A multi-level perspective analysis of the change in music consumption 1989-2014

by Richard Samuels

Thesis submitted for the

Degree of Doctor of Philosophy

School of Geography and Planning

Cardiff University

2018

Abstract

This thesis seeks to examine the historical socio-technical transitions in the music industry through the 1990s and 2000s which fundamentally altered the way in which music is consumed along with the environmental resource impact of such transitions. Specifically, the investigation seeks to establish a historical narrative of events that are significant to the story of this transition through the use of the multi-level perspective on socio-technical transitions as a framework. This thesis adopts a multi-level perspective for socio-technical transitions approach to analyse this historical narrative seeking to identify key events and actors that influenced the transition as well as enhance the methodological implementation of the multi-level perspective. Additionally, this thesis utilised the Material Intensity Per Service unit methodology to derive several illustrative scenarios of music consumption and their associated resource usage to establish whether the socio-technical transitions experienced by the music industry can be said to be dematerialising socio-technical transitions.

This thesis provides a number of original empirical and theoretical contributions to knowledge. This is achieved by presenting a multi-level perspective analysis of a historical narrative established using over 1000 primary sources. The research identifies, examines and discusses key events, actors and transition pathways denote the complex nature of dematerialising socio-technical systems as well as highlights specifically the influence different actors and actor groups can have on the pathways that transitions take. The thesis also provides a broader contribution to the understanding of dematerialisation and technology convergence.

Declaration and statements

This work has not been submitted in substance for any other degree or award at this or any other university or place of learning, nor is being submitted concurrently in candidature for any degree or other award.

Signed ……Date 20/09/2018

STATEMENT 1

This thesis is being submitted in partial fulfilment of the requirements for the degree of PhD.

Signed …….…… Date 20/09/2018

STATEMENT 2

This thesis is the result of my own independent work/investigation, except where otherwise stated, and the thesis has not been edited by a third party beyond what is permitted by Cardiff University's Policy on the Use of Third Party Editors by Research Degree Students. Other sources are acknowledged by explicit references. The views expressed are my own.

Signed …….……..…… Date 20/09/2018

STATEMENT 3

I hereby give consent for my thesis, if accepted, to be available online in the University's Open Access repository and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed ……..…..….. Date 20/09/2018

STATEMENT 4: PREVIOUSLY APPROVED BAR ON ACCESS

I hereby give consent for my thesis, if accepted, to be available online in the University's Open Access repository and for inter-library loans **after expiry of a bar on access previously approved by the Academic Standards & Quality Committee.**

Signed ……..…… Date 20/09/2018

Acknowledgements

This thesis was facilitated by a studentship from the ESRC. I thank them for their financial assistance.

Crucial to the realisation of my research were my supervisors Andrew Flynn and Richard Cowell. I'm thankful for their guidance and encouragement throughout the entire PhD process. I could always count on them to steer me right and make me laugh. I would also like to thank individuals from the wider school community; Peter Feindt who was critical in my applying; Craig Gurney to whom I could always complain; and, Bella who helped make the whole thing bearable.

Most importantly I would like to thank my family. My Mother who was always so supportive and encouraging but is sadly no longer here. Chloë, without her love and friendship the whole thing could never have happened. My children Ehno, Ari and Ottie, without you I could have completed the whole thing in half the time. The rest of my family who feigned interest but supported me all the same. And to the thesis itself I want you to know I hate you, you were an exercise in sustained suffering.

List of Figures

List of Tables

Table of Contents

1 Sustainability and personal consumption

1.1 Introduction

The move to a sustainable future faces many challenges across several domains. Be it water scarcity leading to supply issues or the rapid depletion of natural resources leading to issues of energy supply, existing infrastructure needs considerable financial increase to support renewal and expansion whilst new technologies and increased efficiency drives must reduce resource consumption.

Production and consumption of physical products is materially intensive and is typically a destructive process that removes resources from the earth and commodifies them so that they may be consumed. The commodification of the natural environment such as wood, fossil fuels, water and ores has led to production processes that are unsustainable and that create products that continue to further the environmental harm (Robbins 1999). This commodification is driven by consumers' individual needs and wants as well as collective behaviours of wider society. The United Nations environment panel estimated that by 2010 civilisation was consuming 50bn tonnes of minerals, ores, biomass and fossil fuels annually. This figure is predicted to rise to 140bn tonnes by 2050.

