectives



Chapter 2: The Case of Supply Chains: Carbon's Role in Paper Media[5]

2.1 ABSTRACT

The purpose of this case study is to identify the origins and evolution of carbon management along a supply chain in the paper and print sector. I selected carbon as the environmental metric to track since it is a common and well-understood pollutant, and companies have developed systems and processes for managing their own performance. But carbon can also be used as a proxy for sustainability and environmental performance in general. This chapter offers an investigation of how supply chains, and in particular paper supply chains, consider the environment. The results from in-depth interviews are used to suggest a framework for assessing carbon's impact on the supply chain. I find that the use of biomass for energy and low-carbon transportation, such as rail and sea-based barges, can reduce the carbon footprint of a paper product. The interviews reveal that upstream and downstream supply chain actors are shaped by different pressures. Energy-intensive, upstream actors manage their carbon footprints in order to save energy and in anticipation of regulated carbon emissions. Downstream actors, in contrast, manage carbon in order to strengthen their corporate brand and maintain market share. Businesses trying to balance short-term costs, long-term profitability, and the maintenance of a corporate brand, have identified carbon as a means for progress on all three fronts.

2.2 INTRODUCTION

The challenge of climate change is significant. Shifts in global temperatures, weather patterns, and sea levels may adversely impact ecosystems and societies alike (Garnaut Review, 2008). To address this challenge, governments, corporations, civil society, and scientists are collaborating in efforts to mitigate and adapt to the impacts of climate change (U.S. Climate Action Partnership, 2008). Mitigation strategies are focused on efforts to limit and reduce carbon emissions, often through the monetization of carbon. Carbon, in short, is poised to have a price. Any business that emits carbon will pay for its emissions. This development has implications for supply chains. Monetized carbon may force supply chains to consider a new cost.

[5]A version of this chapter (2.1.) was peer reviewed and published as follows: "J. G. Bull, G. Kissack, C. Elliott, R.A. Kozak, and G.Q. Bull. (2011) Carbon's Potential to Reshape Supply Chains in Paper and Print. *Journal of Forest Products Business Research*, 8(2)

It is the purpose of this chapter to fill a gap, exploring the potential carbon management to reshape supply chains in the paper and print industries. This will be done in two parts. I begin with a case study from the paper and print sector that explores the role of the supply chain in managing carbon. I follow with a framework grounded in my case study that explores how carbon will influence supply chains. The case study synthesizes results of interviews with six corporations along a supply chain in the paper and publishing industries. I explore the origins, evolution, and future directions of carbon management for supply chain actors. I also present a carbon footprint for the supply chain. I suggest that, in the future, a thorough understanding of carbon may become a central issue in supply chain design and business operations.

2.3 BACKGROUND

There is a convergence around carbon. Many sectors of society, from corporations to NGOs to governments and international bodies, have embraced carbon management as central to addressing climate change. Governments have begun to regulate carbon emissions. Internationally, the Kyoto Protocol and subsequent processes are working towards binding international commitments for reducing carbon emissions (UNFCC, 2009; Hedegaard, 2008). At the regional level, the European Union Emissions Trading Scheme is capping and monetizing carbon emissions. Nationally, Australia, Canada, and the United States are moving towards binding emissions targets. There are also regional and local initiatives to cap and trade carbon emissions — the Western Climate Initiative (WCI) and the Regional Greenhouse Gas Initiative (RGGI) are prominent examples.

The corporate world is also responding, treating carbon as both a risk and an opportunity. There is a growing awareness of carbon amongst consumers (Semenza *et al.,* 2008), and government regulations and policies are increasing well (Neil Adger *et al.*, 2005), shaping the corporate response. Those who differentiate their products based on its carbon footprint may be rewarded (Benjaafar *et al.*, 2013). Insurance companies are including climate change in their long-term cost projections and designing incentives to reward climate change mitigation strategies (SwissRe, 2008). Investors are adjusting their decisions to include climate change criteria (UN Principles for Responsible Investing 2009). Carbon also represents a possible source of savings, or perhaps revenue, for business. As carbon gains a price, business may be forced to pay; those that are able to emit less will spend less relative to their competition and may gain market advantages (Luo and Bhattacharya, 2006).

Civil society is active in shaping the response to climate change in a variety of ways. For example, advocates are arguing to include REDD (Reduced Emissions from Deforestation and Degradation) schemes in a post-Kyoto global climate accord (IUCN, 2008). Scientists are also central in this response, from the Intergovernmental Panel on Climate Change (IPCC), a body composed almost entirely of scientists and recipient of the Nobel Peace Prize for its efforts (IPCC, 2007) to the Stern Review (Stern, 2006), science is enjoying a prominent voice in discussions on climate change. Demonstrative of this consensus behind carbon are positions taken by the U.S. Climate Action Partnership (USCAP), a coalition of several major corporations (including Shell, General Electric, and ConocoPhillips), and four prominent NGOs (Environmental Defense, Natural Resources Defense Council, Pew Center on Global Climate Change, and World Resources Institute).

Beyond the convergence of governments, corporations, and civil society, there is a strong theoretical grounding for the management and monetization of carbon (Helm *et al.*, 2012). Typically, the producer of a good pays only the private costs associated with production. Public costs, like carbon, are not captured in the price. The evolution of carbon into a regulated pollutant is an example of internalizing a negative externality. Economic theory has established the "polluter pays principle," which has appeared in academic literature and policy for over 30 years (Gaines, 1991). What is different now is the scale and the application to carbon (Woerdman *et al.*, 2008). Carbon is the largest attempt at internalization to date, and with a pollutant that is so ubiquitous and intangible, challenges arise. The specifics, means, and mechanisms, while well-grounded in theory, are less understood in practice.

2.4 OBJECTIVES

In this chapter, there are three objectives:

1. To measure the relative contribution of various paper supply chain stages to the carbon footprint of a magazine.
2. To elucidate why carbon, in particular, has the potential to encourage collaboration along supply chains in the paper and print sector.
3. To develop a framework for gauging how supply chains can collaborate on environmental issues, thereby changing their composition and behaviour over time.

2.5 METHODOLOGY

Our research measured the carbon footprint of a supply chain with a focus on describing the influence that carbon has on business-to-business relationships between supply chain partners. This chain oriented around the production of a major American magazine, which chose to remain anonymous. Using a case study approach (Yin, 2009), I wanted to explore carbon not only as a quantifiable emission, but as a phenomenon that influences supply chain dynamics. I interviewed six corporations for this case study, after attaining ethics approval (UBC BREB certificate #H08-02734). I investigated the origins, evolution, and future directions of carbon management in each company. In order to strengthen the internal validity of the case study, I shared the findings with all those interviewed and incorporated their feedback.

The steps in the supply chain were as follows. Catalyst Paper sourced fibre from Western Forest Products (WFP), which harvested trees on Vancouver Island, Canada. Residual fibre from WFP's operations was shipped to Catalyst's mill in Port Alberni by truck. After the paper was manufactured, it was shipped by truck and then on barges operated by the Washington Marine Group (WMG) to Catalyst's distribution center in Richmond, Canada. From here, it was shipped by Burlington Northern Santa Fe Railways (BNSF) to Quebecor World's printing plant in Merced, California, where it was printed and then distributed across North America.

The standard approach in quantifying carbon emissions is to conduct a life cycle assessment (LCA). LCAs of magazine products exist (Boguski, 2010; Gower *et al.* 2006) and there is agreement that the paper manufacturing process is significant in the total footprint of a product. For example, Boguksi (2010) found that 79% of lifecycle energy is accounted for by the cradle-to-gate (meaning from harvest in the forest to final product at the paper mill) for coated magazine paper. Gower *et al*. (2006) found that the paper manufacturing process accounts for 61% to 77% of total lifecycle carbon emissions. The approach of focusing on the supply chain partners in direct contact with Catalyst Paper meant that I measured emissions that made up the bulk of the magazine's footprint. I therefore felt confident that the methods were in line with those employed in other LCAs, and chose not to prioritize the replication of LCAs that already exist.

Further, there are problems with LCA that I did not want to introduce into my analysis given the tandem focus on quantifying emissions and qualifying their influence on business relationships. Gadreault *et al.*

(2007) reviewed forty LCAs in the pulp and paper industry and found that sound methodologies for assessing land use and demonstrating the carbon storage advantages of paper were absent. They also noted that generalized coarse-level LCAs are not as robust as LCAs that rely on primary data and describe specific processes or products. Reap *et al.* (2008) took a broader view, and discussed unresolved problems in LCA methodologies. They found that, at each stage in the conduct of LCA, there are several challenges. Most prominent in the context of a paper magazine were the problems of: local environmental uniqueness; spatial variation; time horizons; and data availability/quality. Summarizing these issues, Reap *et al.* (2008, p.384) quotes Bare *et al.* (1999) in stating that it is hard to know "where to draw the line between sound science and modeling assumptions."

Pulp and paper LCAs, in sum, are not without problems. I opted to avoid the full LCA methodology not only because of these problems, but because I also had the advantage of a unique level of cooperation and accessibility to corporate executives, as well as primary data for several stages of the supply chain. I felt that a hybrid approach, quantifying what I could, while describing the qualitative influence of carbon, would lead to a more nuanced understanding of how carbon can influence a supply chain. When I did quantify, I used the most granular data available. I tracked logs from specific logging operations to a specific mill, and along specific transport routes to a specific printer. I avoided generalized emissions factors in favor of specific data whenever possible.

It should be noted that I did not include the distribution footprint for the product. I attempted to estimate this figure using several approaches, but each proved highly sensitive to assumptions made. Variables under consideration were: the average distance traveled by each copy of the magazine; the volume distributed by retail outlets compared to home-delivery; and the precise geography of distribution. Because actual data was not available, and the assumptions produced unacceptable variation in results, I omitted the distribution process from the supply chain footprint. This is an area where further research is warranted.

I also refrained from modeling the carbon emissions of the magazine after disposal by the consumer. Again, there was too much potential variation. Whether the magazine was recycled, incinerated, archived, or buried in a landfill strongly influenced the results. Since my study is distinct from a traditional LCA, I used data for specific facilities and processes rather than aggregate data. The goal was

to describe the carbon emissions of the supply chain stages examined, and to describe the relative emissions of those stages, not the entire lifecycle of the magazine.

The interviews were developed using qualitative methods for exploring complex and intricate phenomena that are difficult to express quantitatively (Cresswell, 1998; Strauss and Corbin, 1998; Yin, 2009). Given the emergent nature of the topic at hand, this approach was deemed the most appropriate for providing a better understanding of carbon's potential to reshape supply chains. The following companies (five of which consented to be identified) and individuals participated in the interviews. I have separated the companies from the individuals interviewed to further protect anonymity.

- **Companies**
  - *Anonymous Magazine Publisher*[6]
    An internationally distributed, monthly magazine.
  - *Burlington Northern Santa Fe Railways (BNSF)*
    A railway operator with an extensive network in western North America.
  - *Catalyst Paper Corporation*
    A paper manufacturer with operations on the west coast of Canada.
  - *Quebecor World Inc.*
    One of the largest printing companies in North America.
  - *Washington Marine Group*
    A shipping company with operations on the west coast of North America.
  - *Western Forest Products (WFP)*
    A forestry company with operations primarily on the west coast of Canada.

- **Individuals**
  - Chief Executive Officer
  - Chief Operating Officer
  - Director, Environmental Affairs
  - Director, Paper Procurement, Environmental Affairs
  - General Director, Environmental
  - Vice-President, Corporate Relations and Social Responsibility
  - Vice President, Health, Safety and Environment
  - Vice-President, Manufacturing

Data were collected through in-depth, semi-structured interviews. Participants received the interview questions in advance (a copy of the interview protocol employed is found in Appendix A). Two researchers conducted each interview, either in person or via telephone. Each interview was recorded and transcribed. The interviews focused on three themes of interest in carbon management: origins;

[6] The magazine chose to remain anonymous out of fear of being criticized by ENGOS for using virgin fibre in their product rather than recycled fibre.

evolution; and future directions. I asked companies to identify how carbon manifested as a management priority, to describe the role that the supply chain played in shaping their perceptions of carbon, and to identify specific examples of interactions with external actors that shaped their carbon strategy. Given the elite status of those being interviewed, I adopted methods (Dexter, 1970) that acknowledged the expertise of the interview subjects. The interview protocol guided each interview, but when the interview subject demonstrated additional knowledge or interest in the subject, I used a semi-structured approach to ensure I could remain responsive to a subject's expertise.

Upon completing the interviews, I supported the analysis with a review of existing literature around carbon and the supply chain. This review, influenced by qualitative methods developed by Glaser and Strauss (1967) and Strauss and Corbin (1998), led to the construction of a framework on efficient, responsible, and resilient supply chains. It is within the context of this framework that I discuss the interview results.

Throughout this chapter, I use the term 'carbon management' in an intentionally ambiguous way. It can mean the measurement of carbon emissions, or the acknowledgement that carbon is an important issue, or steps taken to control carbon emissions. In other words, its specific meaning varies depending on the context.

2.6 RESULTS

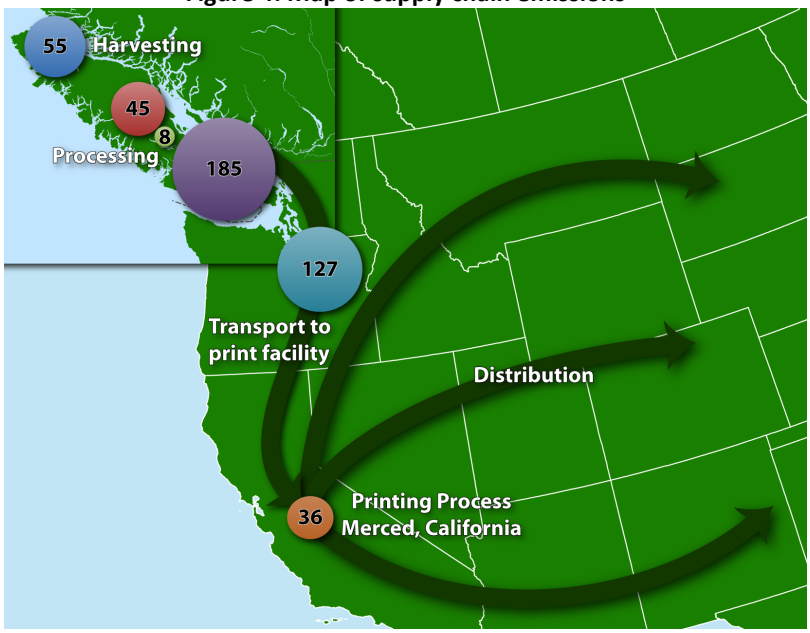
I present the results of my research below, beginning with a review of the carbon footprint of Anonymous Magazine. I follow with an analysis of the interviews, highlighting common themes and particular concerns of individual companies.

2.6.1 Carbon Footprint Analysis

The results were in line with those of other studies (Boguski, 2010; Gower *et al.* 2006) that measured the environmental footprint of magazine products. I found that paper production made up the bulk of greenhouse gas emissions associated with the magazine, but that transportation of paper to the printing facility was a significant source of emissions in and of itself. Figure 4 shows the different stages in the supply chain, while Table 1 provides the specific contributions from each supply chain stage. I follow with a detailed breakdown of the results and assumptions made for each supply chain stage. The data is expressed as greenhouse gas equivalent (referred to as carbon dioxide or $C0_2$ throughout) per air-dried tonne (ADt).

The question of how much carbon was emitted from the felling of the tree compared to how much was stored in the final product was not addressed in our analysis. Life cycle research has often treated emissions from forest activities as carbon neutral, but this assumption has been challenged (Helin *et al.* 2012). Other research suggests considerable variability in the stocks and flows of a forest product's life cycle (Winjum *et al.*, 1998). Some have found that that forest products, when produced efficiently and from well-managed forests, can even act as a carbon sink (Marland and Schlamadinger, 1997; Liu and Han, 2009). The lack of consensus on how to treat embedded emissions, along with the peripheral nature of this question relative to the objectives of this section, led me to exclude further consideration of the issue.

Figure 4: Map of supply chain emissions



Harvesting, road-building felling, transport to sawmills

The data used here was based on a study by the Forest Engineering Research Institute of Canada (FERIC, 1997) that found that 6.9L of diesel is used per m^3 harvested. This is equivalent to 18.5 kg $C0_2$, 0.000816 kg CH^4 (methane), and 0.000466 kg N^2O (nitrous oxide), which expressed in $C0^2$ equivalency, is 18.66 kg $C0_2$ per m^3 harvested wood converted to dimensional lumber. The Western Forest Products Alberni Pacific Division generated 269,000m^3 dimensional wood, 175,000m^3 chips, 307,000m^3 hog in 2008. The effective carbon footprint on all products is 18.66*269000 / (269000+175000+307000) = 6.7 kg $C0_2$ / m^3 chips. The final carbon footprint from harvest is 6.7*8.2m^3/ADt = 55 kg $C0_2$ / ADt.

Sawmilling fibre into dimensional and residual products
Based on WFP 2008 carbon footprint, Alberni Pacific Division scope I & II emissions = 5.5 kg $C0_2$ / m^3 chips. At 8.2 m^3 chips per ADt, sawmill carbon footprint on paper basis = 45 kg $C0_2$ / ADt.

Transport of chips to mills
Estimate average return trip of chip trucks between WFP operations and Catalyst's mill is 100 km. Using International Panel on Climate Change (IPCC) emission factors of 1.02 kg $C0_2$/km from IPCC EF ID 19043, emissions associated with delivery of chips = 102 kg per truckload (at 3500 ft^3 equal ~ 100 m^3) = 1.0 kg $C0_2/m^3$. At 8.2 m^3 chips per ADt, carbon delivery footprint = 8 kg $C0_2$ / ADt.

Conversion of chips to paper at Catalyst
Based on data provided by Catalyst for its carbon footprint in 2008 of Scope I & II[7] emissions = 185 kg $C0_2$/ ADt.

Transport of paper to Quebecor World in Merced
Based on identified supply chain distances, transportation type, and recognized IPCC emissions factors, transport footprint = 127 kg $C0_2$ / ADt.

Printing of paper at Quebecor World in Merced
Based on the Heinz (2006) study, the surveyed printing facilities carbon footprint is 36 kg $C0_2$ / ADt.

Table 1: Supply chain emissions

Activity	Carbon Emissions ($C0_2$/ADt)	Percentage of Total
Harvesting, road-building, felling, transport to sawmills	55 kg	12%
Sawmilling into dimensional and residual products	45 kg	10%
Transport of chips to mill	8 kg	2%
Paper manufacturing process	185 kg	41%
Transportation to print facility	127 kg	28%
Printing process	36 kg	8%
Total	**456 kg**	**100%**

[7] Scope I means all direct Greenhouse Gas Emissions. Scope II is embedded carbon, meaning all indirect emissions from consumption of purchased electricity, heat, or steam.

2.6.2 Origins and Evolution of Carbon Management

The interview process revealed three motives for managing carbon: as a performance metric in pursuing operational excellence; as a basis for product differentiation; or as a strategic priority to satisfy corporate commitments to environmental responsibility. The motivations of a company depended on three variables: the proximity of the corporation to the end consumer; the degree of compliance required by regulations; and the need to enhance the corporate brand. Despite these diverse motives, carbon provided an opportunity for cooperation and shared understanding between supply chain partners.

I classified motives for carbon management into two categories: internal and external. The only internal origin identified was the need to manage energy costs, and by extension, carbon. BNSF and Catalyst were both motivated by internal origins. BNSF, which spent approximately $4.6 billion on diesel fuel in 2008, saw carbon as an entry point for managing fuel costs. To them, "not only does carbon make economic sense, we see it as an opportunity to differentiate ourselves from an environmental perspective." Catalyst, in a similar vein, wanted to reduce its energy use. To do so, "Catalyst invested heavily in the right equipment to turn waste into energy for their operations, and as they did, their reliance on fossil fuels decreased to almost zero." Catalyst then moved beyond operational benefits towards a more sophisticated marketing strategy. By controlling costs, it also produced a unique product; paper produced while emitting as little carbon as possible.

External origins took several forms, and were threefold in their origins: compliance with regulations; response to pressures from civil society; or relationships between supply chain partners. The latter was the most important in the case study. WMG cited a meeting with senior executives of Catalyst Paper as the origin of its carbon management. Catalyst, in trying to reduce its carbon footprint, engaged with WMG to maximize the use of fuel-efficient barges in moving its product. WMG cited this engagement as vital in its own consideration of carbon. WMG was not alone in crediting its relationship with Catalyst as an origin for its understanding of carbon. With the exception of BNSF, every interviewee had been actively engaged with Catalyst on carbon issues. Catalyst also helped connect its supply chain partners with World Wildlife Fund Canada, an ENGO that assisted Catalyst in the measurement of its carbon emissions. Two respondents, Catalyst and BNSF, also credited regulatory requirements as an important motive for managing carbon.

A company's position along the supply chain also affected carbon management. Upstream and downstream actors face different pressures. In the case study, upstream suppliers consume more energy than their downstream counterparts, but are less visible to consumers. As a result, they are more likely to undertake carbon management in order to derive cost savings or comply with regulations. Downstream suppliers, in contrast, use less energy and have fewer financial incentives to undertake carbon management. However, non-financial incentives do influence downstream actors. Quebecor World, for example, suggested that despite an economic downturn, there was a strong interest in sourcing environmentally preferable paper. To meet this demand, the company developed a database of carbon emissions for all of the paper products that it offers. Suppliers are requested to fill out comprehensive surveys that contain information on the carbon emissions of their products. Quebecor World receives an almost perfect response rate to this survey request.

I found that most supply chain actors in this case study were in the early stages of developing a carbon management policy. The evolution, therefore, was not fully understood because most, with the exception of Catalyst and BNSF, had only begun to develop their carbon management plans. All had begun to take the first steps to do so, but were still in the formative stages. Specific reduction targets were the exception rather than the norm. This speaks to the current regulatory uncertainty that exists in North America. National-level schemes are evolving, while regional initiatives, such as the WCI and RGGI, may have impacted some of the corporations interviewed, but were not significant regulatory priorities. British Columbia, Canada, proved an exception, as companies operating there (such as Catalyst, WFP, and WMG) are subject to a carbon tax on their fossil fuel use.

2.6.3 Future Directions of Carbon Management

When asked where they thought the future of carbon management lay, each respondent gave an answer specific to its own corporation and industry. The economic volatility at the time of the interviews (January through March 2009) influenced answers. It should be noted that four of the corporations interviewed were in the print industry (WFP, Catalyst, Quebecor World, and Anonymous Magazine); the particular hardships of this industry shaped interviewees' responses on future directions.

Respondents universally agreed that, in the future, carbon and sustainability will be considered more closely. They recognized carbon as a potential cost, risk, and opportunity. They also felt that the marketplace would increasingly demand information about carbon emissions. They suggested that the

market was unwilling to pay significant premiums on carbon-light products (that is, products that are designed and manufactured with the goal of reducing carbon emissions). However, carbon-light products may be given preference if cost competitive.

Interviewees identified the ability for carbon to create differentiated products. They described carbon's role in the marketplace as a three-step transition. The first step was simple differentiation. The second involved the marketplace rewarding carbon-light products with increased market share; further, they anticipated some scenarios where the market would pay a premium for carbon-light products. The final step depended on how the monetization of carbon plays out. If polluters are eventually forced to pay for emissions, carbon-light producers who currently only enjoy product differentiation may actually gain cost advantages. Respondents saw this as a medium- to long-term development, and felt that differentiation and market preference are priorities in the short-term.

It was suggested that carbon has the potential to change the value of existing industrial assets. This was particularly true for three companies — BNSF, Catalyst, and WFP. Their assets, and their economic value, would change in a low-carbon economy. Catalyst identified the possibility of using underutilized mills to produce electricity with biomass. WFP saw potential in recognizing solid wood products as sinks of carbon. Given that dimensional lumber can exist as a carbon sink in a home for decades and then be recycled, this has the potential to change the market and pricing of wood products. BNSF saw significant opportunities in the future for increased use of rail capacity, as the carbon benefits of shipping by rail may be enhanced by monetized carbon.

These same three firms also expressed concern about the specifics of carbon regulations. Catalyst moved early to reduce its carbon emissions. If allowances under a cap and trade system are calculated using an average of the previous 10 years of emissions, Catalyst could be in a position where further reductions in order to comply with shrinking allowances are almost impossible. In short, they could be punished for good behaviour. BNSF also identified similar risks with cap and trade. WFP identified uncertainty around the measurement of carbon in forest products as risky. Harvested timber is converted to solid wood products that store carbon; pulp is converted to paper and can be recycled; and wood waste can be used to offset fossil fuel use. The methods and assumptions behind the measurement of these (and other) variables impacts the emissions associated with forest operations.

2.7 DISCUSSION

Based on the interview results, I suggest a framework that explains how carbon will transform supply chains. I consider a three-step process, where: at first, efficient supply chains emerge due to carbon's equivalency with energy; next, environmentally responsible supply chains emerge; and finally, resilient supply chains develop as the risks of monetized carbon are mitigated.

2.7.1 Efficient Supply Chains

There are two ways in which carbon efficiency can transform supply chains. Corporations that are carbon-efficient may become preferred suppliers (a status achieved by Catalyst with Anonymous Magazine) and gain market share. Supply chains themselves may also reorient to minimize carbon emissions, as seen with Catalyst's use of barges and rail to reduce transportation carbon. These carbon-efficient supply chains will better adapt to the regulations and cost structures of a low-carbon economy. The carbon emissions associated with supply chains may influence where business is conducted. Supply chains may evolve to locate particularly energy-intensive processes (such as aluminum smelting or paper making) near low-carbon energy sources, such as hydroelectric power (used by Catalyst to reduce the carbon footprint of its paper). Conversely, processes using little energy may relocate closer to efficient transportation networks and major markets, minimizing emissions from transportation and distribution.

2.7.2 Responsible Supply Chains

As carbon emerges as a major component of sustainability, it may play a stronger role in corporate social responsibility (CSR) policies. The prevalence of the Carbon Disclosure Project (CDP, 2009) indicates that corporations already understand this. How this will impact supply chains is less certain. If carbon continues to gain importance, products with large carbon footprints relative to their competition may fall out of favor. Companies that demonstrate an understanding of their supply chain footprint, and steps taken (or at least plans) to reduce it, will benefit.

To achieve reliable and transparent management of carbon, third party auditing and verification will need to be more widespread. While costly, the outcomes of this monitoring may lead to stronger engagement between supply chain collaborators, a phenomenon shown in the case study. The potential to audit supply chains for carbon has several implications. These audits will provide a baseline measurement, and allow for improvements over time. Relationships between supply chain partners that developed around carbon may evolve to include other issues in sustainability. There are potential

trickle-down effects if the demands of one customer change the behaviour of a supplier. The supplier in this case study, responding to one customer's demand, is able to subsequently provide carbon-light products to all of its customers. Carbon management can therefore diffuse along the supply chain due to the requests of only one supply chain partner.

2.7.3 Resilient Supply Chains

Efficient and responsible supply chains build more resilient connections between supply chain collaborators. These connections, observed in the case study, suggest that, in the future, carbon will be considered closely in risk management. I identified three types of risk: regulatory risk; financial risk; and market access risk.

Regulatory risk involves government control of carbon. Businesses that anticipate this control are in a less risky position. Those that emit large amounts of carbon, but have not begun to adjust, are exposed. An illustrative example can be found in the American bond market, where analysts are projecting a premium on corporate bonds for new coal-fired power plants (Stevenson, 2008), reflective of an anticipated cost of carbon. Regulatory risk also involves how regulations are deployed. Companies that have already made progress in reducing their footprints may be put in a difficult position, a danger identified by both Catalyst and BNSF. Good behaviour already underway faces the risk of being punished by the definition and allocation of allowances.

Financial risk involves the ability of companies to secure capital in the long term. Investors have indicated that they will consider carbon in their investment decisions (CDP, 2008). Their reasoning is simple: if a corporation emits a lot of carbon, they will be obligated to pay for these emissions. Some industries cannot avoid emissions, and investors may require the disclosure of emissions and the beginnings of a carbon management plan. In other circumstances, investors may prefer articulated targets and reduction strategies. In either scenario, carbon may emerge as an impediment to securing capital if emissions are not managed. Although no interviewees cited the specific connection between carbon and capital, sources such as the Carbon Disclosure Project (2008) and the UN Principles for Responsible Investing (2009) support the idea.

Market access risk has two components. Understanding carbon emissions may become mandatory for participating in supply chains as businesses seek to collaborate with partners who manage their carbon.

Wal-Mart, for example, has initiated a process requiring all suppliers to measure and disclose their carbon footprints. Consumers may demand carbon labeling on products that they purchase. Although the appetite to pay a premium for sustainably produced goods is small (Manget *et al.* 2009), consumers have a preference for products that are cost-competitive, but also demonstrate an environmental commitment. Carbon, given its current prevalence, has the potential to emerge as an important criterion in consumer choice (MacKerron *et al.,* 2009), but awareness of environmental issues and demographic variables like income play an important role (Moon *et al.,* 2002; Hansla *et al.,* 2008).

Moving beyond efficiency and responsibility, I found evidence that supply chains were becoming more resilient to risk by managing carbon. Regulatory risk around carbon encouraged its management. Financial risk associated with securing adequate investment capital encouraged carbon management as well. Finally, market access risk, with both consumers and businesses preferring environmentally friendly products, motivated companies to manage carbon. Together, these risk management activities suggest that carbon mechanism that can help supply chains become more resilient.

2.7.4 Implications for Businesses and Supply Chains

Through the interviews, it was clear that carbon is emerging as a common cause. Less clear is how this will induce change in purchasing decisions, design of supply chains, and perceptions of sustainability. Businesses trying to balance short-term costs, long-term profitability, and the maintenance of a corporate brand, have identified carbon as a means for progress on all three fronts. Supply chains composed of different actors facing different pressures have been able to align corporate strategies around a common variable.

Location matters if reducing carbon emissions is a priority. As the case study showed, printing contributes a small amount to the total footprint of a product and is best done close to markets and transportation hubs to reduce emissions. Papermaking contributes a large amount to the total footprint of a product and is best done where there are abundant supplies of renewable energy and efficient transportation networks. Focusing on the emissions of just one stage potentially ignores the biggest emitters and the best opportunities for emission reductions.

Supply chains will evolve to better reflect the carbon costs of transportation. Physical locations of supply chain stages may change, with low-energy operations relocating to reflect the carbon costs of

transportation, and high-energy operations moving to reflect the carbon costs of energy bottlenecks in a supply chain. Regions with energy grids that include significant access to renewable energy sources may become increasingly competitive, while regions reliant on carbon-heavy energy could find themselves at a disadvantage.

At present, when carbon is generally without a price, companies are finding that reducing their carbon footprint reduces their fuel costs. As carbon gains a price, these companies will find other benefits. Not only will they save on fuel, emissions will cost less. Some businesses already market a product on its carbon footprint, and if carbon awareness increases, these businesses stand to benefit. While current trends in carbon management are predominantly internal in orientation (steps to reduce employee travel, more efficient office lighting, etc.), there is a limited scope and diminishing returns from such efforts. More sophisticated policies to manage and reduce emissions will look at suppliers, logistics, and operations — in other words, the supply chain

2.8 CONCLUSIONS

Underlying this discussion on carbon are some significant assumptions. It is assumed that monetized carbon will emerge in some form. It is assumed that businesses will begin to consider carbon more carefully. These are assumptions, not guarantees. However, in the case study, I found supply chain actors embracing carbon. At the corporate level, energy efficiency, long term profitability, and responsible branding converged around the concept of managing carbon. This convergence was supported at the political level, where government policies regulating carbon are present and evolving. Along the supply chain, the nature of collaboration between partners and the physical designs of the supply chain seem poised to evolve. I am not suggesting that carbon is the only variable that influences the composition of a supply chain, but I do think it is time to consider the role that carbon may play. This case demonstrates the influence of carbon along a supply chain and offers a framework for further analysis of sustainable supply chains.

Chapter 3: The Case of Consumers: Environmental Values and Media Consumption

3.1 ABSTRACT

The consumption of the written word is changing. The printing press, pioneered by Gutenberg in the 1430s, enjoyed five centuries of dominance. But with the emergence of the personal computer and the Internet, consumers are faced with digital alternatives to paper media. With bewildering speed, the last 30 years have seen computers and electronic devices proliferate. As telecommunications networks matured, the Internet enabled media outlets to deliver content electronically. Desktops, laptops, tablets, and smartphones can now serve the same function of printed newspapers, books, and magazines. Every reader of this dissertation will have experienced this change, either at work or home. Concurrent to this media revolution has been the emergence of environmental sustainability as a pressing – perhaps *the* pressing – challenge of our time. This chapter is a study of the environmental values of media consumers. I used a common method for studying environmental values – the New Ecological Paradigm (NEP) – to investigate the ecological views of two groups of media consumers, those who consume a lot of digital media and those who do not. I arrived at two key findings: media consumers are quickly shifting towards digital sources, and media consumption habits have no influence over environmental values. These findings affirm the idea that a media transition is under way. Further, they suggest that media footprints are not of a source of environmental concern to consumers.

3.2 INTRODUCTION

This chapter focuses on the views of consumers in the midst of two shifts: the media shift and the sustainability shift. I ask whether consumers are thinking about the environmental footprint of their media. Do they see their media consumption habits changing? Do consumers with different environmental values have different consumption habits? To address questions like these, I designed a three-part survey that asked North American consumers to report on their demographic profile, their environmental values, and their media consumption habits. This chapter begins with a brief background on why an analysis of consumers' environmental values and media consumption habits is relevant. It follows by defining research objectives and methodologies. Results are presented in three sections: demographic trends, environmental values, and media consumption trends. Finally, I discuss the implications of my results and relate them back to the literature.

3.3 BACKGROUND

The sustainability shift is a concept present throughout this thesis, but I summarize the idea once more here. It suggests that society is acknowledging the finite capacity of the planet earth to withstand environmental degradation. As a response, sustainability has emerged as a concept across the social spectrum. At its core, sustainability simply means doing something better, or at least less badly. One founding definition comes from the Brundtland Commission, which described sustainability as meeting "the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).

But sustainability can mean very different things to different actors. Seager (2008) captures this dilemma, suggesting that traditional methods of academic inquiry may be ill suited to study such a nebulous concept. It is worth asking once more, what academic would be best suited to study sustainability: an engineer, an ecologist, an economist, or a political scientist? All would have their own methods and perspectives, none of which are necessarily more correct than the others. To alleviate this tension, Seager (2008) suggests an approach to sustainability that operates conceptually rather than technically, much like justice or fairness.

Different actors drive sustainability forward in unique ways. Governments use incentives and regulations to promote more sustainable outcomes (Graedel and Allenby, 2003). Investors encourage sustainability by limiting their support to actors who meet certain requirements (UNEP, 2006). Corporations pursue opportunities to create shared value by increase profits while reducing environmental impacts and becoming more eco-efficient over time (Molina-Azorín *et al.*, 2009). The marketplace has an important role to play too. Business-to-business interactions can promote sustainability, with major buyers forcing their suppliers to disclose and improve their environmental footprints (Home Depot, 2011; Wal-Mart, 2011). Consumers can drive sustainability, as well, leveraging both their buying power and preference for more sustainable products (D'Souza *et al.*, 2007). Some suggest (Diamantopoulos *et al.*, 2003) that consumers have a willingness to change their consumption habits and pay a premium for what they consider to be more sustainable products, but the extent to which they are willing to change is difficult to measure as demographic variables do not consistently predict green consumption patterns. The role that consumers play in motivating more sustainable outcomes is the major reason why I want to investigate the environmental values of media consumers.

Media, much like sustainability, is undergoing a transformation. A shift is happening from paper products to digital alternatives. But it is an uneven and complex shift, and there is no single metric that can capture the diversity in the scope, volume, or intensity of this transition. A huge variety of products previously available only on paper – newspapers, books, catalogues, magazines, and so on – can now be consumed across a system of Internet connected digital devices like laptops, tablets, and smartphones. This shift is not necessarily zero-sum; an increase in digital media consumption does not necessitate a decrease in paper media consumption, but certain product categories – newspapers and magazines come to mind – are more vulnerable to disruption than others.

Since the turn of the millennium and the advent of more sophisticated and affordable ICT, a host of media shifts have taken place. Major magazines have gone bust, no longer able to generate sufficient revenues (Media Life Magazine, 2014). Magazines that have survived have had to supplement their revenue with digital sales, or receive subsidies from major corporate backers (Pew Research Journalism Project, 2013). Revenues from classified sections in newspapers have imploded, as free services like Craigslist emerge, offering hyper-local advertising at little to no cost (Edmonds, 2013). Paper mail volumes have undergone dramatic changes, as well: less and less personal correspondence is being delivered by mail, and companies increasingly prefer electronic invoices. As a result, mail delivery volumes have returned to levels not seen since the early 1980s (United States Postal Service, 2014).

Others have researched this shift, finding evidence that consumers are rapidly embracing new media platforms (Duggan and Smith, 2013; Bell *et al.*, 2013). Chyi and Lee (2013) and Chan-Olmsted *et al.* (2013) both conducted surveys of digital media consumption in order to better gauge the preferences, usage, and intent of media consumers. Researchers have also made efforts to connect media consumption with environmental issues. Holbert *et al.* (2003) use media consumption as a means for testing environmental values, connecting patterns of television viewing with environmental beliefs. Hansen (2010) connects environmental values with media in general, suggesting that how consumers choose to digest media has an important influence over their environmental behaviour. This body of research suggests that connecting media consumption with environmental values in consumers is a suitable backdrop for exploring sustainability and media.

3.4 OBJECTIVES

Given the two shifts I have identified – the media shift and the sustainability shift – I want to understand the interactions between environmental values and media consumption. To that end, I set out in this chapter to:

- Examine the media habits of segments with different environmental values.
- Examine the environmental values of different media segments.
- Identify any patterns or significant trends that contextualizes discussions of the environmental footprint of media, and strengthens our understanding of sustainability.

3.5 METHODOLOGY

I delivered a web-based survey to 1,435 consumers in North America: half in Canada, half in the United States, after attaining ethics approval (UBC BREB certificate #H09-03036). The survey sample mirrored demographic trends from national censuses, with both males and females from representative age groups were polled. The respondents were derived from a survey panel operated by Market Tools, a survey provider that audits and verifies the age, location, gender, and income of survey respondents. As the survey was made available to respondents, controls were put in place to ensure that our sample mirrored data from the latest national censuses from both Canada and the United States. Market Tools verifies the information provided by respondents using a variety of means, including telephone interviews and credit score inquiries. It took the sample approximately a week to respond. There are inherent biases that are introduced by choosing an online survey to assess questions related to paper and pixels. Couper (2000) suggests the proliferation of online surveys may impact the quality of responses, as respondents are saturated with potential surveys to fill out and therefore make choices based on personal interest or entertainment value. There is a risk that over-surveying can diminish the quality of responses, and that the only people filling out online surveys are those who are web-savvy to begin with (Couper, 2000). However, the online survey method allowed us to target very specific demographic groups, strengthening the findings without imposing prohibitive costs.

Our survey was designed after reviewing similar surveys on media consumption and environmental variables (Holbert *et al.,* 2003; Dou *et al.*, 2006; Dutta-Bergman, 2004). I identified questions that reveal information about both the paper and digital media consumption habits.

The survey itself consisted of three sections (for a complete version of the survey questions, see Appendix B). The first investigated basic demographic trends, the second explored the environmental values of consumers, and the third measured the media consumption habits of the segments. The section on demographic trends asked simple questions about age, gender, income, location and similar variables.

To study environmental values, I utilized the widely adopted new ecological paradigm (NEP) scale in order to categorize the respondents. Each respondent received a score that indicates how anthro-centric or eco-centric he or she is. Originally developed by Liere & Dunlap (1980), and then later revised by Dunlap *et al.* (2000), the NEP scale is a tool frequently employed in survey methodologies to gauge perceptions of sustainability (see Cordani *et al.*, 2003; Lundmark, 2007; Rideout *et al.*, 2005; Schultz, 2001). I asked consumers to answer the 15 questions in Table 2 and calculated their NEP score accordingly. Like all studies that employ the NEP scale, the eight odd-numbered questions were worded in such a way that agreement suggests a proecological worldview (a world view biased towards the environment). In contrast, disagreement with the seven even-numbered questions suggests a proecological worldview. The median NEP score of the sample was 52. I then divided the sample in half with 717 respondents with an NEP score of 52 or higher labeled NEP Eco. Another 718 residents, with NEP scores of 52 or lower, were labeled NEP Anthro. This basis for this categorization is the likelihood that the NEP Eco segment prioritized environmental issues when compared to the NEP Anthro segment.

Table 2: The new ecological paradigm

1. We are approaching the limit of the number of people the earth can support	7. Plants and animals have as much right as humans to exist	13. The balance of nature is very delicate and easily upset
2. Humans have the right to modify the natural environment to suit their needs	8. The balance of nature is strong enough to cope with the impacts of modern industrial nations	14. Humans will eventually learn enough about how nature works to be able to control it
3. When humans interfere with nature it often produces disastrous consequences	9. Despite our special abilities humans are still subject to the laws of nature	15. If things continue on their present course, we will soon experience a major ecological catastrophe
4. Human ingenuity will insure that we do NOT make the earth unlivable	10. The so-called ecological crisis facing humankind has been greatly exaggerated	
5. Humans are severely abusing the environment	11. The earth is like a spaceship with very limited room and resources	
6. The earth has plenty of natural resources if we just learn how to develop them	12. Humans were meant to rule over the rest of nature	

The section on media consisted of a variety of queries on consumption habits and technology ownership. I also asked the sample to describe how their media consumption habits have changed. I wanted to explore whether those who use more or less digital media have different environmental values. Because digital media is often touted as a 'green' alternative, I hypothesized that the Digital Heavy segment would have stronger environmental values. To do so, I devised a metric for indicating just how tech-savvy a respondent might be. The objective was to create two groups – 'Digital Light' and 'Digital Heavy' – that represented different groups of media consumers. I asked the respondents several questions, which when taken in aggregate, indicate how much or how little digital media a consumer uses in their lives. For each question answered in the affirmative, a consumer's digital use score increased. The questions used are summarized in Table 3.

Table 3: Digital use score

How long have you been using the Internet?		
How many computers are used in your household?		
How many mobile devices (cellphone, smartphone, etc.) are used in your household?		
Do you own any of the following devices:		
Digital Camera	Flat Panel Television	Tablet Computer
Digital Video Camera	MP3 Player	Cellphone
DVD Player	Desktop Computer	Smartphone
BluRay Player	Laptop Computer	E-Reader
If you get your news online, which of the following sources do you use (check all that apply)?		
Dedicated news sites (e.g. CNN.com, etc.)	Regional newspaper websites	News aggregators (e.g. Google News, Yahoo News, etc.)
National newspaper websites	Local newspaper websites	Blog
Please rate how frequently you use the listed online services with the following scale: Never, Seldom, Sometimes, Often, Always.		
Instant Messaging	Blogging	Watching videos
Email	Research	Online banking
Social Networking	Reading the news	Online shopping

The digital use score was calculated by adding up every instance a consumer answered in the affirmative to a question that would indicate digital media consumption. For example, when I asked, "How long have you been using the internet?" and the respondent provided a number between 1 (relating to a period of 0 to 6 months) and 5 (relating to a period of 6 years or more). The longer the respondent had been using the Internet, the higher their digital use score would be. The same method was used for questions on computers and mobile devices in the household. I asked, "Do you own any of the following devices?" and for each device that a respondent owned, their digital score would increase by one point. It follows that the more digital devices owned by a respondent, the higher their digital use score. I applied the same logic and method to questions on Online News Sources and Online Services. The more a respondent said they used various digital media, the higher their digital use score. While inexact, this method allowed us to categorize respondents who do not use digital media as frequently as others. After calculating the digital use score, I identified the median score and divided the sample into two segments.

Once all the necessary data had been gathered, I applied statistical methods where appropriate. For questions on consumption of different digital media and paper media sources, I conducted a standard t-test to determine statistical significance between means, with $\alpha = 0.05$. For the questions on the use of various online services, I conducted a z-test, in order to ascertain statistical significance between proportions with $\alpha = 0.05$.

While a statistical test would have been appropriate for the questions on willingness to pay for media, because the scale was not an interval scale, I was unable to compute means that could be tested. In these cases, I compared varying levels of willingness to pay with the following method: the percentage of respondents unwilling to pay was subtracted from the percentage of those willing to pay, arriving at a percentage that could be either positive or negative. The more unwilling to pay a certain segment was, the lower the percentage would be. I then converted the percentages from all segments and across all categories into numerical scale between 1.0 (which would imply 100% willing to pay) and –1.0 (implying 100% unwilling to pay). I plotted the results accordingly.

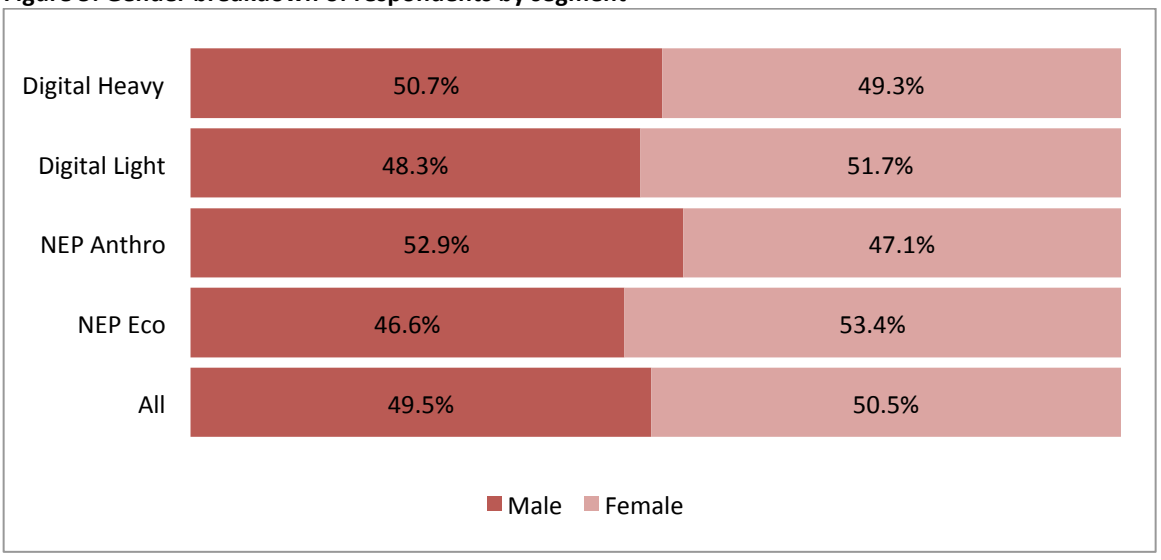
3.6 RESULTS

I present the results in three parts: demographic information, environmental values, and media consumption trends. In each section, I have presented the results using the following segments: NEP Eco, NEP Anthro, Digital Light, Digital Heavy. In some instances, I aggregate results for all respondents.

3.6.1 Demographic Trends

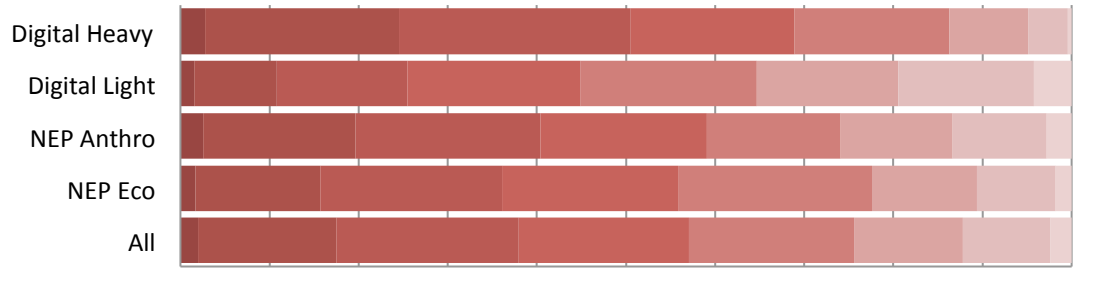
Our survey sample (n=1,435) had the following demographic attributes. The gender breakdown of the sample set is described in Figure 5. The sample was almost evenly split between males and females (49.5% male, 50.5% female). When comparing media consumption patterns, males were more likely to be Digital Heavy than Digital Light, but by a very small percentage (2.4%). On environmental variables males were more likely to be NEP Anthro by a margin of 6.3%.

Figure 5: Gender breakdown of respondents by segment



I also asked respondents to provide their age. The results are presented in Figure 6. The Digital Heavy segment tended to be younger (mean age: 41.7 years) than the Digital Light segment (mean age: 52.1 years). The NEP Anthro and eco segments had similar mean ages (respectively 46.6 and 46.8 years). These figures are similar to the mean for the entire sample (46.8 years).

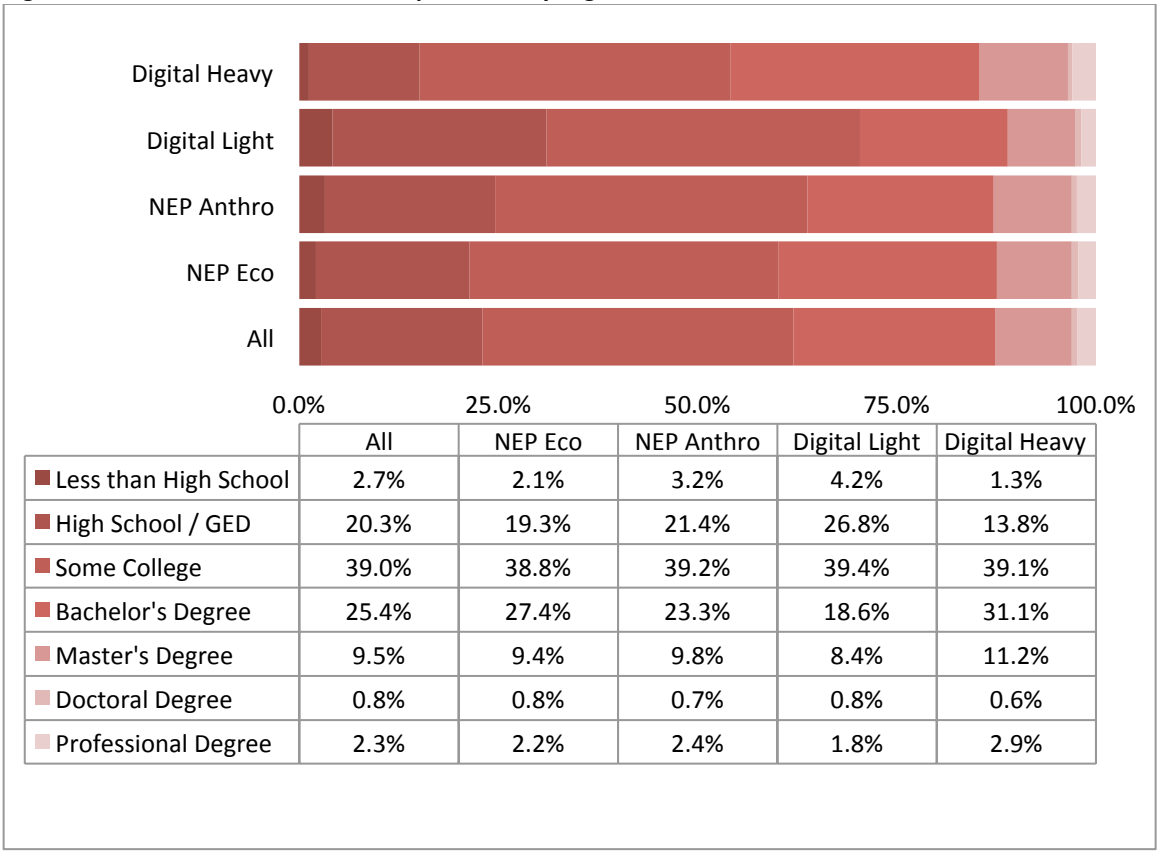
Figure 6: Age breakdown of respondents by segment



	All	NEP Eco	NEP Anthro	Digital Light	Digital Heavy
> 19	2.0%	1.7%	2.5%	1.5%	2.8%
20 - 29	15.5%	14.0%	17.1%	9.2%	21.7%
30 - 39	20.5%	20.4%	20.8%	14.7%	26.1%
40 - 49	19.1%	19.7%	18.7%	19.3%	18.3%
50 - 59	18.5%	21.8%	15.0%	19.9%	17.4%
60 - 69	12.2%	11.7%	12.6%	15.8%	8.8%
70 - 79	9.9%	8.8%	10.5%	15.3%	4.5%
< 80	2.4%	1.8%	2.8%	4.2%	0.4%

I asked respondents to describe their educational achievements, and the results can be found in Figure 7. I found that the NEP Anthro and NEP Eco segments had very similar educational profiles. The Digital Light and Digital Heavy segments did exhibit some differences. The Digital Heavy segment was the group most likely to have attained a Bachelor degree or higher, and the least likely to have not completed high school.

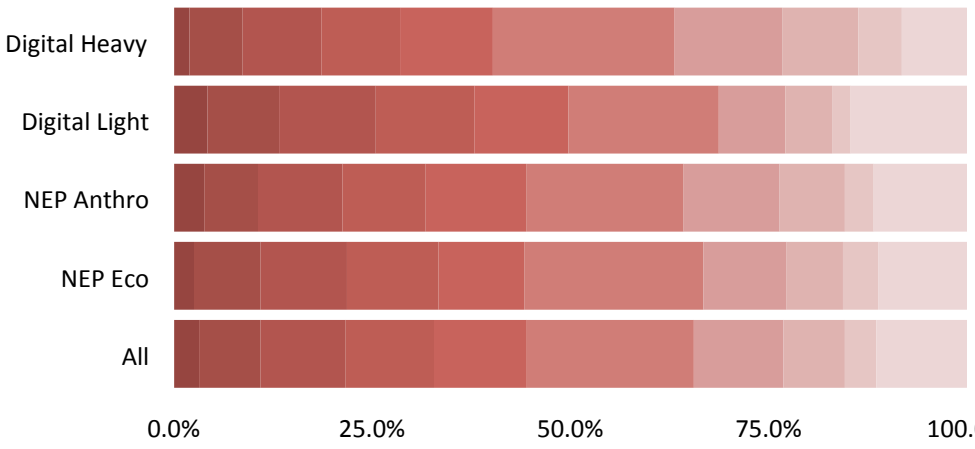
Figure 7: Education breakdown of respondents by segment



	All	NEP Eco	NEP Anthro	Digital Light	Digital Heavy
Less than High School	2.7%	2.1%	3.2%	4.2%	1.3%
High School / GED	20.3%	19.3%	21.4%	26.8%	13.8%
Some College	39.0%	38.8%	39.2%	39.4%	39.1%
Bachelor's Degree	25.4%	27.4%	23.3%	18.6%	31.1%
Master's Degree	9.5%	9.4%	9.8%	8.4%	11.2%
Doctoral Degree	0.8%	0.8%	0.7%	0.8%	0.6%
Professional Degree	2.3%	2.2%	2.4%	1.8%	2.9%

Respondents were asked to describe their household income. The NEP Anthro and NEP Eco segments reported similar income levels that were also inline with trends for the sample as a whole. The Digital Heavy segment reported the highest income levels overall, with 51.54% of respondents reporting a household income of $50,000 or above compared to 35.61% for Digital Light respondents.

Figure 8: Income breakdown of respondents by segment



	All	NEP Eco	NEP Anthro	Digital Light	Digital Heavy
Under $10,000	3.1%	2.5%	3.8%	4.2%	2.0%
$10,000 to $19,999	7.7%	8.4%	6.8%	9.1%	6.7%
$20,000 to $29,999	10.8%	10.9%	10.6%	12.2%	9.9%
$30,000 to $39,999	11.1%	11.6%	10.5%	12.4%	9.9%
$40,000 to $49,999	11.7%	10.8%	12.7%	11.9%	11.7%
$50,000 to $74,999	21.1%	22.6%	19.8%	19.0%	22.9%
$75,000 to $99,999	11.3%	10.5%	12.2%	8.4%	13.5%
$100,000 to $150,000	7.7%	7.1%	8.2%	5.9%	9.6%
Over $150,000	4.0%	4.5%	3.6%	2.4%	5.4%
Would rather not say	11.4%	11.2%	11.7%	14.7%	8.2%

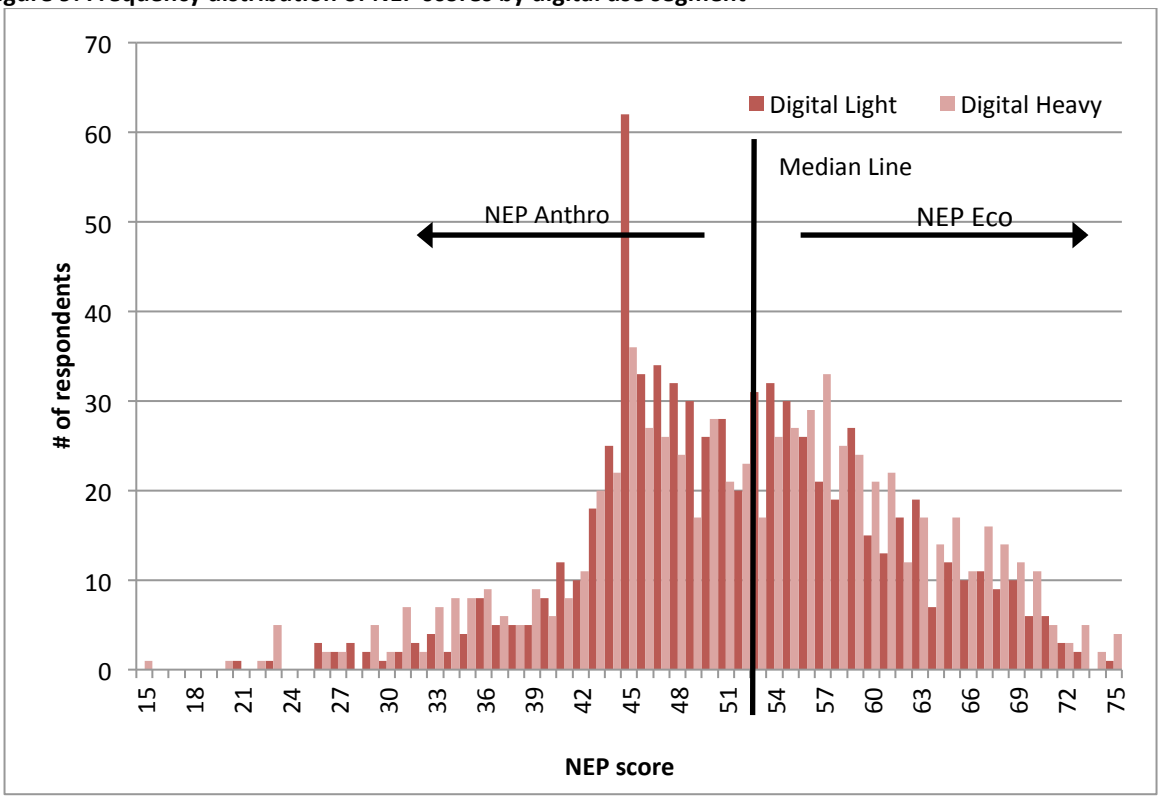
I asked respondents to describe the area in which they live, with Urban, Suburban, and Rural as options. For the entire sample, 33.8% were urban, 41.6% were suburban, and 24.5% were rural. The NEP Anthro and NEP Eco segments answered similarly, but the Digital Heavy segment was more likely to be urban (34.5%) or suburban (44.3%) when compared to the Digital Light segment (33.2% urban; 39.2% suburban).

3.6.2 Environmental Values

Our results on environmental values are presented in Figure 9, showing the frequency distribution of NEP Scores for the Digital Light and Digital Heavy segments. The Digital Heavy segment tends to have higher NEP scores, suggesting that the segment has stronger environmental values. But the difference is slight: the mean NEP score of the Digital Heavy segment is 52.4, while the Digital Light segment has a

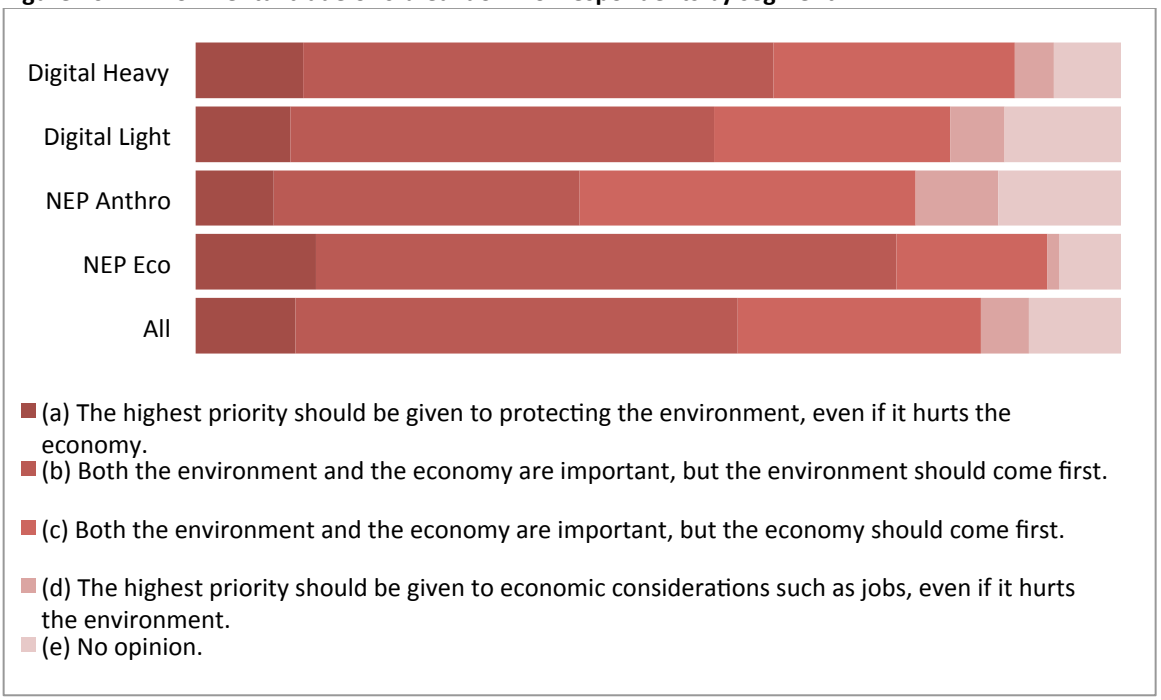
mean score of 51.7. A test reveals a p-value of 0.161, suggesting the difference in means is not of statistical significance.

Figure 9: Frequency distribution of NEP scores by digital use segment



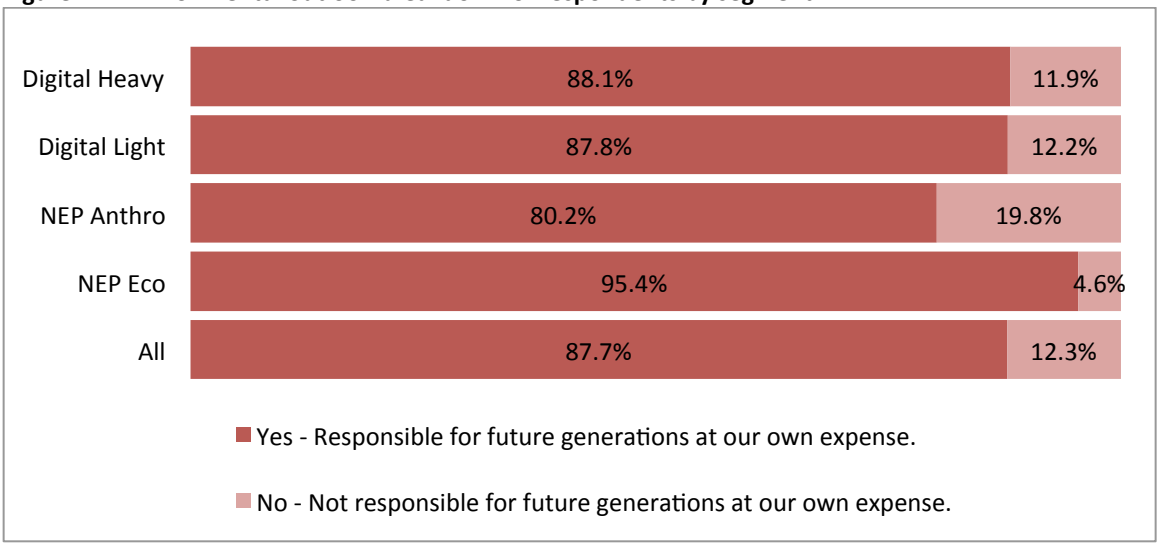
I asked the following: "Many environmental issues involve difficult trade-offs with the economy. Which of the following statements best describes your view?" and presented respondents with five options. The results are summarized in Figure 10. The NEP Eco segment had the highest percentage of respondents who thought the environment should be given the highest priority (13.0%), while the NEP Anthro segment had the smallest number of respondents (8.4%) who felt the environment should be a priority. The NEP Anthro segment was also the most likely to prioritize the economy. The Digital Heavy segment had stronger environmental values than its Digital Light counterpart: 62.3% felt that the environment was more important than the economy, compared to 56.0% of the Digital Light segment.

Figure 10: Environmental trade offs breakdown of respondents by segment



Our final environmental question asked respondents, "Do you believe that I have a responsibility to look out for the interests of future generations, even if it means making ourselves worse off?" The Digital Heavy and Light segments produced almost identical answers. The NEP segments responded in a predictable fashion: only 4.6% of the NEP Eco segment felt that present needs outweighed future needs, compared to 19.8% of the NEP Anthro segment.

Figure 11: Environmental outlook breakdown of respondents by segment



3.6.3 Media Consumption Trends

In this section, I describe the media consumption trends, organized by the four defined segments. I began by asking users to describe the type of Internet connection they use at home. In all but one of the categories, 80% or more of respondents reported that they had DSL (digital subscriber line) or cable broadband. The only exception was the Digital Light segment: 76.1% of respondents said they had DSL or cable. In contrast, the Digital Heavy segment had 87.6% of respondents reporting DSL or cable broadband at home.

I followed by asking the respondents about the online news sources they consult, with full results summarized in Figure 12 and Figure 13. When comparing the NEP segments, the only category to exhibit a statistically significant difference was news aggregators, where NEP Eco used that service more. In the digital categories, Digital Heavy used all online services in statistically significant numbers. Of note, a large number of respondents in both segments reported not reading news online at all.

Figure 12: Digital media sources – NEP segments

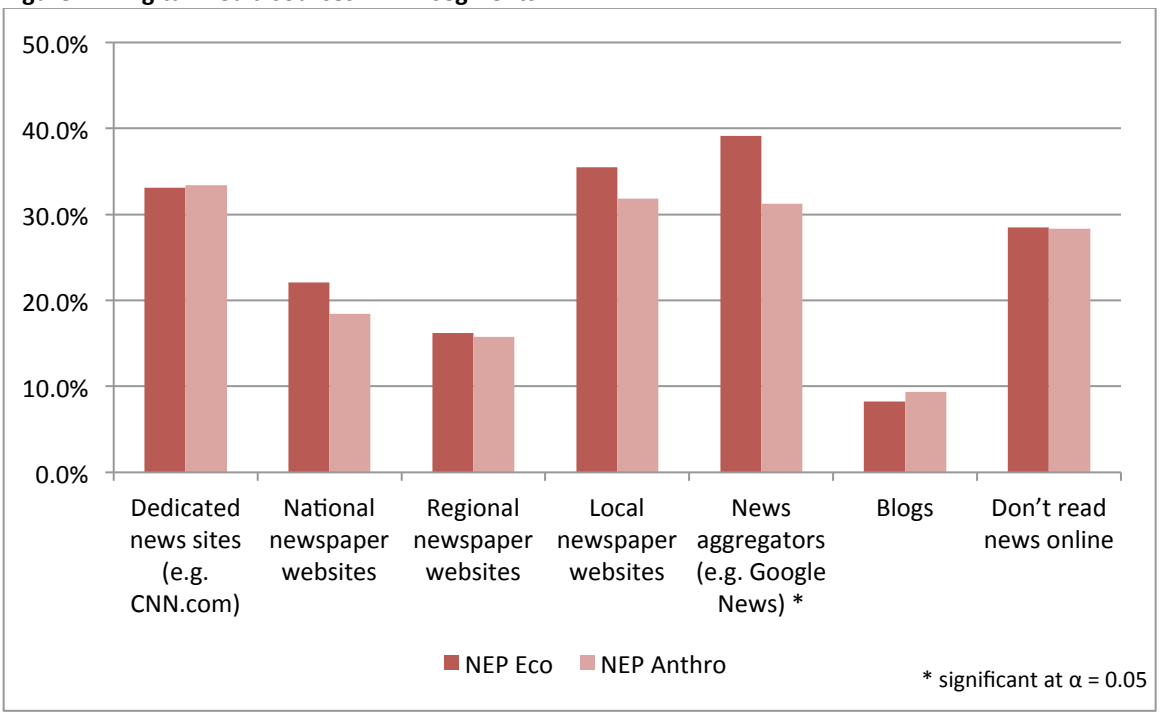
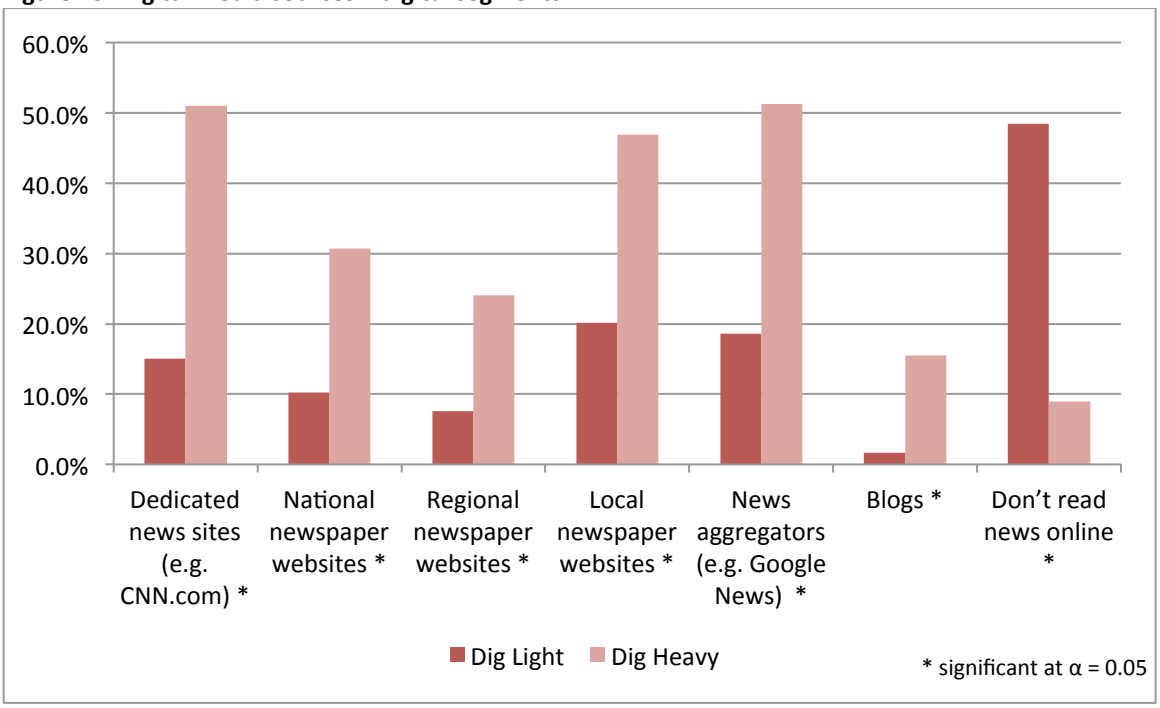


Figure 13: Digital media sources – digital segments



I also asked the respondents to report on the types of paper media that they consume, summarized in Figure 14 and Figure 15. I found that the NEP Eco segment was more likely to consume local newspapers, magazines, and books. The other paper news sources showed no significant variation between NEP Eco and NEP Anthro. When I compared the paper media habits of Digital Heavy and Light, I found statistically significant differences in several categories: local newspapers, hobbyist or niche magazines, and books (purchased or loaned). In each of those categories, Digital Heavy consumed more paper-based media.

Figure 14: Paper media sources – NEP segments

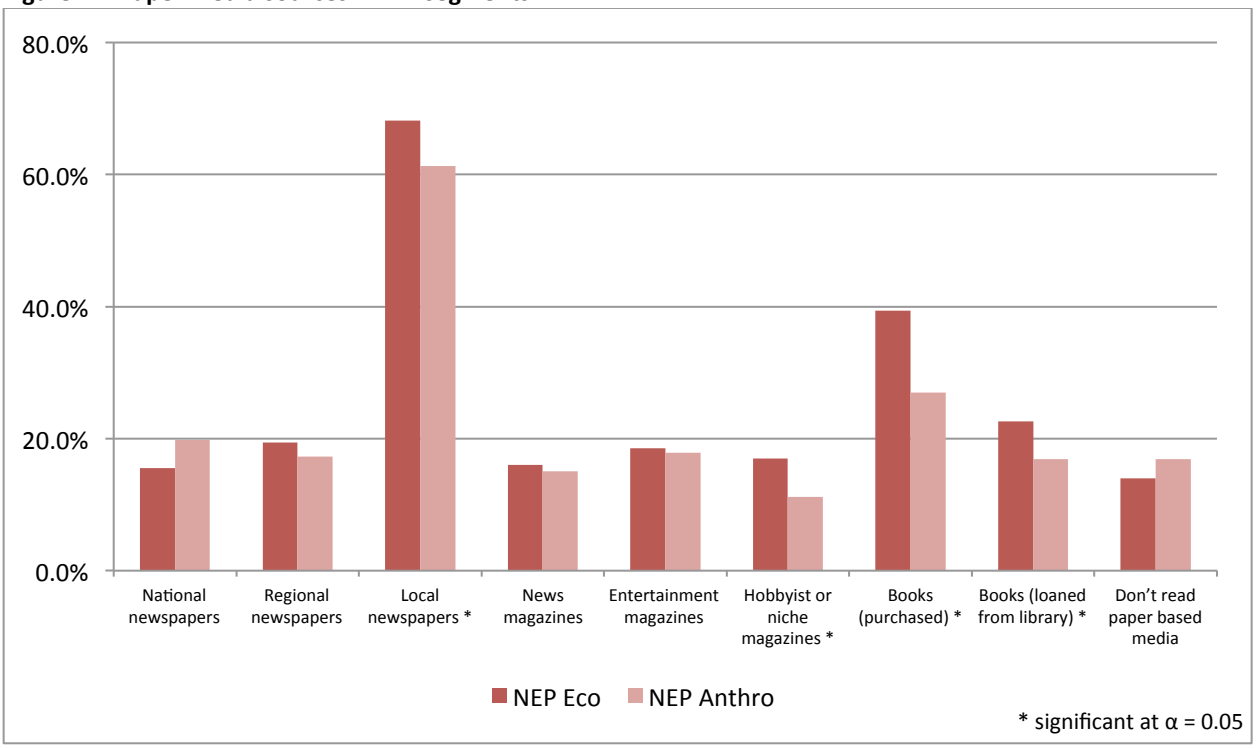
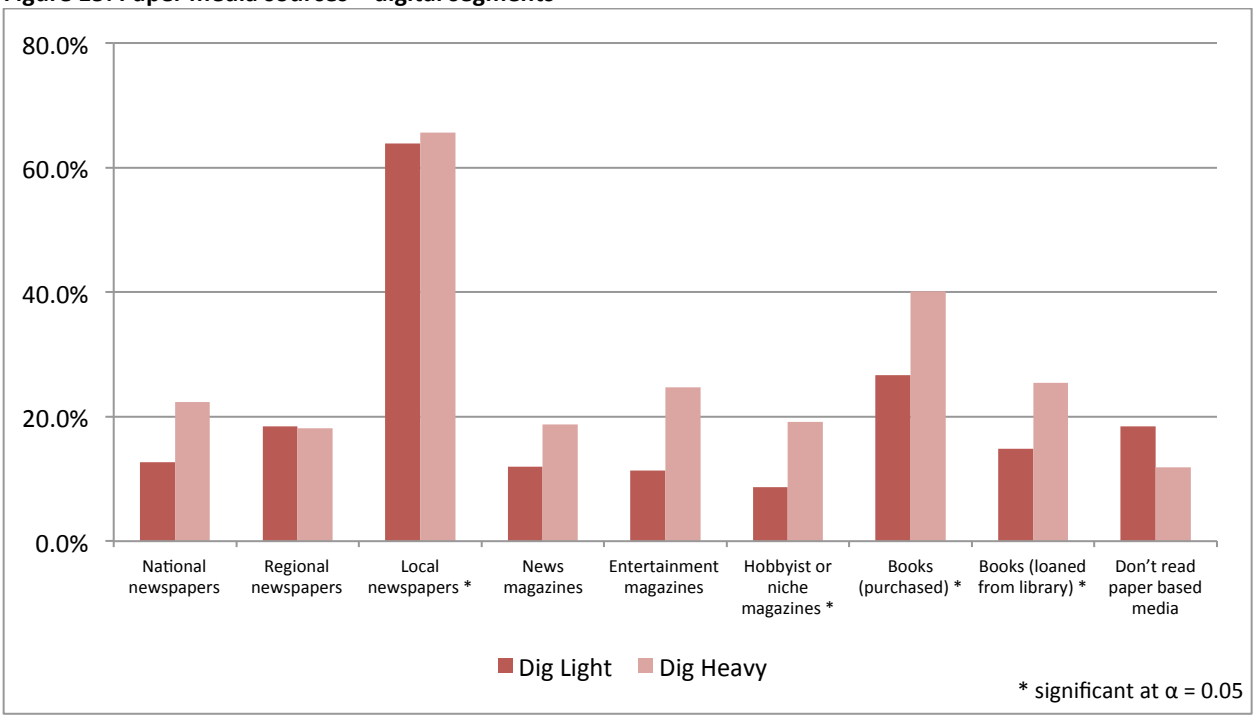


Figure 15: Paper media sources – digital segments



I asked the respondents to give a sense of how often they use a variety of online services, describing their usage on a scale of one to five, one being never and five being often. I then took the mean for each category and have summarized the results in Figure 16 and Figure 17**.** For each category, a paired t-test was conducted to compare the average response of the segments. With the NEP segments, I found statistically significant differences in the usage rates of email, blogging, and research. In the digital segments, the Digital Heavy segment had a statistically significantly higher mean in all categories. For each category, the average response of each segment is shown on a scale of 1.0 to 5.0. Respondents used the following scale: 1 equals never, 2 equals seldom, 3 equals sometimes, 4 equals often, and 5 equals always.

Figure 16: Online services – NEP segments

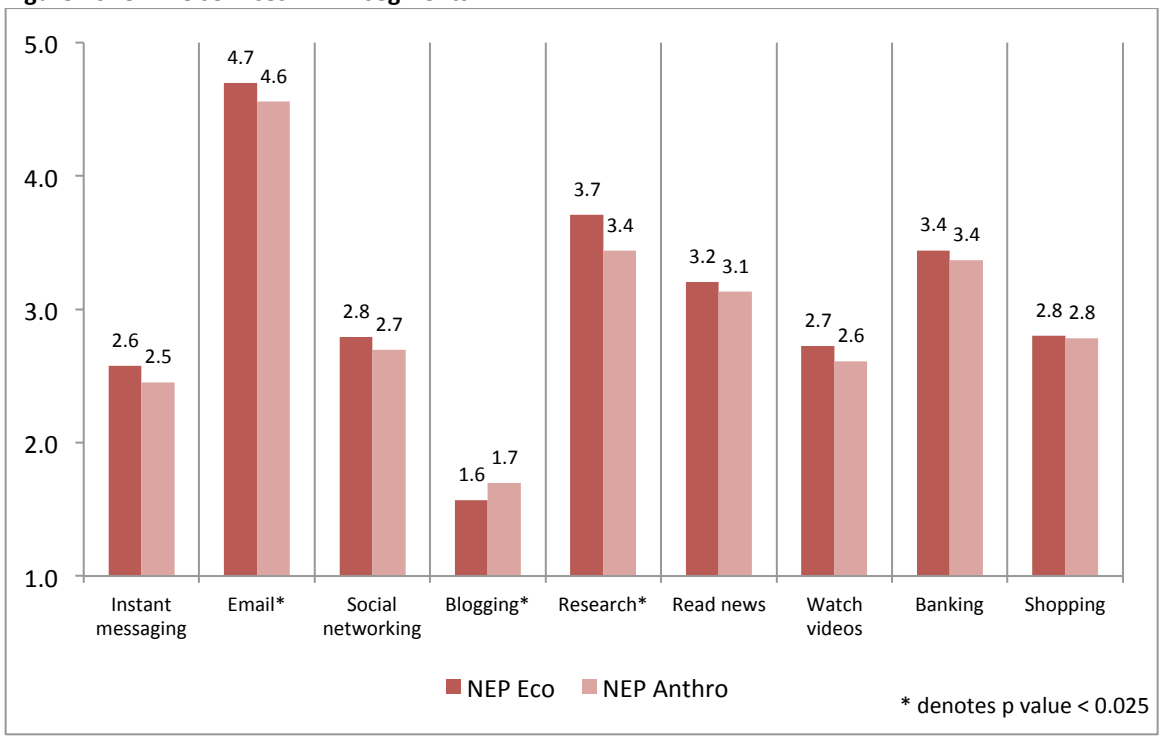
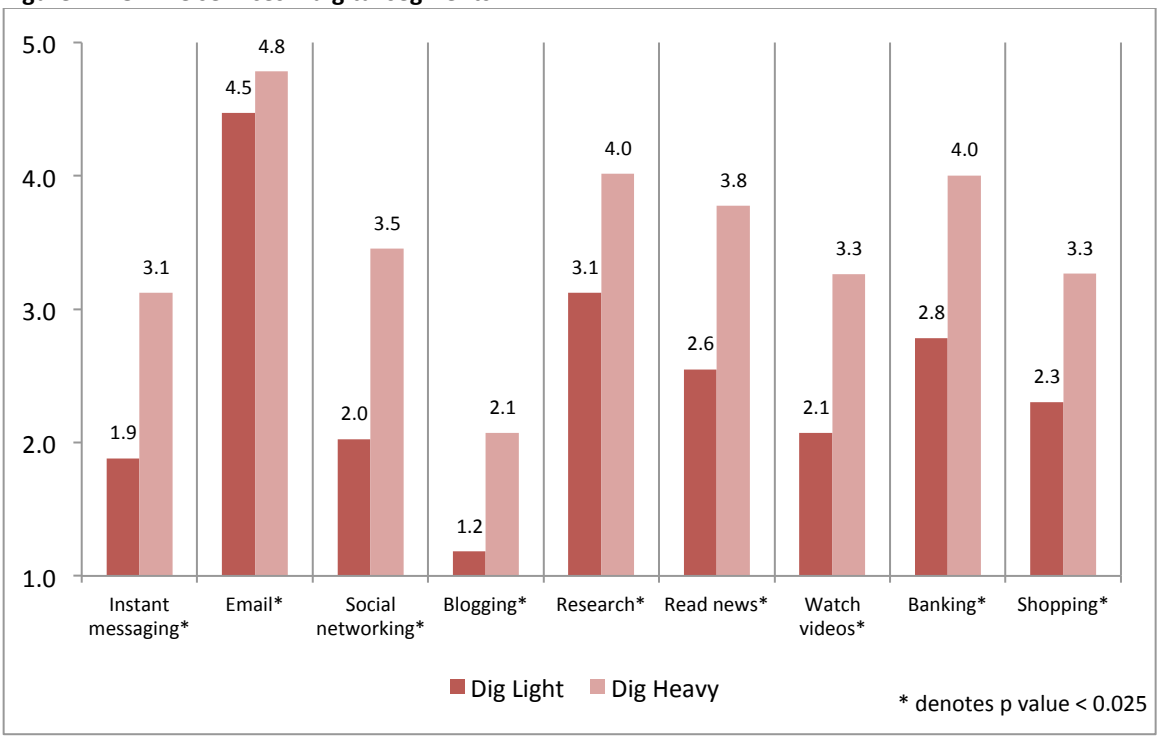


Figure 17: Online services – digital segments



I asked respondents to describe time spent on various activities: browsing the Internet, reading a newspaper, reading a magazine, and reading a book. The findings are summarized by segment in Table 4. I observed that the NEP segments had similar media consumption habits. Across the 24 categories (four media activities and six possible responses on time spent), any differences were slight, with all the responses within ± 6% of each other. I also found that in 17 of the 24 categories, the NEP Anthro segment reported spending more time with media, although by only a small percentage (between 0.1% and 3.8%). When I compared the Digital Light and Digital Heavy segments, I found that Digital Heavy respondents tended to spend more time consuming media in all categories. Digital Light respondents were more likely to spend no time reading a newspaper, magazine, or book during the day.

Table 4: Media activities

	Browsing the Internet		Reading a newspaper		Reading a magazine		Reading a book	
NEP	**Eco**	**Anthro**	**Eco**	**Anthro**	**Eco**	**Anthro**	**Eco**	**Anthro**
None	0.6%	2.0%	23.0%	25.0%	35.9%	34.1%	24.9%	28.6%
Less than 1 hour	20.7%	23.5%	59.1%	52.9%	53.8%	48.5%	30.7%	33.2%
1 to 2 hours	32.8%	29.9%	15.4%	16.1%	8.8%	12.3%	30.6%	24.3%
2 to 4 hours	23.9%	26.1%	2.1%	4.3%	1.3%	2.9%	10.6%	10.2%
4 to 6 hours	13.3%	9.6%	0.3%	0.8%	0.3%	1.1%	2.0%	2.2%
6 or more hours	8.8%	8.9%	0.1%	0.8%	0.0%	1.1%	1.3%	1.4%

Digital	**Light**	**Heavy**	**Light**	**Heavy**	**Light**	**Heavy**	**Light**	**Heavy**
None	2.5%	0.0%	29.6%	19.0%	43.9%	26.5%	33.8%	20.0%
Less than 1 hour	33.7%	10.6%	52.2%	59.2%	44.8%	56.8%	28.1%	35.2%
1 to 2 hours	35.3%	27.5%	15.8%	15.9%	9.6%	11.6%	26.4%	28.6%
2 to 4 hours	16.6%	33.0%	2.1%	4.1%	1.5%	2.7%	8.7%	12.3%
4 to 6 hours	6.6%	16.6%	0.1%	1.0%	0.0%	1.4%	2.0%	2.4%
6 or more hours	5.3%	12.3%	0.1%	0.8%	0.1%	1.0%	1.1%	1.5%

I investigated willingness to pay for different media categories. Results are shown for the NEP segments (Figure 18) and the digital segments (Figure 19). For each product category, I asked respondents whether or not they would be willing to pay to obtain a product. I then calculated a score for each category by adding +1 for each Yes response, 0 for each Maybe, and -1 for each No. The final score represents an aggregate level of willingness to pay for a product. The NEP segments behaved similarly. But comparing the digital segments revealed that Digital Heavy respondents were more willing to pay for all product categories, particularly printed magazines and printed books.

Figure 18: Willingness to pay – NEP segments

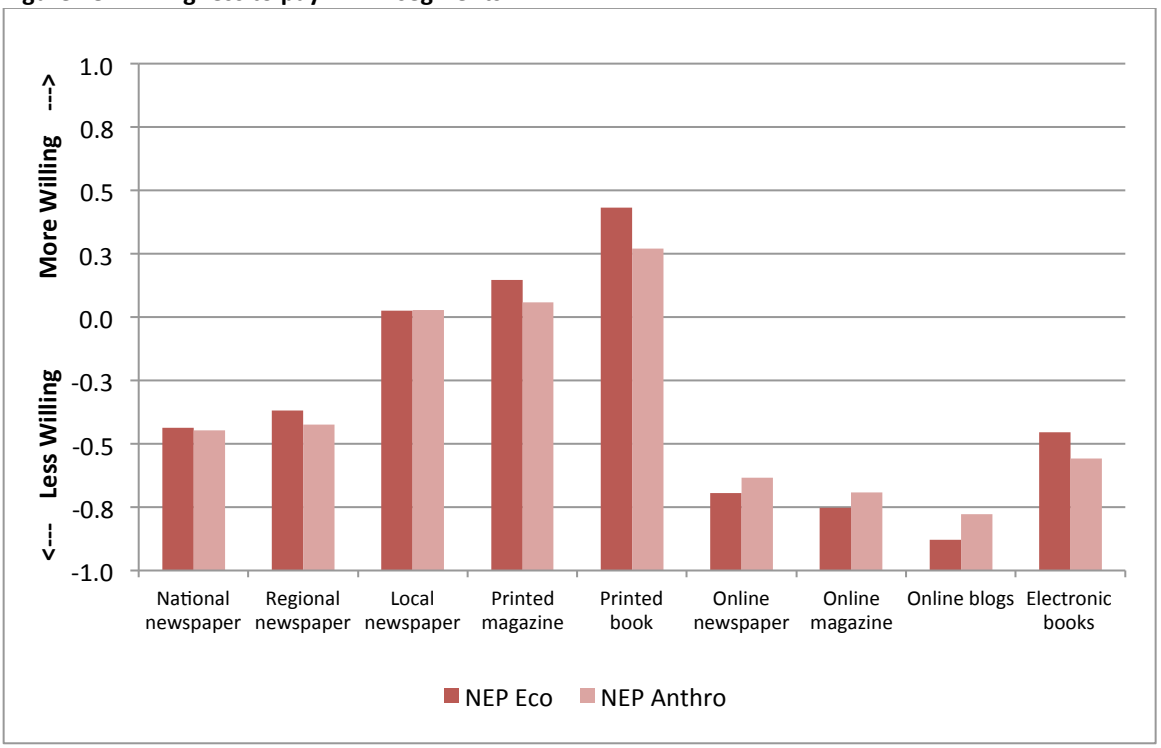
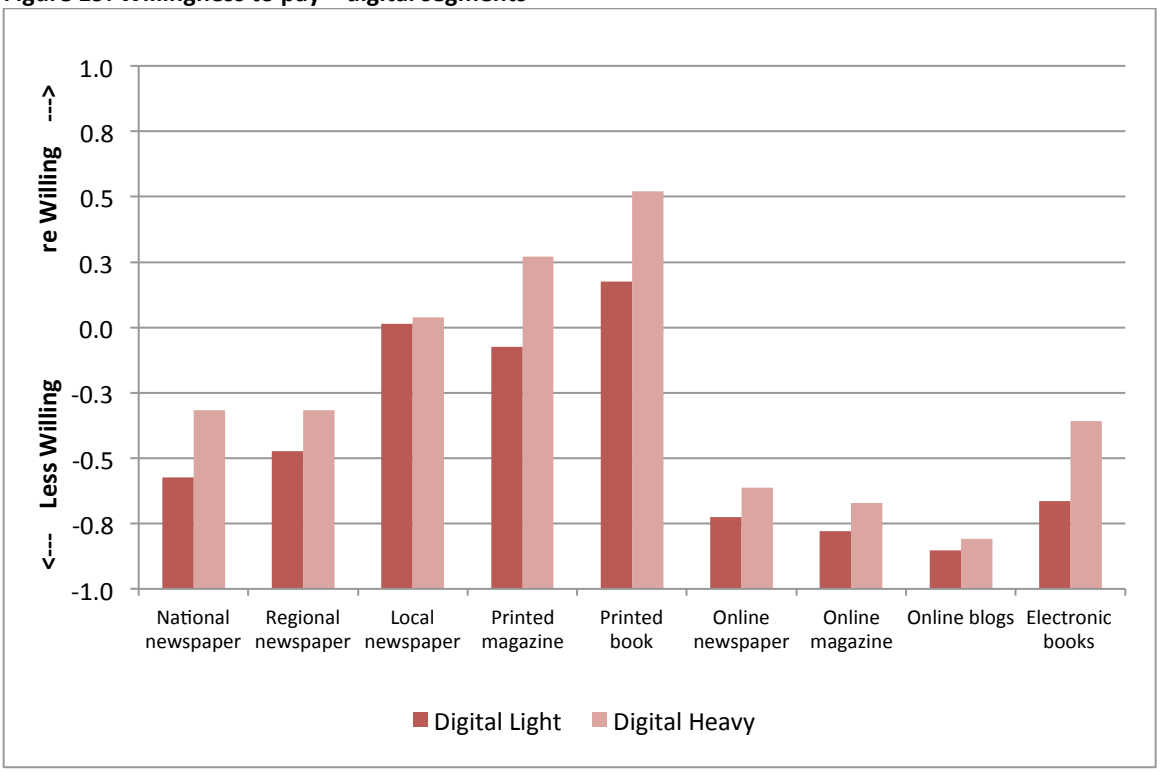


Figure 19: Willingness to pay – digital segments



I asked respondents about their perceived credibility of different media sources: printed newspapers, printed magazines, printed books, online newspapers, online magazines, online news aggregators, and blogs. Respondents ranked each source on a scale that ranged from Not Credible to Somewhat Credible to Credible to Very Credible. Across all segments, the most credible news sources were printed: 64.2% of printed books were considered Credible or Very Credible followed by 61.3% of printed newspapers. Of digital media, online newspapers ranked the highest (51.2% by the same measurement), while online news aggregators (33.4%) and blogs (9.6%) were considered the least credible media types.

Respondents also reported on perceived effectiveness of various advertising types:

Newspapers display	Online banner
Newspapers classifieds	Online pop-up
Newspapers flyer Insert	Online text-based
Magazine display	Online classified (e.g. Craigslist)

I asked them to rank the effectiveness of each on a scale that ranged from Not Effective to Somewhat Effective to Effective to Very Effective. I summed the latter two groups and ranked the categories. The survey group identified newspaper flyer inserts, newspaper classifieds and magazine display advertisements as the most effective. Online advertisements, in contrast, were considered less effective than any paper-based counterpart. Online pop-ups, banners, and text-based ads were the least effective: respectively, 70.4%, 44.7%, and 42.2% found them completely ineffective.

Finally, I asked respondents to gauge how their consumption patterns change over time across a variety of product categories. I measured respondents perceived consumption levels in the past (five years ago), present (today), and future (five years from today). The findings are presented in Figure 20 through Figure 25. There are trends that emerge across all the figures. The first is of paper media's decline across all categories, with only the library serving as the exception (all segments reported the noble aspiration of visiting the library more frequently in the future). The other is increasing digital media consumption. In all categories across all segments, respondents expected to consume more digital media. And in every category, NEP Eco outpaced NEP Anthro in adopting digital media, although by a very small margin. Comparing the Digital Light and Digital Heavy segments revealed similar trends: paper media in decline and digital media on the rise, but Digital Heavy respondents reported a more rapid shift towards digital media.

Figure 20: Media habits: newspaper or magazine delivered to home

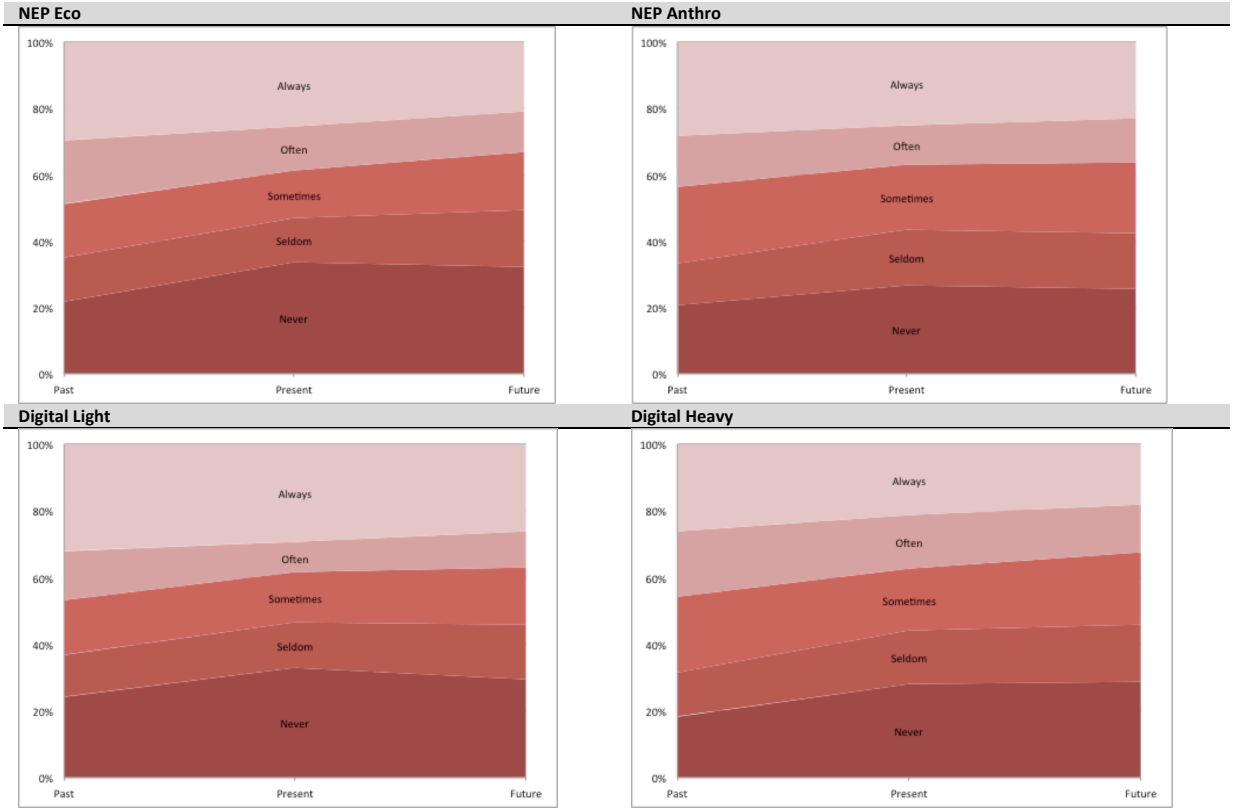


Figure 21: Media habits: books purchased from bookstore

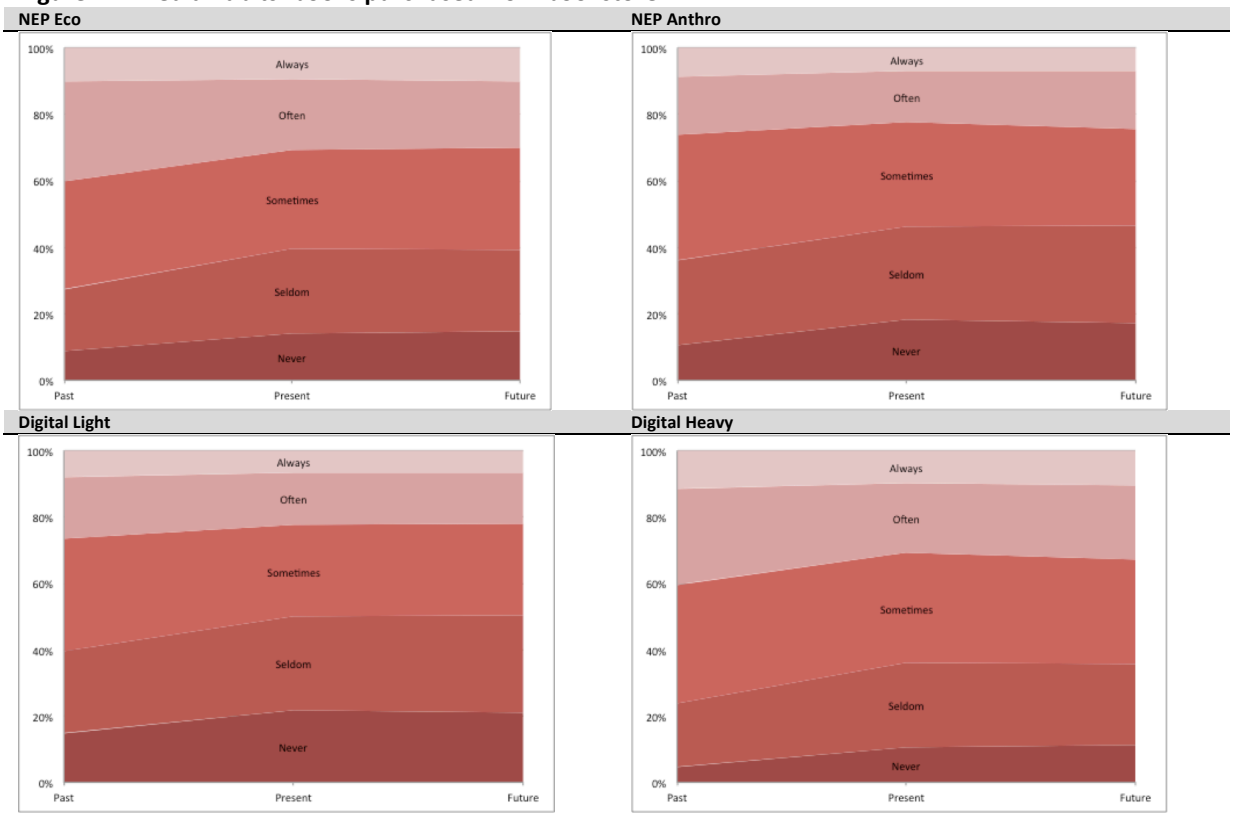
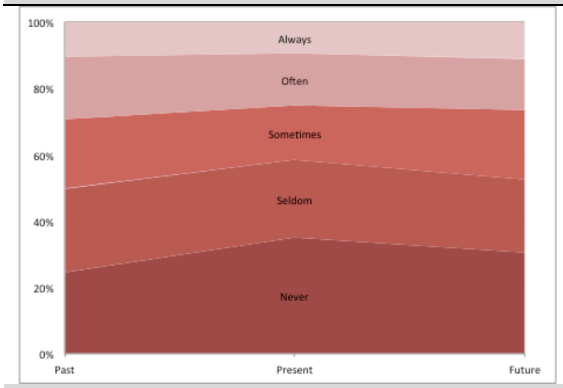
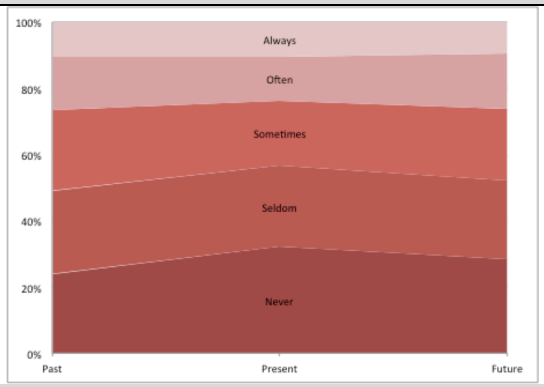


Figure 22: Media habits: books borrowed from library

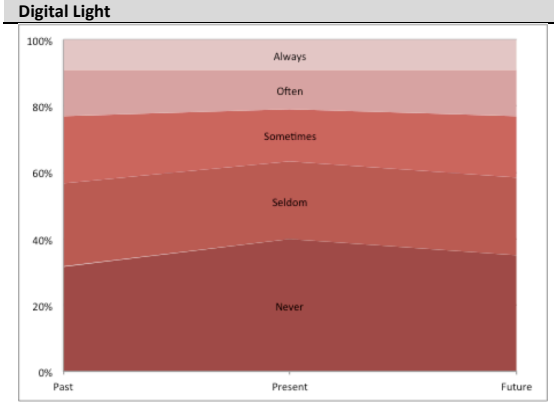
NEP Eco



NEP Anthro



Digital Light



Digital Heavy

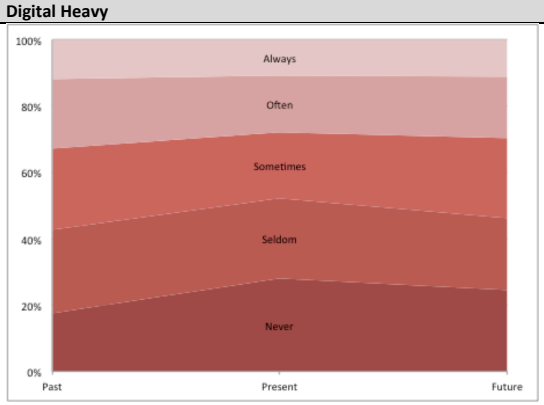
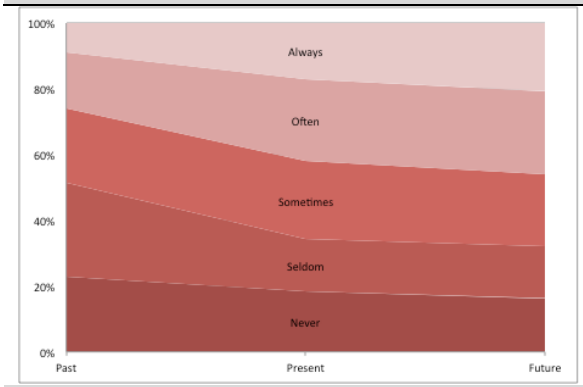
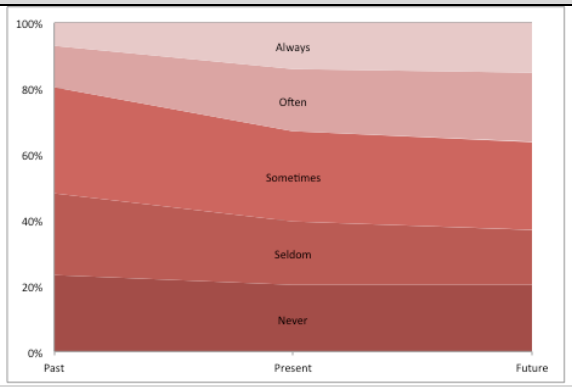


Figure 23: Media habits: reading news on PC or laptop computer

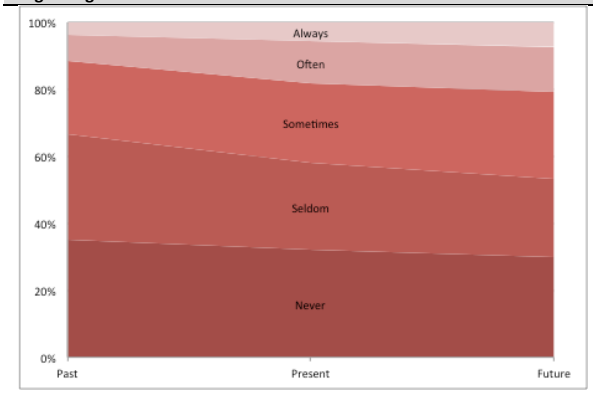
NEP Eco



NEP Anthro



Digital Light



Digital Heavy

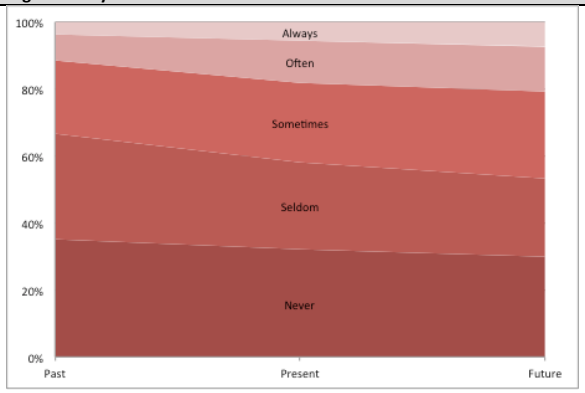


Figure 24: Media habits: read news on smartphone or mobile device

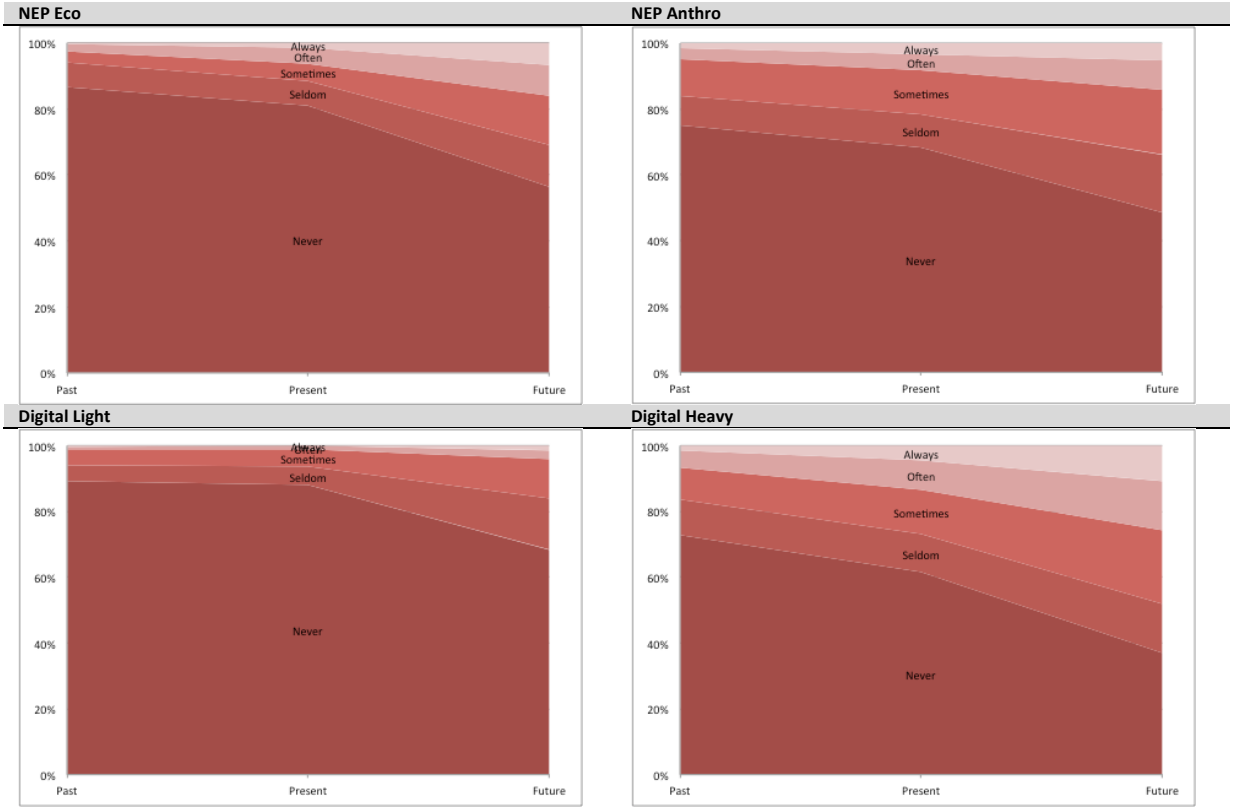
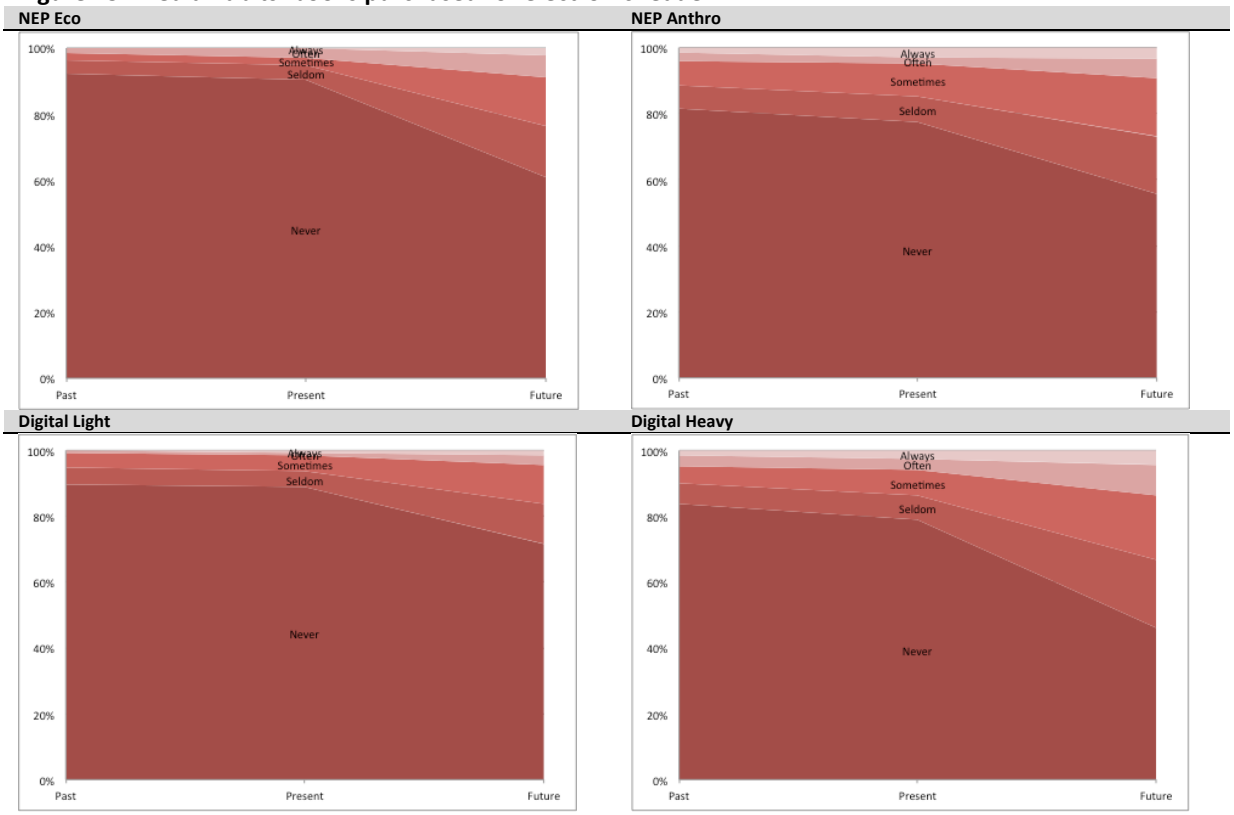


Figure 25: Media habits: books purchased for electronic reader



3.7 DISCUSSION

I sought to answer two questions: what are the media habits of consumers with different environmental values? And what are the environmental values of different kinds of media consumers? I established four segments of respondents: NEP Eco and NEP Anthro, and Digital Light and Digital Heavy. I compared each pair of segments, looking for patterns or trends that could contextualize knowledge of media consumption and the environment.

The NEP segments did not differ significantly on demographic variables: age, income, and gender were all closely aligned. The NEP segments also exhibited predictable environmental values: the NEP Eco segment answered questions about the environment with stronger proecological bias than the NEP Anthro segment. These findings were in line with previous research that uses the NEP (Cordani *et al.*, 2003; Lundmark, 2007; Rideout *et al.*, 2005; Schultz, 2001). But when I measured media consumption, the NEP segments followed similar patterns. Rarely did responses differ by significant amounts, with one outlier: the NEP Anthro segment apparently spends more time blogging, an anomaly amongst otherwise consistent media habits.

The digital segments shared similar environmental values. Their average NEP scores were not statistically different, although the Digital Heavy segment showed a slight bias towards pro-ecological views across all questions. Where the digital segments differed was in demographic criteria. The Digital Heavy segment was younger, more urban, and had higher income and education levels.

When I compared the media consumption habits of the Digital Heavy and Digital Light segments, a few results were noteworthy. While the Digital Heavy segment predictably reported consuming more digital media, it also had a stronger relationship with paper media: the segment reported consuming more local newspapers, niche magazines, and purchased and borrowed more books. Digital Heavy respondents reported spending more time with most forms of paper media, and were also more likely to indicate a willingness to pay for paper products, printed books in particular. I also noticed that all segments reported noticeable differences in how they perceived paper and digital media. Paper media sources were reported to be more credible sources of information and paper-based advertising was seen as more effective than digital equivalents. The four segments also all expressed a stronger willingness to pay for paper media.

And yet, I also observed all of the segments reporting a shift away from paper media, in line with trends observed by others (Duggan and Smith, 2013; Bell *et al.*, 2013). Newspapers and magazines were products that the literature identified as particularly vulnerable to disruption (Media Life Magazine, 2014; Pew Research Journalism Project, 2013). And all of the survey segments reported using more in the past than they do today, and an intention to consume less in the future, verifying what the literature has suggested. All segments also reported consuming more books (either purchased or borrowed) in the past than they do today. They also all reported aspiring towards more book consumption in the future.

More dramatic than reported changes in paper consumption, however, were the consistent responses from all segments on changing digital media habits. All segments reported that in the future they would consume more news online, use mobile devices more often, and even start using an electronic reader. They also reported consuming more types of digital media today than they did in the past. These observations are in line with other surveys of consumers (Chyi and Lee, 2013; Chan-Olmsted *et al.,* 2013) that have identified a shift in media consumption habits from paper to digital sources. This digital shift underlies another trend: however they feel about the environment, consumers are shifting towards digital media. And despite what people consumers think about paper media, they are also anticipating a shift towards digital. It follows, then, that environmental values have little influence over media consumption. So in the midst of a media shift, the environment seems to be playing little or no role at all.

Our results also revealed some features of the NEP score. While it was a reliable indicator of environmental values – as the NEP segments strongly correlated with pro-ecological views in other environmental questions – the two NEP segments showed similar demographic patterns. The NEP scale is, no doubt, a valid indicator of environmental values, befitting a methodology that has been extensively used by other researchers (Cordani *et al.*, 2003; Lundmark, 2007; Rideout *et al.*, 2005; Schultz, 2001). But the fact that the NEP segments did not have significantly different demographic variables was a puzzle. Some research (Grossman and Krueger, 1995) has suggested that income and the environment are related, but the results do not support the idea that higher income and education achievement results in stronger environmental values, although I did not attempt to explicitly test that hypothesis.

Our research establishes that media consumption is shifting from paper to digital media. In the midst of that shift, I found two key trends. Demographic variables – like age, income, and education – tend to influence media consumption, but not environmental values. Environmental values do not seem to influence media consumption habits. If there is no connection between environmental values and media consumption, it could be that consumers who are concerned about the environment aren't applying those values to media consumption. Because media is omnipotent and transient (digital appears virtually; paper can be delivered, and disposed of when no longer needed), perhaps the materiality of media footprints eludes consumers' concern.

This disconnect should be a source of concern. The environmental footprint of paper was improved by the concerns of consumers: efforts to use better inks, save important forests, and avoid harmful bleaches were all driven by consumer's worries. Paper media has been the recipient of environmental scrutiny. But I have established, and the literature has confirmed that paper media is in decline (Duggan and Smith, 2013; Duggan and Brenner, 2013). New digital platforms are proliferating rapidly and media is increasingly virtual and dispersed (Bell *et al.,* 2013). The imperative of environmental sustainability suggests that environmental values should be applied to all media types to ensure that environmental impacts are documented and reduced.

3.8 CONCLUSIONS

In this chapter, I had three objectives: to examine media habits of different environmental segments; to examine the environmental values of different media segments; and to identify patterns in these segments that might deepen an understanding of sustainability and media. I found that media consumption patterns had little influence over environmental values: people consuming large amounts of paper media or large amounts of digital media did not vary much in their ecological bias. I also found that stronger or weaker environmental values did not consume media in significantly different ways. My interpretation of these results suggests that media consumption is a consumptive choice that seems to have escaped the environmental scrutiny. Media, both paper and digital, has characteristics that make it intangible and transient. Consumers, are a result, may be disconnected from media footprints, playing a weaker role in driving sustainable media than they otherwise could.

Chapter 4: The Case of Life Cycle Comparisons: Efforts to Measure Paper and Digital Media[8]

4.1 ABSTRACT

The consumption of the written word is changing, as media transitions from paper products to digital alternatives. I reviewed the life cycle assessment (LCA) research literature that compared the environmental footprint of digital and paper media. To validate the role of context in influencing LCA results, I assessed LCAs that did not compare paper and print, but focused on a product or component that is part of the Information and Communication Technology (ICT) sector. Using a framework that identifies problems in LCA conduct, I assessed whether the comparative LCAs were accurate expressions of the environmental footprints of paper and print. I hypothesized that the differences between the product systems that produce paper and digital media weaken LCA's ability to compare environmental footprints. I also hypothesized that the characteristics of ICT as an industrial sector weaken LCA as an environmental assessment methodology. I found that existing comparative LCAs offered problematic comparisons of paper and digital media for two reasons – the stark material differences between ICT products and paper products, and the unique characteristics of the ICT sector. I suggested that the context of the ICT sector, best captured by the concept of "Moore's Law", will continuously impede the ability of the LCA methodology to measure ICT products.

4.2 INTRODUCTION

The consumption of the written word is changing. Newspapers, magazines, books and other paper products are being replaced by a complex system of interconnected electronic devices. The nature and pace of this transition is uneven. Some paper media products and publishers may survive, while others will adapt or disappear. Given the importance of sustainability – broadly defined as activities that do not compromise the well-being of future generations (United Nations, 1987) – it is worth considering the implications of a shift from paper to digital media from an environmental perspective.

The Internet and Information and Communication Technologies (ICT) are transforming the profile of the global economy and impacting the environment. ICT includes technologies such as desktop and laptop computers, smartphones, e-readers, software, peripherals, and connections to the Internet that fulfill

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information processing and communications functions. The impact of ICT on the global economy is complex. Berkhout and Hertin (2004, p.903) studied the direct, indirect, and structural impacts of the ICT sector. They found that the sector and its impacts are "complex, interdependent, deeply uncertain and scale-dependent." Hilty *et al.* (2006, p.1618) worried that "there is some risk that ICT will become counterproductive with regard to environmental sustainability." They encouraged a systematic view of ICT to ensure its application is used in support of sustainable development. Williams (2011, p.354) argues for a broad view on the impacts of ICT, suggesting that the "energetically expensive manufacturing process, and the increasing proliferation of devices needs to be taken into account." Andrae and Anderson (2010) found that not all LCAs of ICT products are created equally. They found desktop and laptop LCAs to be the least consistent of the consumer products that they examined, rooted in subjective choices and different system boundaries and lifetimes. Malmodin *et al.* (2010) found that, in 2007, the ICT sector produced 1.3% of global greenhouse gas emissions and used 3.9% of global electricity. Given the growth of the ICT sector since 2007, this figure has likely increased.

4.3 BACKGROUND

Given the emergence of ICT and its potential to disrupt various sectors of the economy, researchers have studied the potential environmental trade-offs. Researchers have compared traditional and web-based retailing (Edwards *et al.,* 2010), working at the office or at home (Mokhtarian *et al.*, 1995), different music delivery methods (Weber *et al.*, 2010), and paper-based telephone directories and online equivalents (Zurkirch & Reichart, 2002). But one of the most frequently considered transitions is that from paper to digital media. Products such as invoices, telephone directories, textbooks, office paper, magazines, and newspapers all have digital alternatives.

The environmental impact of these trade-offs has most commonly been measured by means of a life cycle assessment (LCA), a rigorously defined and transparent methodology for quantifying environmental burdens associated with the creation, use, and disposal of products and systems. LCA is rooted in efforts to compare products, with a seminal study conducted in 1969 that examined the differences between various beverage containers (LeVan, 1995). The tool was extended to other comparisons contrasting, for example, paper and plastic bags, cloth and disposable diapers, or steel beams and dimensional lumber. All of these comparisons are trade-offs between two product systems that can be defined in a straightforward way. The trade-off between paper and digital media, however, is more complex. Digital products can replace paper consumption, but this is not their only function.

Researchers have also found that increased digital media consumption does not necessarily reduce paper media consumption (Sellen and Harper, 2001). These compounding factors suggest that the ICT sector may strain LCA's ability to make meaningful comparisons.

LCA excels in considering trade-offs between product systems that can be clearly defined and in comparing products that are discrete substitutes. A paper or plastic bag is a straightforward consumptive choice. The same cannot be said for paper or digital media. Studies suggest that the more discrete and precise the trade-off considered, the more effective the LCA is as a tool of environmental assessment (Gaudreault *et al.*, 2007a, 2007b). Earlier research has also shown that the LCA is constrained in its ability to compare at all, with Finnveden (2000, p.299) suggesting that, "it can in general not be shown that one product is environmentally preferable to another, even if this happens to be the case." Should process *x* or *y* be employed to minimize environmental footprint? Would product *a* or *b* have a smaller environmental footprint? These are the questions that LCAs can and should answer. But sometimes the relationships between *x* and *y* are enormously complex. Managing this complexity imposes unavoidable uncertainty and a resulting series of assumptions. How does the LCA perform in assessing a complex consumptive choice? Further, how does the LCA perform when complexity lies not just in a lack of a discrete trade-off, but in the fundamental character of one of the subjects being studied?

4.4 OBJECTIVES

Given the complex trade offs between paper and digital media, I hypothesize that the differences between the product systems that produce different media undermine the LCA's ability to accurately compare environmental footprints. I also hypothesize that the characteristics of ICT as an industrial sector weaken LCA as an environmental assessment methodology. To test this latter hypothesis, I also examined LCAs that looked exclusively at ICT products.

This chapter answers these questions by reviewing comparative LCAs that have examined paper and digital media. By doing so, I aim to elucidate the strengths and weaknesses of LCA as a comparative tool. Further, I seek to strengthen my understanding of the role that context plays in LCAs, and in this particular case, the context of the ICT sector. I focus on ICT throughout the chapter because I believe this sector warrants particular scrutiny. It is disruptive to many aspects of the global economy and several industrial sectors beyond paper-based media, with direct, indirect and behavioural effects. It is

changing rapidly, with new products, processes and devices emerging. Forestry and paper production are not without environmental impacts, with land-use change, emissions from production, and the creation of waste as prominent examples. (For a more detailed review of issues associated with paper LCAs see Gaudreault *et al.,* 2007a, 2007b).

4.5 METHODOLOGY

I describe an analytical framework for assessing problems in the conduct of an LCA, and the methods for selecting comparative LCAs and validating the results through ICT LCAs. I organize the results around problems identified in an analytical framework. I describe the problem, examine how it is addressed in comparative LCAs, and then assess the approach of ICT LCAs.

An LCA is a four-step tool designed to estimate the potential environmental impact of a product, process, or system (ISO, 2006). These four steps, and the challenges that occur at each stage, are summarized by Reap *et al.* (2008a, 2008b). The four stages of conducting an LCA are goal and scope definition, inventory analysis, impact assessment, and interpretation. Along these four stages, the authors suggest six challenges that are of particular concern: functional unit definition, boundary selection, allocation, spatial variation, local environmental uniqueness and data availability/quality. These six challenges structured the review of comparative LCAs that examine paper and digital media. Reap *et al.* (2008a, 2008b) identified these challenges as most important because they had significant influence over study results and adequate solutions are available to ameliorate impacts. I describe the specifics of each challenge in the Results section, followed by the analysis of comparative LCAs and ICT LCAs.

I chose studies that specifically examined potential trade-offs between paper and digital media for several reasons. Paper and digital media are very distinct product systems, and I wanted to gauge the robustness of the LCA when comparing such different units of analysis. Further, the ICT sector is a dynamic and growing industry that has disrupted many existing industrial sectors. The idea of the "paperless office" was held up as an environmentally preferable future (Sellen and Harper, 2001). The phrase "please consider the environment before printing this email" is often appended to emails. It suggests that printing on paper is bad for the environment, while sending an email is innocuous. I wanted to understand whether this assumption that digital media is preferable is supported by academic research. I searched academic databases for peer-reviewed literature on the subject, but also

considered publically available technical reports and white papers. In the end, this left us with seven studies which I summarized using the six key challenges in Reap *et al.*'s (2008a, 2008b) analytical framework. The studies reviewed are listed below.

- Deetman, S. & Odegard, I. (2009*) Scanning Life Cycle Assessment of Printed and E-paper Documents based on the iRex Digital Reader*. [Online] Available from: http://media.leidenuniv.nl/legacy/irex-dr1000-lca-scan-final-report.pdf. [Accessed: 9th June 2014]
- Enroth, M. (2009) Environmental impact of printed and electronic teaching aids, a screening study focusing on fossil carbon dioxide emissions. *Advance in Printing and Media Technology.*36. p. 1-9.
- Gard, D. L. & Keoleian, G. A. (2003) Digital versus print. Energy performance in the selection and use of scholarly journals. *Journal of Industrial Ecology.* 6 (2). p. 115–132.
- Hischier, R., Wäger, P. & Gauglhofer, J. (2005) Does WEEE recycling make sense from an environmental perspective? The environmental impacts of the Swiss take-back and recycling system for waste electrical and electronic equipment (WEEE). *Environmental Impact Assessment Review.* 25 (5). p. 525-539.
- Kozak, G. L. & Keoleian, G. A. (2003) Printed Scholarly Books and E-book Reading Devices: A Comparative Life Cycle Assessment of Two Book Options. *Electronics and the Environment, 2003. IEEE International Symposium on.* p. 291-296.
- Moberg, Å., Borggren, C. & Finnveden, G. (2011) Books from an environmental perspective-Part 2: e-books as an alternative to paper books. *International Journal of Life Cycle Assessment.* 16 (3). p. 238-246.
- Moberg, Å., Johansson, M., Finnveden, G. & Jonsson, A. (2010) Printed and tablet e-paper newspaper from an environmental perspective — A screening life cycle assessment. *Environmental Impact Assessment Review.* 30 (3). p. 177-191.
- Toffel, M. W. & Horvath, A. (2004) Environmental implications of wireless technologies. News delivery and business meetings. *Environmental Science and Technology.* 38 (11). p. 2961–2970.

Reap *et al.*'s (2008a, 2008b) framework provided the concepts and theory necessary to identify whether inaccuracies in LCAs result from a failure to implement the LCA methodology appropriately. But the framework cannot identify whether there are problems outside the scope of LCA methodology that influence results. To identify the potential of context to influence comparative LCA results, I triangulated the results by also using ICT LCAs that did not attempt to compare one product to another. The underlying logic is that if the same problems are identified in both comparative LCA s and ICT LCAs, I can better gauge the role of context in influencing LCA results.

The key findings of each LCA are presented in Table 5. In every comparative LCA, it is found that digital media is preferable to paper media. However, in many of the studies the authors suggest that there is insufficient data to express much confidence in the study findings. Each study expresses its results in different units, from energy used to global warming potential to impact indicators specific to the LCA

model being employed. Nonetheless, a consistent trend of finding digital media preferable while also noting the extent of uncertainty and assumption in the digital lifecycle is present.

Table 5: Key findings of comparative LCAs

Study	Functional Unit
Deetman & Odegard	The authors concluded that the iRex reader performed better than printers and paper in supplying information for the office worker. They indicated that using LWC paper, after 3000 single-sided prints the e-reader was preferable. Using woodfree uncoated paper, 5000 prints were required before the e-reader was a preferable option
Enroth	The study found that the impact on global warming of a web-based electronic teaching aid was approximately 10 times higher than the environmental impact of a printed textbook.
Gard & Keoleian	The study found that digital media consumption varied between 4.10 and 216 MJ per functional unit. Paper media consumption varied between 0.55 and 525 MJ per functional unit.
Hischier & Reichart	The study found that reading the news on the Internet causes more impact than viewing it on a TV, but reading on the Internet causes less of an impact than a physical newspaper. They concluded that comparing multifunctional products using strict functional units did not reflect environmental impacts.
Kozak	The e-reader was found to have environmental impact preferable to paper media in most scenarios, with the only exception being when a paper text book is re-used at least 4 times.
Moberg *et al.* (2010)	The printed newspaper in general had a higher energy use, higher emissions of gases contributing to climate change and several other impact categories than the tablet e-paper newspaper. It was concluded that tablet e-paper has the potential to decrease the environmental impact of newspaper consumption
Moberg *et al*. (2011)	The study found that when the e-book was compared with a paper book, the number of books read on the e-book reader during its lifetime was crucial in evaluating environmental performance compared with paper books. The results indicated that there are impact categories and circumstances where paper books are preferable to e-books from an environmental perspective and vice versa.
Toffel & Horvath	The authors compared reading a newspaper to reading the same information on a PDA. They concluded that reading the news on the PDA results in the release of 23-140 times less $C0_2$, several orders of magnitude less NO_X and SO_X, and the use of 26-67 times less water.

Below is a list of eight non-comparative LCAs from the ICT sector that I also reviewed for this chapter:

- Choi, B., Shin, H. S., Lee, S. Y., Hur, T. (2006) Life Cycle Assessment of a Personal Computer and its Effective Recycling Rate. *International Journal of Life Cycle Assessment.* 11 (2). p. 122-128.
- Duan, H., Eugster, M., Hischier, R., Streciher-Porte, M. & Li, J. (2009) Life cycle assessment study of a Chinese desktop personal computer. *Science of the Total Environment.* 407 (5). p. 1755-1764.
- Durucan, S., Korre, A. & Munoz-Melendez, G. (2006) Mining life cycle modelling: a cradle-to-gate approach to environmental management in the minerals industry. *Journal of Cleaner Production.* 14(12-13). p. 1057-1070.
- Frey, S. D., Harrison, D. J. & Billett, E. (2006) Ecological footprint analysis applied to mobile phones. *Journal of Industrial Ecology.* 10 (1-2). p. 199-216.
- Liu, C. H., Lin, S. J. & Lewis, C. (2010) Life cycle assessment of DRAM in Taiwan's semiconductor industry. *Journal of Cleaner Production*. 18 (5). p. 419-425.
- Lu, L. T., Wernick, I. K., Hsiao, T. Y., Yu, Y. H., Yang, Y. M. & Ma, H. W. Balancing the life cycle impacts of notebook computers: Taiwan's experience. *Resources, Conservation and Recycling.* 48 (1). p. 13-25.
- Plepys, A. (2004) The environmental impacts of electronics. Going beyond the walls of semiconductor fabs. *Institute of Electrical and Electronics Engineers.* p. 159-165.
- Scharnhorst, W. (2006) Life Cycle Assessment of Mobile Telephone Networks, with Focus on the End-of-Life Phase. *International Journal of Life Cycle Assessment.* 11 (4). p. 290-291.
- Williams, E. D., Ayres, R. U. & Heller, M. (2002) The 1.7 Kilogram Microchip: Energy and Material Use in the Production of Semiconductor Devices. *Environmental Science & Technology.* 36 (24). p. 5504-5510.

4.6 RESULTS

I detail the results of the review of comparative LCAs and non-comparative ICT LCAs below. The results are organized according to the analytical framework developed by Reap *et al.* (2008a, 2008b) that identifies the six key challenges in the conduct of the LCA. However, because of their similarity, spatial variation and environmental uniqueness are discussed in tandem in section 4.6.4. I summarize the LCAs reviewed in aggregate, identifying and detailing indicative results when appropriate.

4.6.1 Functional Unit Definition

The functional unit is a measure of the performance of the functional outputs of the product system (ISO, 2006). It is designed to provide a reference to which inputs and outputs are related, and a basis for comparability of LCA results. Challenges emerge when trying to incorporate products that have multiple functions. According to Reap *et al.* (2008a, p.292), "not identifying, decomposing, specifying and/or prioritizing these [multiple] functions appropriately with respect to a study's goal and scope might yield a functional unit that fails to reflect reality well". Non-quantifiable or difficult-to-quantify functions can also be a source of error.

Table 6 summarizes the functional unit in the comparative LCAs reviewed, with a mix of single-function and multi-functional units. The paper product was consistently considered a single-function product (although in some instances, such and Enroth (2010) and Kozak (2003), the author modeled the ability to reuse the product). Some ICT devices were considered single-function, such as the e-readers modeled in Deetman and Odegard (2009), Moberg *et al.* (2010), and Kozak (2003). Other ICT devices, such as the PC (personal computer) modeled in Gard and Keoleian (2002) and Hischier and Reichart (2003) and the PDA (personal digital assistant) modeled by Toffel & Horvath (2004) were multifunctional. In order to specify multi-functionality, the studies relied on average data for consumer behaviour. For example, Hischier and Reichart (2003) used survey data from Switzerland to quantify average Internet-use time. Most of the studies oriented their functional unit around a product rather than a service. The exceptions were Hischier and Reichart's (2003) second and third scenarios, which modeled the service of being "well informed". However, they only considered one device, a home PC, as necessary to staying well-informed using ICT products, an assumption that may not reflect the reality of digital media consumption. Another consistent characteristic was the modeling of discrete functional units. The trade-off between one product and another was always absolute, viewing the paper and ICT products as substitutes, rather than potential complements.

Table 6: Summary of functional units of the comparative LCAs reviewed

Study	Functional Unit
Deetman & Odegard	One year of office paper use, using either an e-reader or a laser printer with paper
Enroth	The use of a teaching aid (either a textbook or a computer) over the course of five years by 5,000 students per year.
Gard & Keoleian	Reading a scientific journal article in a traditional or digital library system.
Hischier & Reichart	1. Reading of a 500-word article (either online or in a newspaper). 2. Staying "up-to-date" by watching either 25 minutes of TV, 10 minutes online or reading 43% of a newspaper. 3. Daily media consumption, either 110 minutes of TV, 74 minutes on the Internet or an entire newspaper.
Kozak	40 scholarly textbooks 500 pages in length, either purchased in physical form or downloaded to an e-reader.
Moberg *et al.* (2010)	The consumption of a newspaper during one year, either in physical form or on an e-reader.
Moberg *et al*. (2011)	One specific book bought and ready by one person, either as a 360 page hardcover novel or a 1.5 MB PDF file.
Toffel & Horvath	One year's worth of the New York Times, either delivered in Berkley California or wirelessly to a PDA.

The functional unit was not a source of much discussion or concern in the ICT LCAs. The authors did not attempt to allocate burdens between various activities, thus avoiding many of the challenges associated with functional unit definition. This approach avoids many of the challenges discussed above, such as how to appropriately model consumer behaviour. With the exception of Hischier & Reichart's (2004) attempt to model being "well informed", the LCAs reviewed picked a single product (be it a PC, a mobile phone or a component inside an ICT device) and designed their LCA accordingly.

4.6.2 Boundary Selection

Boundary selection determines which processes and activities are to be included in an LCA. The LCA scientist must balance the desire to produce objective, scientific and repeatable LCAs with the constraints of resources and time to carry out an LCA. Implicit in boundary selection is the definition of cut-off criteria, which involves deciding whether a particular flow of mass or energy should be included in the LCA. Commenting on cut-off criteria, Reap *et al.* (2008a, p.293) summarizing Suh *et al.* (2004) suggest:

1. "There is no theoretical or empirical basis that guarantees that a small mass or energy contribution will always result in negligible environmental impacts.
2. Some input flows bypass the product system and do not contribute mass or energy content to the product.
3. Environmental impacts by inputs from service sectors cannot be properly judged on the basis of mass and energy.
4. While the individual inputs and outputs cutoff may be insignificant, their total sum might change the results considerably."

Ideally, an LCA would establish system boundaries after reviewing existing data and determining that particular flows are not significant enough to merit inclusion. However, if the data exists to make this determination, it is not clear why the LCA should not include this data in the first place. This is what Reap *et al.* (2008a) consider a paradox in the conduct of an LCA.

Boundary selection can pose additional challenges. Input-Output (IO) analysis, where the burdens of a system are estimated by measuring energy and mass inputs and outputs and then allocating these estimates to a unit of product, has become a popular method of defining system boundaries in LCAs. Reap *et al.* (2008a, p.294) referencing Lenzen (2000) found that this method can be problematic when studying the estimated fossil fuel consumption associated with commodities extraction. Using the IO method, an error range of 9% to 100% was identified when comparing the results of an IO method with

estimates derived using field measurements. It is safe to assume that similar problems would be found when comparing IO estimates with activities besides commodities extraction.

The comparative LCAs reviewed were screening LCAs, designed to use readily available data to identify the most important stages and processes in the lifecycle of a system or product. Few measured data were used, with a reliance on secondary sources, proxy data, average data and life cycle inventory (LCI) databases. This impacted the definition of system boundaries, as authors could be broad and inclusive since little data was actually being measured. The only author to explicitly consider cut-off criteria was Kozak (2003). He chose to not model the impact of any material that constituted less than 1% of the mass of the functional unit. All of the LCAs refrained from modeling "content creation" as this was assumed to be a variable common to both paper-based and digital media systems.

In the comparative LCAs, defining boundaries in the ICT sector was a particular challenge due to limited data availability. Only Deetman and Odegard (2009) and Moberg *et al.* (2010) had access to actual data on the ICT product being considered. However, these data were considered confidential and were not disclosed. Kozak (2003) and Toffel and Horvath (2004) demonstrated just how acute the challenge of ICT data can be when broad boundaries are set. They were forced to use equivalency ratios from LCAs for entirely different products to describe the functional unit being used. They found an existing LCA, took the impact to mass ratio for a particular product and applied this ratio to an entirely different product. The actual energy and materials embodied in the ICT device was understood only by proxy. None of the studies explicitly modeled the abiotic resource depletion associated with ICT products. Given the presence of hundreds of different metals, rare earth minerals and chemicals (Lau *et al.*, 2002) in an ICT device, there was a potential for "significant insignificants" (a concept used by Reap *et al.* (2008a, p.299) to describe the potential environmental impacts of small flows of energy or mass) in all of the comparative LCAs.

Other challenges in boundary selection occurred in the use stage. For a paper product, the inclusion of personal transportation to a retail outlet had a potentially significant, but highly variable, influence over study findings (Kozak, 2003; Moberg *et al*., 2010). For ICT products, boundary selection was complicated by efforts to model the Internet backbone (cables, routers, switches, and data centers) that delivers digital media. Some studies (Deetman and Odegard, 2009) refrained from attributing any impacts to the Internet. Gard and Keolian (2002) recognized that that digital media utilized the Internet, but file sizes

are tiny relative to overall volume handled and, consequently, they did not include the Internet in their LCA. Both Moberg *et al*. (2010) and Enroth (2010) attempted to model the energy and material requirements of the Internet. However, they expressed these figures with hesitation, citing their reliance on Economic Input-Output (EIO) data that are dated and may not accurately reflect the potential impacts of Internet infrastructure.

Modeling the downstream impacts of the products considered was another challenge. The end-of-life (EOL) management of both paper products and ICT was modeled in several ways. Some studies, like Toffel and Horvath (2004), did not model EOL at all. Others, like Kozak (2003), assumed that paper products would not be recycled, but instead be held in perpetuity, while ICT products would be disposed of in a local landfill. Several studies (Deetman and Odegard, 2009; Hischier and Reichart, 2003; Moberg *et al.*, 2010) assumed that ICT EOL would occur within the regulatory confines of the European Waste Electrical and Electronic Equipment (WEEE) Directive and the modeled EOL impacts are representative only of waste-handling in Europe under ideal conditions. Hischier and Reichart (2003) assume that 95% of the ICT equipment is recycled or incinerated, with the rest going to a landfill. The others assume 100% recovery of ICT equipment for either recycling or incineration.

The ICT LCAs reviewed had similar challenges with boundary selection. The complexity of ICT required system boundaries to be broad and inclusive. As with the comparative LCAs, the raw material requirements of the ICT product were often not modeled due to a lack of available data (Choi *et al.*, 2006; Frey, 2006). While aggregate volumes of a particular element, such as copper, were available, the supply chain and footprint of each particular element were never actually modeled. Choi *et al*. (2006) demonstrated how an ICT LCA includes a complex network of pre-manufacturing activities. However, they were only able to model the basic raw material requirements of these activities. Any impacts associated with processing these materials were unaccounted for. Further, Choi *et al*. (2006) suggested that several components in the pre-manufacturing stage were not modeled due to a lack of data. But they also found that the pre-manufacturing stage was the source of the majority of the environmental impacts in the manufacture of a desktop computer.

4.6.3 Allocation

Allocation is the "procedure of appropriately allocating the environmental burdens of a multi-functional process" (Reap *et al.*, 2008a, p. 296.) The question of how to apportion the burdens of multi-functional

processes to single products or functions is considered one of the classical methodological problems in LCA science (Rusell, 2005). Examples of multifunctional processes include landfills and oil refineries: facilities that are connected to many kinds of products and functional units. Many solutions to the allocation problem have been suggested. These include: sub-dividing a process into sub-processes to create more explicit connections; allocating based off of physical relationships in cases where subdivision is not possible; allocating based off of non-physical relationships if physical relationships cannot be proven; and expanding the product system under consideration in order to avoid allocation problems altogether (Reap *et al*., 2008a, 2008b). Each solution, however, creates its own set of problems. Subdivision may not produce sub-processes that actually relate to the function unit. Expanding the product system is difficult as it imposes additional data requirements on the life cycle inventory (LCI). Non-physical relationships, such as energy, mass, volumes and economic value, are often used to assist in allocation procedures. Reap *et al*., (2008a, p.298) suggest that these relationships, "have generally been discredited for lack of justification [and] despite these warnings from the LCA community, non-causal relationships seem to be the predominant allocation method used in LCI practice."

The problem of allocation procedures was given some attention in the comparative LCAs that I reviewed. The consumption of digital media requires many processes that are multi-functional. Computers, with some exceptions like e-readers, are multi-functional. The infrastructure that delivers digital media is also multifunctional. The supply chains that manufacture computers, from mines to petrochemical facilities to component factories, are all multi-functional processes. Toffel and Horvath (2004) used energy consumption of the communications equipment sector to determine the environmental impact of manufacturing a mobile phone, an example of using a non-physical relationship. In the other comparative LCAs, allocation procedures were only discussed with regards to paper media, not digital.

In the ICT LCAs reviewed, only two discussed the problem of allocation. Choi *et al.* (2006, p.125) suggest that a "skillful recycling expert" was needed to allocate various waste flows associated with a PC. Allocation procedures were required to model the packaging of a PC, the construction of the steel frame that houses a PC and the assembly of a PC. All of these allocations were made using volume and weight, relationships identified by Reap *et al.* (2009a) as problematic. Durucan *et al.* (2006) reviewed the conduct of LCAs in the mining industry, which supplies many of the raw materials present in digital

products. They found that, with regards to aluminum and steel, "very little or no emphasis has been placed on the extraction of the mineral ore and the consequent waste handling aspects of the industry in relation to the allocation of environmental burdens." (Durucan *et al*., 2006 p.1058)

4.6.4 Spatial Variation and Environmental Uniqueness

Impacts generated over a product's life cycle can have effects at the local, regional, or global level. Site-generic LCAs lack spatial information and assume globally homogenous effects, which can embed inaccuracies in LCA results. Environmental impacts like acidification and eutrophication, for example, can vary by a magnitude of three due to local meteorological variations (Huijbreghts *et al*., 2001; Potting *et al*., 1998). Hellweg (2001) suggests that geological conditions and geographic location can impact groundwater contamination from landfills by four orders of magnitude. Land use is also highly dependent on spatial variation. Infrastructure that supports a product's life cycle can occupy land of varying ecological productivity and can indirectly change local meteorological and hydrological patterns (through, for example, changing run-off patterns of precipitation). As stated by Canals *et al.* (2006), "land use impacts are highly dependent on the conditions where they occur." Reap *et al.* (2008b, p.378) summarizes: "Each environment affected by resource extraction or pollution is, to a greater or lesser extent, unique. As a result, each local environment is uniquely sensitive to the stresses placed upon it by a particular product system's life cycle."

Issues of spatial variation and local environmental uniqueness were given little attention in the comparative LCAs reviewed. It should be remembered that these were screening LCAs that relied on available data. Given the complexity of the systems under consideration, describing a system with sufficient precision to account for spatial variance would be resource-intensive, if not impossible. However, certain modules in the comparative LCAs reviewed were more geographically precise. Kozak (2003) and Gard and Keoleian (2002), for example, modeled specific activities at the University of Michigan. They used the power bundle for the region, mapped out the network infrastructure for the campus and assumed personal transportation that reflected averages for local geography. Hischier and Reichart (2003) modeled several components at the regional level, using data for Swiss media consumption, energy consumption, and recycling rates. For other variables, however, they relied on global data sets, reflecting the nature of ICT supply chains. These screening LCAs, combined with the complexity of ICT supply chains and the lack of high-quality data on ICT products, resulted in major variation in spatial scale inside each individual comparative LCA. While some parts of the LCAs were able

to reflect local variation (electricity bundles being the most common example), similar precision was not possible for other variables. None of the comparative LCAs reviewed discussed whether this mixture of local, regional, and global scales had the potential to impact study findings. By the same token, the characteristics of screening comparative LCAs (estimated data, global scale, broadly defined system boundaries) preclude them from including local environmental issues. And again, the authors did not discuss the potential impacts on study findings.

Issues of spatial variation and local environmental uniqueness followed similar trends in ICT LCAs as those found in comparative LCAs. The complex global supply chains of ICT products required authors to rely on LCI databases that often consisted of national-level statistics. The ICT industry relies on original equipment manufacturers (OEMs) that are highly specialized and provide almost all of the components inside a device; tracing and measuring the impacts of all of these suppliers would be extremely resource-intensive. This is not to suggest that spatial variation and local environmental uniqueness do not matter in ICT. Rather, they are just attributes that are very difficult to measure.

One particular area where ICT LCAs relied upon global averages was in modeling the raw materials present in a device. Durucan *et al.* (2006) examined why assuming consistent environmental impacts between commodity supplies is problematic. They found that most of the data available in mining LCAs pay very little attention to modeling the extraction of mineral ore or the waste handling processes at a specific site. They considered available LCA data on mining to be a "largely simplified … single fact sheet." (p.1058) Given these uncertainties, and the connection of the mining sector with the pre-manufacturing stage of an LCA device, confidence in ICT LCAs should be adjusted accordingly. The raw material figures used are a reflection of averages that Durucan *et al*. (2006) suggest do not necessarily reflect actual environmental impacts.

4.6.5 Data Availability and Quality

Problems revolving around data availability and quality are numerous. According to Björklund (2002), there are five challenges related to data quality: badly measured data; data gaps; unrepresentative (proxy) data; model uncertainty; and uncertainty about methodological choices. Further, both data and models can fail to accurately represent the temporal and spatial scope defined in an LCA. Some data is virtually unobservable, in instances of product recovery or end-of-life management. Data can be sourced from a standardized LCA database, but these data sets may not be peer-reviewed and finding the

original data sources can be a challenge (Björklund, 2002). Data measuring the same variable, but from different sources can arrive at conflicting conclusions. Reap *et al.* (2008b, p.383) suggests that, "in general, the literature tends to agree that data for life cycle inventories is not widely available nor of high quality." Data can be outdated, compiled at different times, and correspond to different materials produced over different time periods.

The opportunities for low-quality data to enter an LCA are, therefore, abundant. And although one instance of low-quality data might not have a significant impact on LCA results, many compounded instances of suspect data can potentially diminish confidence in LCA findings. As Bare *et al.* (1999, p.301) suggest, it is hard to know "where to draw the line between sound science and modeling assumptions." The comparative LCAs reviewed had significant issues with data quality and availability. Two factors contribute to this: the broad system boundaries defined and the particular challenge of modeling ICT products. All of the studies relied on LCI databases. Moberg *et al.* (2010), Deetman and Odegard (2009) and Hischier and Reichart (2003) used the Ecoinvent LCI database. Toffel and Horvath (2004) relied on data from other LCAs, using equivalency ratios and the Carnegie-Mellon EIO-LCA database, a source specifically identified by Reap *et al.* (2008a, p.294) as problematic. Kozak (2003) and Gard and Keoleian (2003) relied on the Ecobilan DEAM database for several modules in their LCA. In two instances, Kozak (2003) and Toffel and Horvath (2004) relied on proxy data. More problematic is how proxy data were used to model several parts of a product, compounding whatever errors the use of proxy data might introduce. Given resource and time constraints, as well as the scale and diversity of the product systems being compared, it is not surprising that issues of data quality and availability were prominent. However, most authors did not comment on these issues, and those who did (Kozak, 2003; Toffel and Horvath, 2004) expressed a generally high degree of confidence in their data.

Data availability was addressed as a serious challenge in all of the ICT LCAs I reviewed. Frey *et al.* (2006) and Scharnhorst (2006) cited a paucity of data in trying to measure the environmental footprint of a mobile phone. Lu *et al.* (2006), when measuring a notebook computer in Taiwan, had to rely on a consulting report from 1998 (Atlantic, 1998) that used voluntary survey data from private companies that described manufacturing processes from the mid-1990s. In modeling the footprint of a desktop PC, Choi *et al.* (2006) relied on 66 different databases, either private databases from the Simapro© software package or Korean national databases. All of these studies focused on a finished product, not a component. Their reliance on LCI databases that are private, outdated, or populated by estimated data

is a source of concern. However, the authors were faced with few alternatives given the scope of the ICT supply chain. Studies that focused on more specific components in the ICT supply chain (Liu *et al.*, 2010; Plepys, 2004; Williams *et al.*, 2002) were able to use more site-specific data, which had higher resolution and could be directly attributed to the products of the systems under review.

4.7 DISCUSSION

I reviewed a number of LCAs that compared paper and digital media using an analytical framework developed by Reap *et al.* (2008a, 200b). The findings of these LCAs were variable and relied on several assumptions to cope with uncertainties. By also reviewing ICT LCAs, I found that these uncertainties were not necessarily the result of poorly implemented LCAs. Instead, the stark difference between paper and digital products weakened the LCA as a tool of comparison. Further, using the LCA to study digital products forced LCA practitioners to deal with the particular complexities of the ICT sector. These results support my initial hypotheses: that the differences between the product systems that produce paper and digital media weaken LCA's ability to accurately compare environmental footprints and that the characteristics of ICT as an industrial sector weaken LCA as an environmental assessment methodology. Moberg *et al.* (2011, p.245), after comparing the footprint of a hardcover book, and an e-book suggested that there is "the need for more studies on a macro level in order to assess the magnitude of the environmental impacts of changing media practices."

I organize the discussion here in three parts. I examine the unavoidable uncertainties in comparative LCAs, the assumptions that result, and the role the ICT sector plays in weakening the conduct of LCAs. The structure of this discussion reflects a concept present in all LCA work –uncertainties exist and assumptions are required.

4.7.1 Uncertainties in Comparative LCAs

The main source of uncertainty in all of the LCAs reviewed surrounded the data for products and processes in the ICT sector. Data on raw material inputs requirements for ICT devices was based on estimates or relied on aggregated sources. The connections between a manufactured product, such as a semiconductor, and the global mining sector were not explicitly discussed. Authors relied on assumptions and allocations made by LCI databases, which may not necessarily capture the complexity of the ICT sector. ICT devices have hundreds of metals and minerals, and their manufacture requires extremely pure inputs. These databases sometimes relied on economic input-output (EIO) methods,

where industry-wide inputs and outputs are used to determine environmental impacts. Where primary data was available, it was often the average footprint for an element (*e.g.* silicon) that may not reflect the grade of element used in the ICT manufacturing process.

Similar uncertainty surrounded efforts to measure the Internet backbone. Only Moberg *at al.* (2010) and Enroth (2010), who simply borrowed Moberg *et al.*'s (2010) findings, attempted to model the footprint of the Internet. They both used a figure that was derived using EIO methods from the USA SimaPro Input Output database. These figures are from 1998 and, as Moberg *et al.* (2009, p.42) stated, "the results concerning potential impact of using telecommunication infrastructure are too uncertain to draw any real conclusions from." The Internet has evolved at a breakneck pace, with infrastructure like routers, switches and data centers constantly being updated. This infrastructure has increased in energy efficiency, but may be characterized by the rebound effect, where a particular activity becomes more efficient, but the scale of use increases at such a rate that the overall impact increases (Williams *et al.*, 2002). In the comparative LCAs reviewed, the exclusion of the Internet in some studies was justified because of the sheer volume of data contrasted with the miniscule size of the functional unit under consideration. This is a legitimate claim from the technical standpoint of conducting an LCA. However, it does pose a risk, as cut-off criteria might eliminate a key variable – the Internet – that could alter study findings. If the impacts of Internet infrastructure are not included in LCAs of digital media consumption, it is worth asking *where* exactly they should be considered.

Another source of uncertainty associated with ICT data comes from end-of-life (EOL) management. E-waste, which is waste made up of discarded, obsolete, or broken electronic devices, is a significant global issue (Grossman, 2006), but the seriousness of this issue is not evident in the decisions made by the comparative LCA authors. Robinson (2009) found that globally, 20 to 25 million tonnes of e-waste are generated every year. Most of this comes from Europe, the United States, and Australasia, but developing countries will become major contributors as their economies grow. The changing nature of e-waste could potentially mitigate this problem, as device miniaturisation shrinks the overall flow of waste (Robinson 2009, p.186). But globally the majority of E-waste is still disposed of in a landfill, rather than properly processed in a modern facility.

Many of the comparative LCAs were conducted in Europe, which has a strong regulatory framework for managing e-waste. The WEEE Directive (European Commission, 2012, Hischier *et al.*, 2005.) forces

suppliers to recover and properly process e-waste, and compliance is high. In contrast, only 18% of e-waste in the United States is processed domestically (EPA, 2008). Kozak (2003), however, assumed that all e-waste is disposed of in a local landfill. Toffel & Horvath (2004) did not attempt to model EOL. Another reason why EOL was given little attention is that most of the studies (Hischier and Reichart (2003), Kozak (2003), and Moberg *et al.* (2010) being the exceptions) only focus on issues of energy use and global warming potential (GWP). Duan *et al.* (2008) when conducting sensitivity analyses around EOL impacts found that modern technical systems are assumed, the environmental impact of this lifecycle stage are reduced. E-waste can be a highly toxic and localized environmental issue, with a small energy footprint but a large environmental footprint. The LCA, as a tool of environmental assessment, falls short when attempting to model highly localized environmental issues, an issue discussed extensively by Reap *et al.* (2008a, 2008b). This focus on GWP is unsurprising, given the prevalence of climate change as an environmental concern. However, these studies should not inspire confidence in understanding the range of potential environmental impacts associated with media consumption. On issues such as toxicity, abiotic resource depletion, and land use impacts, to name a few, there remains a high degree of uncertainty.

There are also uncertainties about the social impacts of paper and digital media consumption. The effects on human health, for example, from manufacturing ICT products have been found to be toxic and at times carcinogenic. Processing e-waste is another social hazard associated with ICT, as e-waste is often exported and processed by underage workers in jurisdictions with weak environmental controls. I mention this only in passing, as the focus of the review is the environmental, not social, implications of media consumption. However, investigating the social impacts of ICT as a macro level is an important subject and warrants further research.

4.7.2 Assumptions in Comparative LCAs

The studies reviewed here should not be faulted for having to estimate several variables in the life cycle of ICT products. However, there is a danger that the LCAs are driven more by assumptions made than by actual data collected, and that study results are presented in such a way as to minimize the potential uncertainties in the analyses.

As has been mentioned, almost all of the studies (Hischier and Reichart (2003) being the exception) assumed a functional unit that is a product, not a service. It should be asked whether these discrete

product-based functional unites are reflective of consumer behaviour. Deetman and Odegard (2009) modeled an office worker switching from printing 10,000 pages a year to using nothing but an e-reader. Kozak (2003) modeled 40 textbooks, either in print or on an e-reader. Moberg *et al.* (2010) did the same for newspapers, as did Toffel and Horvath (2004). In short, there was a pattern of perfect substitution. Paper and ICT products were seen as alternatives, not complements. There is a recognizable advantage for the modeler in choosing such a trade-off, but it is unclear if this is reflective of actual consumer behaviour.

Hischier and Reichart (2004) bucked this trend and attempted to model the environmental impacts of being "well informed". They made assumptions that are worth looking at closely. For paper products, they assumed that only one daily newspaper is read. An alternate and perhaps more accurate scenario might look at the overall print media consumption, modeling a bundle of newspapers, books, and magazines in order to measure environmental impact. The same bundling approach would also provide a richer analysis of the impacts of ICT products. To stay well informed, many consumers use a computer at home, another computer at work, a mobile device, and a tablet computer. Measuring the aggregate impact of these ICT products would provide a better understanding of staying informed with ICT products. Defining how consumers are digesting digital media would be an important but challenging baseline to establish, but there are data available that might help serve that purpose (see, for example, Bohn and Short (2009)).

Comparing the findings of Enroth (2010) and Kozak (2003) further demonstrates the influence that assumptions exert on LCA findings. Both modeled the use of a textbook, although Enroth's (2010) textbooks are for school children, while Kozak (2003) considered a university environment. Enroth (2010) found that the global warming potential (GWP) of an electronic textbook is 10 to 30 the GWP of a printed textbook. Kozak (2003) did not express the difference in GWP, but he did state that the lifetime energy use of an e-reader system is more efficient by a factor of approximately five (742 MJ (megajoules) for the e-reader, 3,794 MJ for the textbooks). Explaining the difference between the two shows how far assumptions can go in driving study results. Enroth (2010) assumed that five different students use a textbook over a period of five years. The study did not include the energy necessary to transport students to and from school in the footprint of the textbook. Kozak (2003), in contrast, assumed that a student purchases a textbook and retains it for life. Further, the study modeled the energy necessary to transport the student to a bookstore to purchase the textbook. This personal

transportation constituted almost a third of the energy used in the lifetime of a textbook. When Kozak (2003) assumed the textbook could be resold, and did not include the energy of a trip to the bookstore in the footprint of the textbook, it only took three different students using the same textbook for the energy footprint of the printed product to match that of the ICT product.

4.7.3 The Drivers of Uncertainty and Assumptions: The Context of Moore's Law

The assumptions in the comparative LCAs reviewed were the result of stark differences between the products being compared – paper and digital media. The uncertainties, however, originated in the ICT sector and its unique complexity. The ICT sector is defined by an inexorable pace of innovation. This process was first expressed by Ronald D. Moore, founder of Intel©, who suggested that transistor density on a circuit board would double every 24 months and that the cost of a producing a transistor would halve over the same period. For over forty years, Moore's prediction has held true, and is now referred to as Moore's Law. This reliable rate of advancement has given investors the confidence needed to support a massive research and development budget in ICT (Jorgenson and Wessner, 2004). The outputs of this steady cycle innovation disrupt existing industries and the resulting profits justify continued investment.

Moore's Law has implications. The rate of innovation ensures that technologies and their associated manufacturing infrastructure quickly become obsolete. The nature of ICT innovation – higher density circuits that are always shrinking in size – creates specific environmental challenges. Plepys (2004) studied the environmental impacts of semiconductor manufacturing. Semiconductors are the backbone of ICT and their environmental impact is of central importance to any assessment of ICT products. Semiconductor manufacturing has rapidly evolved, and the increasing sophistication of ICT products relies on component miniaturization and increasingly complex integrated circuits. Put simply, the ability for a smartphone today to out-compute a desktop computer just ten years old is due to advances in semiconductor manufacturing (Rupp and Selberherr, 2011). These advances have translated into sophisticated manufacturing processes. At the time of writing, Plepys (2004) found that over 200 process steps are required in the production of a semiconductor. Today, that number is likely higher. These steps involve metal disposition, rinsing, and etching the semiconductor with a variety of chemicals. Purity of the chemicals employed is of central importance. Impurities can be tolerated only at a level of parts-per-billion (Pelpys, 2004). Plepys (2004, p.159) found that "increasing material purity requirements may contribute to shifting the centre of manufacturing-related environmental impacts

from circuit fabrication to raw material production stages." He found that existing LCAs did not actually model the environmental impacts of these chemicals, but instead used LCI data for bulk-chemicals several grades lower than the purities required for semiconductor manufacturing. He concluded, "for this reason a potentially large part of upstream energy consumption remains unaccounted." (p.160)

There are hundreds of components inside any device, with hundreds and perhaps thousands of contractors and sub-contractors responsible for different aspects of an ICT product (Adexa, 2000). This creates a logistical challenge for simply manufacturing an ICT product. It presents perhaps an insurmountable challenge for producing a rigorous LCA of an ICT product. It also implies that part of the footprint of an ICT product is spread out over many private entities, over which a final manufacturer has no significant control or oversight. Recent struggles by Apple© (Fair Labor Association, 2012) in managing the environmental and human hazards at their suppliers facilities' in China highlight this concern. If a company with the resources of Apple© has difficulties managing their supply chain, it is reasonable to assume other companies experience similar challenges. The pace of innovation and the potential profits associated with a new product also incentivizes a degree of secrecy in ICT companies (Williams *et al.*, 2002).

Moore's Law has driven down the price of computers to the extent that two billion people currently access the Internet (Miniwatts, 2012). New ways of accessing the Internet and using ICT devices continue to emerge, as tablet computers and smart phones complement existing desktop and laptop computers. Part of every digital footprint exists in the "cloud", a series of data centers worldwide that offer computing services to consumers and corporations. The energy profiles of devices themselves are changing. Small devices use less power, shifting the impacts of their footprint from their operation to their construction and running of the cloud to which they connect (Singhal, 2005). The constant stream of new devices means old devices are always being replaced, creating a large flow of e-waste. Some suggest that 3% of the global pool of electronic components become obsolete each month (Sandborn, 2008). This pattern of obsolescence requires complex and often wasteful logistical planning for managers of electronic systems that have long lifespans. Because electronic components are only produced for a relatively short period of time, systems with lifespans greater than three years must buy excess components to hedge against future failures in 10 or 15 years. While some of the challenges posed by Moore's law are only indirectly related to the consumption of digital media, taken as a whole, these challenges explain why the LCA methodology fails to adequately model the ICT sector.

Moore's Law and the rapid pace of innovation, adoption, obsolescence and consumption in the ICT sector presents a challenge when producing meta-analyses of LCAs. The time range of the LCAs reviewed spans from 2003 to 2010. Over that time, the ICT sector evolved. LCAs produced in 2003 were written when smartphones like the iPhone had not even been conceived of (the first iPhone was released in 2007). Tablet computers did exist, but they were completely unlike modern products like the Apple iPad, which was released in 2010 or the Amazon Kindle, released in 2007. When looking at comparative LCAs that span over a decade, the quality of the data and the nature of the products being described have changed. Over ten years, ICT products have evolved. Entire new form factors – like the tablet computer and smart phone – have emerged, while others – like the CRT (cathode ray tube) monitor and desktop monitor – have lost previous dominance. At the same time, the LCA methodology has evolved. The LCA achieved ISO standardization in 2006, and several methodological problems are still being addressed (Finnveden *et al.*, 2009). This reality makes it difficult to compare LCAs from different time periods. Unfortunately, such comparisons are unavoidable given the limited supply of LCAs that compare paper and digital media consumption.

While the ICT sector evolved, the background data that fed into the LCAs I reviewed evolved as well. The earliest studies, Hischier and Reichart (2003), Kozak (2003), and Toffel and Horvath (2004) used multiple data sources in order to construct their LCI databases, as the existing commercially available LCI databases could not support the desired LCA. As time progressed, standardized LCI databases improved. Products like Ecoinvent and SimaPro (both LCI databases) have increased in sophistication, adding data on specific electronic components that was not available in early iterations. This suggests that over time the underlying LCI databases improved, but whether these improvements have kept pace with the innovation cycle of ICT is not clear.

4.8 CONCLUSIONS

To model, conduct, and assess an LCA in an objective and repeatable way is a challenge in and of itself. To produce an LCA using a functional unit that divides a product between multiple uses introduces a host of challenges when allocating environmental burdens. An LCA that attempts to compare two completely different products introduces a whole set of other uncertainties and assumptions. To produce an LCA for a product in the ICT sector means grappling with one of the most complex and globalized industrial sectors. A comparative LCA of paper and digital media is a culmination of these challenges.

I have seen that, in the cases reviewed, that the LCA has drawbacks in modeling ICT. At several stages in the supply chain, but most acutely in the raw material acquisition stage, pre-manufacturing, and Internet backbone stages, the LCAs reviewed used coarse, estimated, and outdated data to measure ICT products. Research has suggested (Plepys, 2004) that significant environmental impacts are simply unaccounted for. It is also likely that ICT data poorly represents the raw material requirements of a product, especially in light of the number of raw materials present and the potential variation in raw material supply chains. Given the potential for site-level variation in the extractive industry sector, this unexplored relationship of ICT's connection with nonrenewable raw materials is problematic. At some point or another, almost all of the studies I reviewed relied on proxy data, estimating the impact of a component or product by manipulating data available for something similar. What is unclear and, in my view, a pressing concern is the compounding effects of all of the estimates, guesses, cutoff criteria, and low-resolution data that characterize lifecycle explorations of ICT.

It is clear that the scope for variation between LCA findings, and inside an individual LCA is large. What is less clear is where this variation is borne: in a lack of precise data; in the nature of ICT supply chains; in the challenge of modeling consumer behaviour; in modeling a multifunctional product; or in attempts to compare. All of these variables should be considered closely when reading the existing literature on paper and digital media. These comparisons rely on averages out of necessity, not neglect. Indeed, it is not whether study findings are a reflection of available data, but whether available data are of sufficient quality to inspire confidence in the study findings. But given the scope for variation inside comparative LCAs, I am forced to ask, are there alternative means of understanding the footprint of media consumption besides the LCA? And should the LCA alone inform what I consider to be "better"?

Looking forward, an important trend is that ICT devices are getting smaller and more-energy efficient. This means that the environmental profile of an ICT device is shifting. More and more of the impacts are found upstream in raw material extraction and production, or downstream in the EOL stage, precisely where LCAs are weakest. And during the use stage, more impacts will come from accessing the Internet. The footprint of cloud computing, and the Internet backbone more generally, is poorly understood. In short, the environmental burden of digital media is shifting towards areas that are least understood. Gordon Moore, interviewed in 2005 was unintentionally prophetic in a discussion about his eponymous law, saying, "It can't continue forever. The nature of exponentials is that you push them out and eventually disaster happens." (Dubash, 2005, n.p.) While he was discussing the technical feasibility of

the perpetual doubling of transistor density, his comments might also apply to the similarly relentless pace of new gadgets and methods for consuming media.

Chapter 5: Discussion and Conclusions

5.1 Conclusions

It has been said a few times already, but it bears repeating: the consumption of the written word is changing. New technologies, business models, and evolving consumer preferences are driving a shift from paper to digital media. But this shift is uneven and complex. By no means are all forms of paper being replaced – hygienic uses are likely to endure for a long time indeed – but for some product categories, like newspapers, books, and magazines, digital media has represented an existential threat to paper alternatives. I call this "the media shift".

Meanwhile, society is finally waking up to the environmental challenges that we face. Concepts like climate change, ecological carrying capacity, and environmental footprint have gained traction. The impact of human industry and consumption on the planet is being felt. Some have suggested that we are entering the age of the Anthropocene, where the most influential force on the planet is *homo sapiens* (Zalasiewicz *et al.,* 2010). In response, the concept of sustainability has emerged. The general idea is that, as society progresses, we should do better, or at least less bad. This has manifested across the social spectrum, from corporations to consumers to governments. An array of drivers and responses to sustainability has started changing how we organize human civilization. I call this, "the sustainability shift."

It is no surprise, then, that the sustainability shift has intersected its media counterpart. The impact of consuming the written word should be taken into account and, wherever possible, reduced. But do we know for certain that the media shift is sustainable? Have we adequately measured and verified the relative footprints of paper and digital media?

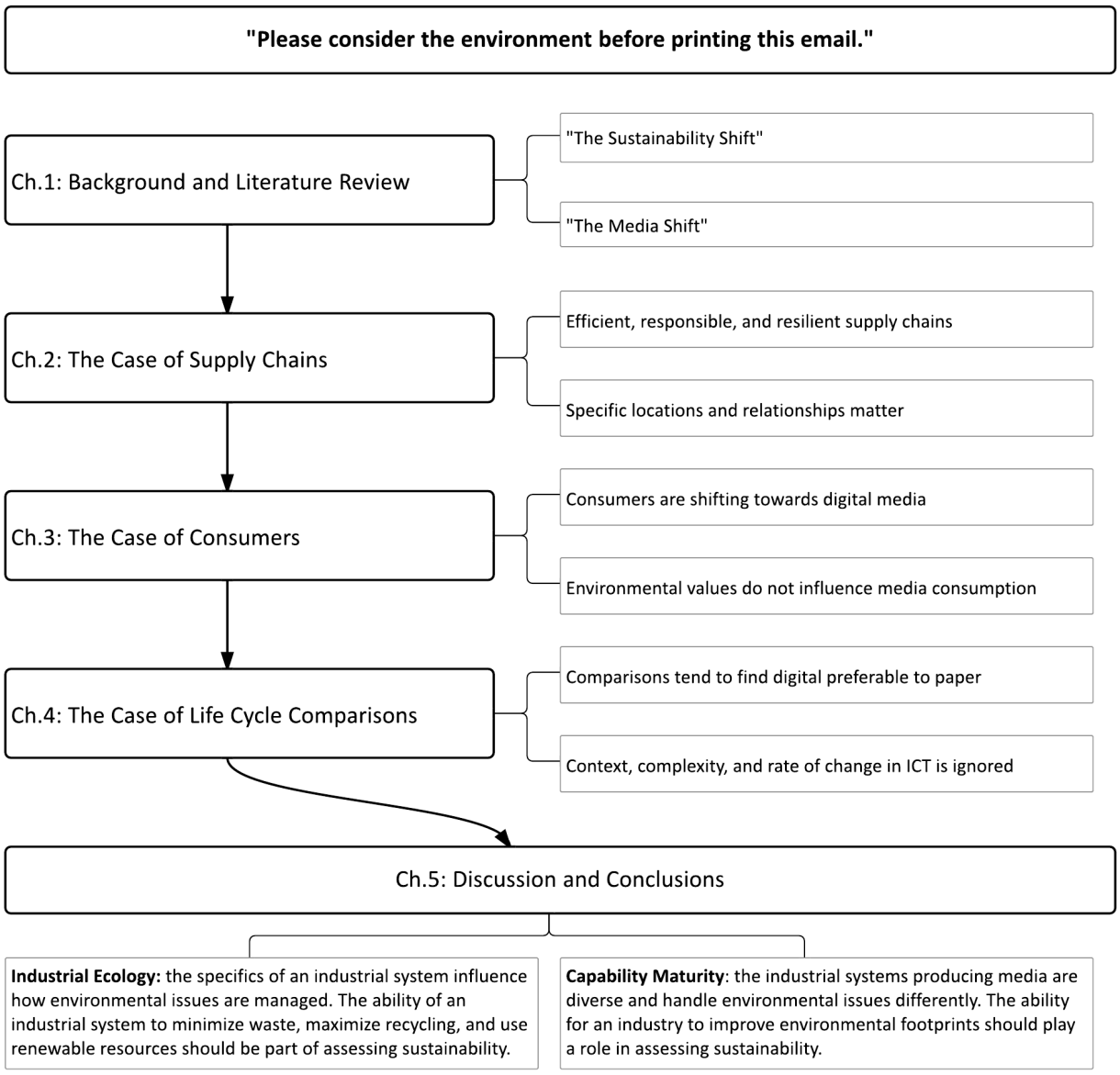
This thesis was motivated by the phrase "please consider the environment before printing this email." But instead of deciding in the moment on whether to hit the print button, I took a deeper approach. What does it mean to consider the environment? And why is it the printing of an email, rather than its transmission, that is worthy of consideration? Clearly something is afoot. Other choices that involve paper versus digital media have experienced similar characterizations. For example, the idea that a printed magazine is the "dead tree edition" of a digital equivalent is particularly prevalent.

By exploring how digital media came to be seen as preferable to paper alternatives, this thesis seeks to add to my understanding of sustainability. Many foresters care about the environment, perhaps more than most. The idea that forest products are environmentally inferior to digital alternatives might lead some foresters to take umbrage. Although this thesis is not a counseling exercise for offended foresters, it is an earnest attempt to pause and consider the actual environmental impacts of media consumption.

Our consideration of the environment had three phases: I began by examining a paper media supply chain in the forest products industry. Following this, I reviewed the media consumption habits and environmental values of consumers. I concluded with an analysis of academic efforts to compare paper and digital media. This final chapter weaves these investigations together, connecting them to the research objectives, offering ideas for potential applications and further research, and identifying the strengths and limitations of my research. I discuss two concepts – industrial ecology and capability maturity – that offer insights into the comparison of paper and digital media, and deepen an understanding of sustainability.

Earlier in the thesis, I presented a flow chart identifying the key research objectives and questions. In Figure 26, I present a modified version of this chart, identifying the key conclusions of each research chapter and how these ideas contributed to the two concepts – industrial ecology and capability maturity – that I discuss in this chapter.

Figure 26: Summary of research chapters and conclusions



5.1.1 Sustainability Perspective: Media Supply Chains

Our first research question was, "how does sustainability operate along a paper media supply chain?" I found that the supply chain is critical in managing environmental footprints. Every supply chain is slightly different. The specific actors, their location, their management practices, and the extent to which they collaborate are all important in efforts to manage and reduce environmental footprints. I found that, for example, the location of Catalyst Paper in British Columbia allowed paper to be manufactured with clean energy, in this instance, hydroelectric power. I also found that the transportation networks in British Columbia helped reduce the footprint of Catalyst's product. In particular, the easy access to sea-

based shipping and rail networks helped reduce the amount of inefficient transportation by truck. I also found that Catalyst, by locating its mills in areas of relative water abundance, was able to strike the right balance between energy and water use in the paper making process. All of these factors together helped improve the footprint of Catalyst's product.

But another trend was at play too: Catalyst was trying to produce a paper product with the smallest carbon footprint possible. And without collaborating with its supply chain, it would never have been able to do so. Catalyst's own staff worked closely with key suppliers – including Western Forest Products, Washington Marine Group, and Burlington Northern Santa Fe Railways – to optimize the energy used in producing and delivering its product. This collaboration on environmental issues underscores a key driver of sustainability: when "win-win" solutions are available, businesses will work together in order to improve environmental performance. In this instance, win-win solutions were found when carbon emissions reductions were sought. Carbon is, for all intents and purposes, analogous with energy, and using energy costs money. By collaborating together, the Catalyst supply chain was able to reduce emissions and costs.

Reducing emissions together was just the first step in supply chain collaboration I observed. By being more efficient, I found that supply chain actors began a process of becoming more responsible. Washington Marine Group, for example, cites Catalyst's request for information on carbon emissions as a key driver in evaluating energy use across its entire fleet. But the move from efficiency to responsibility was only the first step. The interviews with supply chain actors revealed that, through close collaboration, the supply chain was actually becoming more resilient. When I spoke to executives and managers, it was late 2008 and early 2009. The financial crisis was in full force, and almost all corporate actors were concerned for their own well being. Despite this existential threat, they suggested that cooperating together to reduce carbon emissions had actually strengthened relationships along their supply chains.

Our findings, to a large extent, validate the existing literature on how corporations respond to sustainability. In my review of "the sustainability shift", I discussed a variety of different approaches a firm can take to manage for environmental variables, using a framework developed by Auld *et al.* (2008a), who identified seven categories that capture corporate responses to sustainability: individual firm efforts; individual firm and NGO agreements; public-private partnerships; information-based

approaches; environmental management systems (EMSs); industry association codes of conduct; and non-state market-driven (NSMD) governance in the form of private-sector hard laws.

Of these seven categories, my case study validated at least four concepts. I saw evidence of individual firm efforts to promote environmental responsibility, as Catalyst did when it decided to purchase carbon offsets to reduce the footprint of its operations. I also saw firms working with ENGOS, in this instance Washington Marine Group and WWF Canada, an approach identified by Auld *et al.* (2008a) and Yaziji and Doh (2009) that I observed in practice. I observed information-based approaches in action, as supply chain partners exchanged information about environmental footprints and operational logistics in order to manage and reduce impacts. Finally, I saw EMSs deployed to help measure and gather all the relevant data needed to take meaningful action.

This case study was a targeted investigation into one supply chain on the west coast of North America. But it revealed a few important things about sustainability and media that are worth noting:

- Not all media is created equally: location and collaboration can strongly influence the footprint of a media product.
- Supply chain collaboration is key to reducing environmental footprints: without transparency and engagement, companies can only ever reduce their own direct emissions. Working together unlocks opportunities to improve environmental performance.
- The media supply chain that I examined demonstrated maturity and capability in its management of environmental performance. I found the motivation, capacity, and managerial oversight required to promote environmental sustainability.

5.1.2 Sustainability Perspective: Consumer Media Habits

Our second research question was, "has sustainability impacted consumers media consumption habits?" To test this idea, I designed a survey for 1,435 consumers in North America, with a sample that mirrored census results in Canada and the United States. Four segments were created: Digital Light, Digital Heavy, NEP Eco, and NEP Anthro. I devised a scoring system to approximate the digital media consumption habits of the digital segments. The NEP segments were produced using the New Ecological Paradigm (NEP) (Dunlap *et al.*, 2000), a commonly employed academic framework for representing the environmental values of a survey sample.

I found that consumers are, indeed, shifting from paper to digital media sources. Not only did all segments report using more digital media today than five years ago, all segments expect the shift to accelerate. This reaffirms the concept of "the media shift", validates findings from the literature (Duggan and Smith, 2013; Duggan and Brenner, 2013; Bell *et al.,* 2013), and gives credence to my efforts to consider the environmental footprint of media.

What I wanted to investigate, however, was whether environmental values had any effect over media consumption. In the review of "the sustainability shift", I found that consumers preferred sustainable products (Diamantopoulos *et al.,* 2003; D'Souza *et al.*, 2007) and, in some instances, are willing to pay a premium for products (Ottman, 2011). I surmised that there would be some relationship between environmental values and media consumption: the prevalence of the phrase, "please consider the environment" suggests that people connect the environment with their media consumption all the time. But to my surprise, I could find almost no evidence to suggest that the two variables interact. Those with stronger environmental values had media consumption habits that were almost identical to those with weaker environmental values. This suggests that, for whatever reason, concern for the environment plays no role in media consumption habits. Why might this be?

Media – both paper and digital – is somewhat transient. Digital media arrives at the click of button, hosted on the vast network of ICT that hums away in the background of today's economy. Digital products appear and disappear at the whim of the consumer, and there are few (if any) moments when the aggregate impact of all this digital media consumption might occur to consumers. In many ways, paper media is similar. It arrives at the door, is consumed, then stored on a shelf or tossed it into a recycling bin. The impacts of paper media consumption are removed from the consumer, although perhaps less than its digital counterpart.

That I observed, for the most part, no connection between the NEP segments and media consumption is an interesting contribution to the literature on the NEP. Many academics have used it to segment and explore the habits of different groups. Ardahan (2012) and Amburgey *et al.* (2012) found the NEP a meaningful scale for exploring the habits of consumers pursuing recreational activities in Turkey. Velayudhan and Srividya (2013) deployed the scale in India to understand the environmental perspectives of consumers there. Kopina (2012) and Corraliza *et al.,* (2013) both employed the NEP scale to segment and understand the development of children. In short, the NEP has provided a reliable

indicator of environmental preferences amongst a variety of different segments. But in my research, I found that the NEP did little to elucidate the preferences of different segments of media consumers. This reinforces the concept that there is weak connectivity between consumers and media.

If media is transient and consumers environmental values don't influence media consumption patterns, it follows that consumers are disconnected from their own media footprint. This lack of connectivity does much to explain why the footer, "please consider the environment when printing this email" is so popular. In a world where consumers have little sway over the environmental impacts of entire industrial systems, they do have a choice when it comes to hitting print. Perhaps then, consumers want to care about the footprint of their media consumption, but they are faced with few opportunities to do so. When considering the environment, how connected a consumer is to the impacts of their media habits must be taken into account.

This case of consumers revealed three important things about media and the environment:

- It affirms that a shift from paper to digital media is under way.
- It demonstrates no meaningful connection between environmental values and media consumption.
- It suggests that the transient nature of media leads to weak connections between consumers and their media choices, explaining the disconnect between environmental values and media habits.

5.1.3 Sustainability Perspective: Comparing Media Choices

Our final research question was to ask, "has sustainability compelled academics to compare different media types?" As consumers are shifting from one media type to another, I assessed academics' comparisons of the environmental attributes of this shift. In this analysis, I focused on digital media. I wanted to investigate how the standard academic approach of measuring and comparing environmental footprints, the life cycle assessment (LCA), handles a comparison between two very dissimilar products, and how the LCA methodology copes with measuring complex ICT products.

I found that, with one exception (Enroth, 2009), LCAs determine that digital media is environmentally preferable to paper alternatives. The one exception involved a textbook in elementary school that is

shared several times. Only after several consecutive years of textbook use does the footprint of paper seem preferable to using a computer in-class.

But more interesting than the findings of the LCAs was everything the authors did not, or could not, discuss. For example, the rapid expansion of ICT infrastructure and devices was never discussed. This established and global trend was never connected – explicitly or implicitly – to the footprint of digital media. Nor was the nature of the ICT industry itself ever considered. ICT is evolving rapidly, best captured by the concept of Moore's Law. Every couple of years, the efficiency of ICT doubles, while its cost halves. This leads to remarkable technological innovation. It also leads to a rapid cycle of obsolescence, as older ICT is discarded in favour of new products. The fact that ICT is dependent on non-renewable resources like rare earth minerals, metals, and plastics was never mentioned, nor was any connection between non-renewable resource dependency and digital media ever established. All of the waste that ICT generates through its rapid cycles of innovation and ever-increasing presence was never given serious consideration. While the LCAs would assume that ICT waste was properly disposed at local facilities, they never considered the more likely alternative: that it would be shipped overseas to be dismantled with grave environmental and human consequences (Grossman, 2006; Robinson, 2009). Moore's Law also ensures that the data being considered by an LCA is almost always out of date. Collecting life cycle inventory data is a slow and expensive process. With the ICT sector constantly innovating, it is no surprise that data is often outdated on digital media; studies published in 2010 were using estimates on the footprint of the Internet from the late 1990s.

The LCA is a methodology designed to consider discrete trade-offs between one option and another (Gaudreault *et al.*, 2007a). But what happens when it considers two completely different media types, paper and digital? Paper media is grounded in the world of forestry, with a wide range of potential environmental impacts. Digital media is a virtual product dependent on a complex and interconnected global ICT system. Trying to figure out exactly what percentage of that system should be allocated towards a particular digital media experience is akin to counting angles on the head of a pin.

I cannot definitively say where the limitations of LCAs are borne. Is it the lack of precise data; the nature of ICT; the challenge of modelling consumer behaviour; or in the difficulty of comparing two totally different things? But the aggregate effect is a series of studies that reveal little about the relative attributes of paper and digital media. Instead, they reveal more about what I don't know than what I do.

It is not whether the LCAs are a fair and accurate representation of available data. It is whether available data is of sufficient quality to inspire confidence in the study findings. This research suggests that these LCAs, rather than provide definitive answers, are, in fact, scoping exercises that do much to reveal how little is actually known. Should these studies be relied upon to determine what is more sustainable?

Our findings validate research (Plepys, 2004; Williams *et al.*, 2002) that suggests there is a hidden footprint related to ICT that current methods do not capture. Plepys (2004) identifies chemical purity as a particular concern, citing the fact that LCAs use data for wholesale grade chemicals, rather than the ultra-pure chemicals that semiconductor manufacturing actually requires. Lu *et al.* (2006) rely on data from 1998 in order to measure the footprint of a laptop computer, underlying the difficulty of finding contemporaneous data. The backbone of ICT – the Internet – also proved a challenge to measure: most of the LCAs I reviewed refrained from measuring it, or if they did, expressed little confidence in their findings: "the results concerning potential impact of using telecommunication infrastructure are too uncertain to draw any real conclusions from" (Moberg *et al.*, 2010, p.42). Studies measuring the footprint of digital products, therefore, mostly ignore, out of necessity not neglect, the entire backbone of ICT infrastructure that actually makes digital media possible. Without the Internet, digital media would not be able to be delivered with such speed and at such volume. And yet studies of digital media can't even measure the Internet's footprint.

Relating back to the objectives of this thesis, it is clear that, when considering the environment, researchers should be more ambitious than simply considering a single discrete trade-off between one product and another. There is a pressing and tangible need to consider the industrial systems that produce media. And the ICT that produces digital media is the world's most complex and dynamic industrial sector, presenting a challenge to any effort to measure its environmental footprint. The three key conclusions that emerged from my comprehensive review of comparative LCAs were:

- LCAs comparing paper and digital media almost always find the latter to be environmentally preferable.
- The assumptions required to compared two vastly different products undermine the focus and effectiveness of LCAs.
- The uncertainty introduced by measuring the ICT sector – which is global, complex, and constantly evolving – makes a macro-level study of an ICT product like digital media particularly difficult.

5.2 POTENTIAL APPLICATIONS AND FUTURE RESEARCH

Three key themes have emerged from this thesis, themes that when considered together provide opportunities for future research and applications in the real world. If the findings of Chapters 2, 3, and 4 were distilled to their most basic elements the following concepts would emerge:

- Location and collaboration along a supply chain matter in measuring, managing and improving environmental footprints.
- Consumers are detached from their environmental impacts, unless an easy decision with an obvious material impact, like printing an email, is available to them.
- Discrete trade-offs involving comparisons between two totally different products only partially advances an understanding of sustainability: there is a need to think systemically as well.

The second theme is perhaps the most obvious, but the least fruitful for future research. Consumers are a busy group, and expecting an evolved and sophisticated understanding of sustainability is probably a bit much. But the first and third themes – the power of supply chains, and the need to consider industrial systems – offer powerful concepts and opportunities for further work.

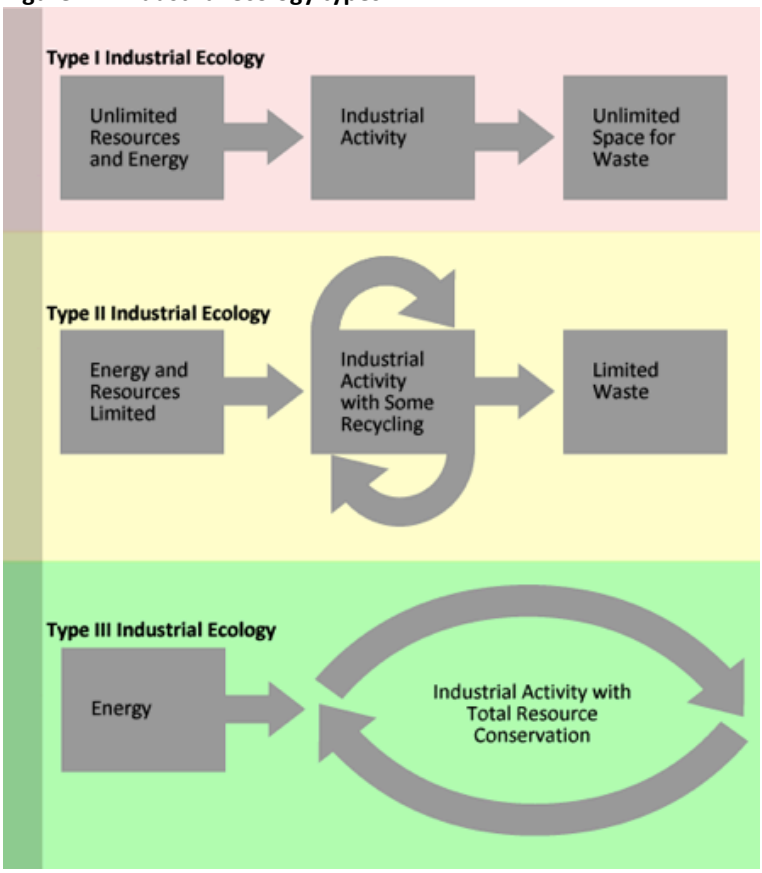
To better understand the sustainability of media, this thesis offers two concepts for consideration. The first has already been discussed: industrial ecology. This is the notion that industries can be thought of as systems with the potential to minimize waste and maximize efficiency, mimicking nature as closely as possible. The second is a new concept, but one that is already used in the world of business: capability maturity models. These concepts are presented in turn, connecting them to the literature as well as my own research in order to see how they might potentially be applied.

5.2.1 Industrial Ecology

I have already reviewed the concept of industrial ecology (see Chapter 1.1.1.1.1), but it is worth revisiting. Given the LCA's limited abilities in comparing completely disparate products (paper and media), as well as its weakness in handling the complexity of ICT, industrial ecology may offer a broader, complimentary perspective to my understanding of sustainability. It is founded on the idea that much can be learned from natural systems to improve the environmental footprint of industrial systems. Given that industrial systems have had a brief history, at least compared to ecosystems, taking a closer look at the structures and successes of nature can provide insights into how to devise more effective and sustainable systems (Seager, 2008).

Figure 27 shows three industrial ecologies. The first, Type I, is an open loop, with energy and materials flowing in, being processed, and flowing out. It assumes an unlimited availability of resources, and an unlimited ability for the planet to absorb the impacts of industrial activities. Type II describes most existing industrial systems as they occur today. There are limited supplies of materials and energy, and industry cannot pollute freely without incurring costs. A completely closed loop Type III system is impossible for industry, as total resource conservation is unachievable. However, it is something that industry can aspire to. Ecological systems are Type III systems, as nature has only one input (solar energy), and waste does not exist as every material is eventually reused by the system (Gradel and Allenby, 1995; Erkman, 1997).

Figure 27: Industrial ecology types



When comparing paper and digital media, what might a framework of industrial ecology say? Are forestry and ICT Type I or Type II systems? And if a method for measuring the "strength" of a system could be devised, would one system be stronger than the other?

Forestry, in the best case scenario, depends on sustainably manage forests that produce a product (trees) that can be renewed in perpetuity (Boltz *et al.,* 2003). The processing of trees can be done with renewable energy, like biomass or hydro (Bajpai, 2011), and the goods it produces, from pulp to dimensional lumber, can be recycled at the end of their useful life (Merrild *et al.*, 2009). In the best case scenario, forestry has the potential to be a strong Type II industrial ecology.

ICT, on the other hand, is more complex. It depends entirely on non-renewable resources like metals, plastics, and rare-earth minerals (Lau *et al.*, 2002). It is dispersed and dynamic, and best case scenarios may be hard to define. Because of the need to compete on cost as well as specialize, very few ICT firms are vertically integrated (Christiaanse and Kumar, 2000). Instead, they rely on a massive network of suppliers, contractors and subcontractors (Paija, 2000), and enforcing environmental performance under these conditions is difficult. ICT is also doing much more than simply replacing paper media. It has spawned a massive wave of innovation across the economy – from financial services to entertainment to car sharing – that is adding economic value and potentially diminishing environmental impact. The diffuse and disruptive nature of ICT makes an assessment of its industrial ecology particularly difficult. ICT uses large volume of non-renewable resources, requires toxic chemicals to produce, and results in waste. But it is also reshaping the face of the global economy.

Many industries have benefited from the efficiency, information availability, and new technology that ICT has provided (Yi and Thomas, 2007). ICT itself has become more efficient, just as Moore's Law would suggest. Devices are getting smaller and smaller, using fewer raw materials as a result (Williams *et al.*, 2002). Products like computer monitors and televisions used to be large and heavy, full of glass and lead and other materials. Today, they are light and made mostly of plastics. In a way, ICT is now doing more with less. The forest sector itself has also benefited greatly from ICT in developing more efficient supply chains and industrial processes (Kollberg, 2005). But some argue that any resource efficiency that has been unlocked by ICT is more than offset by the increase in economic activity, as classic example of Jevon's Paradox (Polimeni, 2009). So, there is a tension in understanding ICT: on the one hand, it is getting increasingly more efficient. On the other, it unlocks more and more economic growth with commensurate environmental impacts. This paradox is not a question to be answered, but a feature of ICT to be acknowledged.

The potential of industrial ecology is in helping economic actors take a deeper and more contextual assessment of their own environmental behaviours. Beyond simply measuring productivity and efficiency, industrial ecology offers a concept to aspire towards: maximize renewability and minimize waste. This concept does not preclude other methods of environmental assessment from being used. In fact, given that its strengths are conceptual rather than quantitative, other methods should be encouraged. But as I demonstrated in Chapter 4, when the same environmental tool (in this instance the LCA) is used again and again to answer basically the same question, key parts of the puzzle can be missed.

In the case of paper or digital media, the context of paper and ICT media was simply ignored. Forestry's potential strengths – renewability, recyclability, and strong best case scenarios – went unrecognized by any over the research. And ICT's inexorable pace of innovation, complexity, resource consumption, and growth eluded all of the LCAs consideration. This is not to say that every LCA should also contain a lengthy discourse on the conceptual and contextual aspects of sustainability surrounding a particular decision, but somewhere in the academic landscape such review should take place. This dissertation has acted as such a review, but more than that, has identified a need and opportunity to do so at a larger and deeper scale.

Industrial Ecology, and the core concepts it contains, offers the opportunity to strengthen considerations of the environment. If environmental assessments are not considered in isolation, but instead framed as part of the larger ecology of an industry or economy, there is an opportunity to promote truly positive outcomes. Relying exclusively on limited and narrow methods of assessment carries the risk only passively promoting sustainable outcomes, ignoring the opportunity to conduct holistic assessments that consider how industries organize themselves. The ICT industry could use industrial ecology as an aspirational tool, promoting the increased use of renewable and recyclable materials. But in order to do so, it will need to evolve and strengthen its supply chains' ability to manage environmental criteria.

5.2.2 Capability Maturity Models

Capability maturity models (CMM) are a concept that emerged from the world of software development (Humphrey, 1989). Institutions all over the world test the resilience of their processes and procedures using CMM (Paulk, 1993; Paulk, 1995). Governments, consulting agencies, and procurement

departments use CMM to improve their performance (Fraser *et al.*, 2002). The idea is that, over time, policies and procedures can be developed that increase the capability of a particular business function. At the outset, it may begin with simply defining necessary steps. But over time, metrics may be developed. These metrics, once fully understood can lead to the active optimization of a particular process.

There is an opportunity to apply this concept to media supply chains, or any other industrial sector. In the supply chain case study (Chapter 2), I saw the power of specific actors working together to manage environmental performance. The more they collaborated, the more efficient, responsible, and resilient their supply chain became. In a way, it became more capable and mature. I also saw (Chapter 4) that in the ICT industry, an evolving and complex industrial system makes it difficult to measure environmental performance. The question is how might the idea capability maturity be used along media supply chains?

Consider the perspective of a major media buyer, like a global retailer with a catalogue distributed worldwide. They may see a material risk associated with their media purchases and decide to minimize that risk. This means that they want to avoid sourcing from irresponsible suppliers. If that retailer were found to have used illegal fibre from a high conservation value forest, it would damage its reputation and brand. So the buyer would insist only on buying certified fibre, the first step in developing capability maturity along its supply chain. The next step might be asking for enterprise-level reporting from all its suppliers on energy use and carbon emissions, along with a plan to reduce environmental impacts. The buyer could go further, and insist not only on enterprise-level reporting, but site-level (e.g. a pulp mill) or product level (e.g. a tonne of paper) data. The final step would be to insist that all suppliers audit and verify their product level data, bringing in third-party verification where appropriate. Verified product-level data with third-party input would indicate a very mature and capable supply chain indeed.

The same thought experiment could be applied to the ICT sector. How would that media buyer ensure its digital presence has the best environmental performance possible? They would start by contacting the data center operators that host its website and digital applications. The same enterprise to site to product level data rubric could be applied. Insisting on verified data could also be an option. But ICT is unlike forestry. The networks are much more diffuse, and simply talking to data center operators by no means implies that the environmental impact of digital media has been measured and managed to the

fullest extent possible. Further, forestry is an industry that has withstood public scrutiny for a long time. Environmentalists have long been engaged in promoting sustainable forestry, while also publicly criticizing companies that engage in practices that are damaging to the environment. As a result, the forest products industry has had to develop certification schemes and transparent supply chain practices in order to secure its social license to operate.

The ICT industry has only recently to endure this kind of scrutiny. As work on this dissertation unfolded, new legislation in the United States emerged asking companies to report on so-called "conflict minerals" in their supply chain. With the passage of the Dodd-Frank Wall Street Reform Act, a series of rules was introduced to ensure that ICT companies disclose their use of these minerals (SEC, 2012). Conflict minerals are sourced from the Congo Basin, and include: columbite-tantalite, used in the production of capacitors; cassiterite, an ore used to produce tin, essential for the production of solder on the circuit boards of electronics; wolframite, a source of tungsten which is used in the vibrator function on cell phones; and gold. Research suggests (Ochoa and Keenan, 2011) that the dispersed and complex global supply chain for metals and minerals will make it difficult for ICT companies to distinguish a legitimate source of a mineral form one that is prohibited. ICT companies are working (Motorola, 2014) to identify legal suppliers and are working together to jointly improve their procurement practices. But progress has been slow, with a recent report suggesting that most companies are not adequately investigating their supply chains to identify illegal sources (Michaels, 2014). Intel, a prominent American semiconductor manufacturer, has met significant resistance in its efforts to weed out conflict minerals (King, 2014).

The difficulty in sourcing just a few minerals demonstrates the difficulties of managing environmental variables in the ICT sector. Given the massive number of minerals and metals present in ICT products (Lau *et al.,* 2002) and the increasing complexity of the processes and chemicals used (Plepys, 2004), it follows that the ICT industry is going to have a difficult time developing both capacity and maturity in managing environmental footprints along its supply chain. But these are questions that the LCAs reviews in Chapter 4 neglected to ask. In the rush to determine what was better – paper or digital – the authors ignored the context of ICT. But given what I learned in Chapter 2 when studying a paper media supply chain, ignoring the context has consequences: specifics, location, and collaboration all matter. And along paper media supply chains, there is demonstrated capacity and maturity for grappling with environmental issues.

To return to the example of a media buyer: by using a common framework along both paper and ICT supply chains, a buyer might discover that one industry is more capable than the other at handling environmental issues. Should this and does this impact a consideration of the relative footprint of paper and digital media? I have seen throughout the literature (Gauthier, 2005; Auld *et al.*, 2008a; Dauvergne and Lister, 2012) that companies play a particularly critical role in promoting sustainability. Good environmental performance is dependent on the responsible and transparent behaviour of private actors. This suggests that considerations of the environment should include an assessment of the capability maturity of a particular supply chain or industry. Further developing the concept of capability maturity models is a promising field of research.

5.3 STRENGTHS AND LIMITATIONS

The strength of this research is its willingness to take diverse research and connect it together in order to advance a definition of sustainability. It identifies the role of supply chains, consumers, and life cycle comparisons that consider the environmental impacts of media. By connecting case studies, consumer surveys, and comparative analyses conducted by others, it advances the understanding of what sustainable media means.

But this thesis is just one in an effort to expand and refine theories of sustainability. It is clear that "doing better" (or "doing less bad") is a complex concept that can mean different things to different people. Industry, consumers, and academics all have their own unique contributions that have to be taken into account. Industry operates in a profit-driven world and is often loathe taking steps to improve environmental performance unless there are tangible benefits to the bottom line. Consumers, despite all their good intentions, do not have the time, resources, or skills to fully assess the sustainability of their decisions. And when that decision involves two wildly different products – paper and digital media – it is not reasonable to expect a particularly sophisticated decision-making process. Academics are compelled by scientific methods and the need for testable hypotheses. They develop standardized and rigorous methodologies like the LCA that are transparent and driven by data. But when data is scarce and uncertainties and assumptions arise, academic methods can fail to see the forest for the trees. In this instance, the LCAs I reviewed did not grapple with the complex context of ICT and comparative media choices. The strength of this thesis is to acknowledge the shortcomings of different actors, but not be swayed away from asking big and difficult questions.

The limitations of this research, however, are significant. While it combines three focused and rigorous scientific studies, connecting them together involves a willingness to think conceptually. But concepts of sustainability are nebulous and difficult to test. It is worth revisiting Seager's (2008, p.447) definition:

> "Sustainability might best be defined as an ethical concept that things should be better in the future than they are at present. Like other ethical concepts such as fairness or justice, sustainability is best interpreted conceptually rather than technically."

The limitation, then, is that I am studying an objective and scientific issue – environmental impacts of media consumption – but I am advancing an ethical concept. A more focused effort – for example, studying one part of the ICT lifecycle and trying to advance data availability – could enjoy additional scientific rigour. But it would be primarily a technical effort and would not achieve as much in advancing definitions of sustainability or providing concepts that might help compare the attributes of industrial systems.

Instead, this dissertation is best considered as a guide for more focused investigations into media footprints. While additional research into environmental footprints of media consumption are quite necessary, this thesis offers a broad and contextual overview that can ground environmental investigations in a broader understanding of what it means to be sustainable.

In the investigation of the paper supply chain, I acknowledge that there are limitations to the methods employed in this research. Any extrapolation from a specific case study to a more general population should be treated with caution. That said, I did triangulate the interview findings to strengthen their validity and, in so doing, developed a framework that potentially extends beyond this case study. The concepts of carbon as a catalyst for deeper integration between supply chain partners, and carbon as a starting point for a transition from efficient to responsible to resilient supply chains has been validated for this case study of the paper and print sectors. However, I cannot infer that these patterns will hold true in all supply chains, although they are likely to manifest in some.

In my investigation of media consumers, there are potential weaknesses as well. The NEP scoring system, often used to identify the environmental values of a sample, is less commonly employed to create two different segments. In my research, the mean NEP score of the two segments was very similar, and the overall environmental values of the two may not have differed much. To create the

Digital Light and Digital Heavy segments I had to devise my own scale that has not benefitted from the rigor of multiple academic applications. And finally, in my comprehensive review of comparative LCAs, the level of detail and methodological background provided by LCA authors limited the depth of comparison I was able to undertake.

5.4 FINAL THOUGHTS

This thesis set out to consider the environmental footprint of media. I reviewed the important role of supply chains in improving environmental performance. The habits and values of media consumers were established, showing a clear shift towards digital media, but with little regard for the environmental implications. Finally, academic efforts to compare paper and digital media were found wanting, as they failed to consider the complexity of the comparison being made or the industrial systems they were measuring. I have found that considering the environment is much more difficult than deciding whether to hit print or not. It involves big, ethical concepts like sustainability, as well as complex and dynamic systems like ICT and forestry. I discussed two concepts – industrial ecology and capability maturity models – that should be further developed by future research, ensuring that the context of media consumption is always considered in parallel with specific media choices.

But with all that said, please consider the environment before printing this thesis.

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Appendices

Appendix A

The following set of questions was used to structure the interviews along the paper supply chain. These questions formed part of a semi-structured interview, and additional questions or follow-ups were commonly employed.

1. Is reducing carbon emissions important to your corporation? If so, why?
2. If a carbon management policy exists, what has motivated its development?
3. What has guided the development of a carbon management policy?
4. How do environmental issues such as carbon, manifest themselves along your supply chain? (for example, market demand for carbon neutral paper, pressure from NGOs)
5. Have your performance measures and monitoring and evaluation procedures changed as a result of trying to reduce carbon emissions? If so, how has this impacted supply chain management for your organization?
6. What external actors (NGOs, Government, Corporations) have you been engaged with in considering carbon emissions? What has their role been?
7. Does collaboration along your supply chain play a role in your organization's carbon management policy?
8. Has the pursuit of a carbon management policy affected your financial performance?
9. Have you changed any relationships along your supply chain in order to reduce carbon emissions? If so, please describe the impacts of this change.
10. Do you anticipate changing your supply chain management in order to deal with government regulations associated with carbon?
11. Where do you see your business in 10 years? 20 years? How will this affect your supply chain?

Appendix B

The following survey questions were delivered through a website to our survey sample.

Are you Male or Female?

What is your age?

- 14 to 17
- 18 to 21
- 22 to 25
- 26 to 30
- 31 to 40
- 41 to 50
- 51 to 60
- 61 or older

What best describes your education level?

- Less than High School
- High School / GED
- Some college
- Bachelor's Degree
- Master's Degree
- Doctoral Degree
- Professional Degree (JD, MD, etc.)

What is your own yearly income?

- Under $10,000
- $10,000 to $19,999
- $20,000 to $29,999
- $30,000 to $39,999
- $40,000 to $49,999
- $50,000 to $74,999
- $75,000 to $99,999
- $100,000 to $150,000
- Over $150,000
- Would rather not say

What is your total yearly household income, including all earners in your household?

- Under $10,000
- $10,000 to $19,999
- $20,000 to $29,999
- $30,000 to $39,999
- $40,000 to $49,999
- $50,000 to $74,999
- $75,000 to $99,999
- $100,000 to $150,000
- Over $150,000

- Would rather not say

Which of the following best describes the area you live in?

- Urban
- Suburban
- Rural

Which of the following categories best describes your primarily area of employment (regardless of your actual position)?

- Homemaker
- Retired
- Student
- Unemployed
- Agriculture, Forestry, Fishing, or Hunting
- Arts, Entertainment, or Recreation
- Broadcasting
- Education - College, University, or Adult
- Education - Primary/Secondary (K-12)
- Education - Other
- Construction
- Finance and Insurance
- Government and Public Administration
- Health Care and Social Assistance
- Hotel and Food Services
- Information - Services and Data
- Information - Other
- Processing
- Legal Services
- Manufacturing - Computer and Electronics
- Manufacturing - Other
- Military
- Mining
- Publishing
- Real Estate, Rental, or Leasing
- Religious
- Retail
- Scientific or Technical Services
- Software
- Telecommunications
- Transportation and Warehousing
- Utilities
- Wholesale
- Other (Please specify)

Which of the following best describes your role in industry?

- Upper management
- Middle management
- Junior management

- Administrative staff
- Support staff
- Student
- Trained professional
- Skilled laborer
- Consultant
- Temporary employee
- Researcher
- Self-employed
- Other (Please specify)

The organization you work for is in which of the following:

- Public sector
- Private sector
- Not-for-profit
- Don't know
- Other (Please specify)

Section Two: Media Consumption

How long have you been using the Internet?

- Never used it
- Less than 6 months
- 6 to 12 months
- 1 to 3 years
- 4 to 6 years
- 7 years or more

How many computers are used in your household?

- 1
- 1 to 3
- 4 or more

How many mobile devices are used in your household?

- 1
- 1 to 3
- 4 or more

Do you own the following devices: Yes No Don’t Know

Digital Camera
Digital Video Camera
DVD Player
BluRay Player
LCD or Plasma Flat Panel Television
MP3 Player (such as Apple IPod)
Desktop Computer
Laptop Computer
Netbook Computer
Cellphone

Smartphone or Handheld Mobile Device (such as Apple IPhone)
E-Reader (such as Amazon Kindle)

How often do you replace the following devices:

	> 1 year	Every year	Every 1 to 2 years	3 years or more
Desktop computer				
Laptop computer				
Cellphone, smartphone or handheld device				

How frequently do you access the web from the following places?

	Daily	Weekly	Monthly	Less than once a month	Never
From home (including a home office)					
From work					
From school					
From a public terminal (e.g. library, cybercafé, etc.)					
From a mobile device					
From other places					

What type of Internet connection do you have at home?

- Dial-up
- DSL Broadband
- Cable Broadband
- Don't know
- Other (Please specify)

Do you use a mobile device to connect to the Internet?

- Yes
- No
- Don't know

Where do you get your news online (select those which apply)?

- Dedicated news sites (e.g. CNN.com, etc.)
- National newspaper websites
- Regional newspaper websites
- Local newspaper websites
- News aggregators (e.g. Google News, Yahoo News, etc.)
- Blogs
- Other (Please specify)

What type of paper-based media do you consume (select those which apply)?

- National newspapers
- Regional newspapers
- Local newspapers
- News magazines
- Entertainment magazines
- Hobbyist or niche magazines
- Books (purchased)
- Books (loaned from library)

Please rate how frequently do you use the following online services using the following scale: Never (N), Not Frequently (NF), Somewhat Frequently (SF), Frequently (F), Very Frequently (VF), Don't Know (DK):

Instant Messaging
Email
Social networking
Blogging sites
Research
Reading the news
Watching videos
Online banking / financial management
Online Shopping

Please state how many hours, on average, you spend a day doing the following activities, using the following scale: None Less than 1 1 to 2 2 to 4 4 to 6 6 or more Don't Know

Browsing the internet
Reading a newspaper
Reading a magazine
Reading a book

Please state your willingness to pay for content on the following printed media formats, answer Yes (Y), No (N), Maybe (M) or Don't Know (DK).

Printed newspaper
Printed magazine
Printed book
Online newspaper
Online magazine
Online blogs
Electronic books

Listed below are various information sources. Please state how credible you feel the content and information is (Not Credible (NC), Somewhat Credible (SC), Credible (C), Very Credible (VC), Don't Know (DK):

Printed Newspapers
Printed Magazines
Printed Books
Online Newspapers
Online Magazines
Online News Aggregators
Blogs

Please rate how effective you find the following types of advertising, based on this scale: Not Effective (NA), Somewhat Effective (SE), Effective (E), Very Effective (VE), Don't Know):

Newspapers – Display Ad
Newspapers – Classified Ad
Newspapers – Flyer Insert
Magazine – Display Ad

Online – Display Ad
Online – Pop-Up Ad
Online – Text Based Ad

Please answer the following questions on your trends in print media consumption. I ask that you give a sense of your consumption patterns five years ago, today, and how you think you will consume in five years from now using the following scale: Never – Rarely – Somewhat Often – Often – Very Often

Newspaper or magazine delivered to home?
Books purchased from bookstore?
Books loaned from library?
Read news on PC or laptop computer (including newspapers, magazines, blogs, etc.) ?
Read news on smartphone, cellphone, or other handheld device (from media outlets such as newspapers, magazines, blogs, etc.)?
Books purchased for electronic reader?

Listed below are statements about the relationship between humans and the environment. For each one, please indicate whether you Strongly Agree (SA), Mildly Agree (MA), are Unsure (U), Mildly Disagree (MD) or Strongly Disagree (SD).

1. I are approaching the limit of the number of people the earth can support
2. Humans have the right to modify the natural environment to suit their needs
3. When humans interfere with nature it often produces disastrous consequences
4. Human ingenuity will insure that I do NOT make the earth unlivable
5. Humans are severely abusing the environment
6. The earth has plenty of natural resources if I just learn how to develop them
7. Plants and animals have as much right as humans to exist
8. The balance of nature is strong enough to cope with the impacts of modern industrial nations
9. Despite our special abilities humans are still subject to the laws of nature
10. The so-called "ecological crisis" facing humankind has been greatly exaggerated
11. The earth is like a spaceship with very limited room and resources
12. Humans were meant to rule over the rest of nature
13. The balance of nature is very delicate and easily upset
14. Humans will eventually learn enough about how nature works to be able to control it
15. If things continue on their present course, I will soon experience a major ecological catastrophe

Rate your level of environmental concern associated with the following scale:

None Unconcerned Somewhat Concerned Concerned Very Concerned

Deforestation and illegal logging…
Global warming and climate change…
Mining of minerals and metals…
Depletion of non-renewable fossil fuel resources…
Nuclear power and nuclear waste…
Water use and conservation…
Handling of electronic waste…
Growth and increasing consumption in developing countries…
Growth and increasing consumption in developing countries…

What types of environmental issues concern you most?

- Local (near your home)
- Regional (in your state or country)
- Global (affecting the entire planet)

Many environmental issues involve difficult trade-offs with the economy. Which of the following statements best describes your view?

(a) The highest priority should be given to protecting the environment, even if it hurts the economy.
(b) Both the environment and the economy are important, but the environment should come first.
(c) Both the environment and the economy are important, but the economy should come first.
(d) The highest priority should be given to economic considerations such as jobs even if it hurts the environment.

Do you believe that I have a responsibility to look out for the interests of future generations, even if it means making ourselves worse off?

(a) Yes
(b) No