As a response to these issues a new research stream has emerged within academia burgeoning over the last decade or so which argues that "addressing [these concerns] requires large-scale sustainability transitions in socio-technical systems related to transport, energy and agri-food" (Geels 2013 p.67). Yet as Markard *et al.* (2012 p.955) point out these transitions are exacerbated by "strong-path dependencies and lock-ins … observe[d] in existing sectors" where only incremental change is apparent. Such incremental change is insufficient "to cope with the prevailing sustainability challenges" (Markard *et al.* 2012 p.956).

Reduction of resource use is often apparent in sustainability transitions' literature, but dematerialisation is typically addressed at the state economic level rather than at that of personal consumption. However, criticism of dematerialisation at the state level is used to brush aside any investigation of dematerialisation of production and consumption as there seems to be an assumption that both Jevons' paradox and material substitution apply across the entire scope of dematerialisation. Assumptions are dangerous however and without proper research we risk overlooking dematerialisation and the factors that drive it.

1.2 Dematerialisation and the music industry

The initial focus on the music industry came from a statement made in a lecture that raised questions about the materiality and resource use of the change in the way people listen to music. It was assumed that CDs being physically smaller than vinyl are less resource intensive, likewise MP3s being simply bits on a computer had a smaller resource requirement still.

Processes of dematerialisation are largely unstudied. As the literature review will show, there has been a specific focus on dematerialisation at the state level but few studies that address dematerialisation at the level of personal consumption. The music industry was chosen as a case study as it is one that has historically undergone several distinct socio-technical transitions with significant shifts in how music product is delivered to consumers. Carving out the case study temporally focuses the research more sharply on the last two decades or so where the CD sound format became the dominant means through which to consume music and covers several other competing technologies. From attempts to replicate the success of CD such as mini-disks to more recent streaming technologies, such a Spotify and Deezer, that are thought to be a completely dematerialised form of music consumption.

The apparent dematerialisation of the music industry is explored through two different lenses of enquiry. In the first instance, where the aim is to establish the nature of dematerialisation of music sound carriers a MIPS (Material Intensity per Service unit) methodology is employed. The purpose is to establish whether dematerialisation in the music industry has occurred, or whether apparent reductions have been mitigated by increased consumption or increased by "hidden" resource use in supporting technologies.

The second lens of enquiry utilises the sustainability transitions literature, which is often quick to dismiss dematerialisation, to examine dematerialisation transitions. Collectively several strands of social science research fall under the broad title of transition studies all of which in some way seek to shed light on sustainability transitions, but it is the multi-level perspective on socio-technical transitions that has proven the most attractive. It assumes no *a priori* issues of the nature of the transition and as such is a framework through which to tell the story of music industry transition. The two enquiries interact, the multi-level perspective analysis of the historical transitions in the music industry provide several scenarios for MIPS analysis. The MIPS analysis reveals the very different levels of resource use found in the different ways in which music is consumed.

1.3 Research Aim, Objectives and Questions

The initial seed for this research was planted when someone stated to me that "Records are more materially intensive than CDs and CDs are more materially intensive than downloads". Expecting to

find research to back up this claim it became quickly apparent that little research had been conducted in this area. The rise of streaming music was also predictable at this point further complicating an already uncorroborated assessment of resource utilisation in music consumption. The aim of this research is therefore to increase knowledge in this area. Specifically, the aim of this research is to understand the nature of resource use in the changing modes of music consumption.

The objectives and research questions are tied tightly to this aim but expand on it further. How such a set of complex socio-technical transitions came about was unclear, despite living through it. Therefore, the first objective of this research was to enhance the methodological implementation of the multi-level perspective on socio-technical transitions by undertaking an in-depth historical analysis of transitions in music consumption by analysing the history of transitions in the music industry from the time of the introduction of the Compact Disc. The second objective, was to enhance discussion of processes of dematerialization by focusing on material changes in personal consumption of music so that it would become clear whether dematerialisation in the music industry was occurring or if changes in upstream and downstream sectors mitigated any apparent material losses in the music industry. As such, the second objective was focussed around the nature of dematerialisation and its relationship with personal consumption. The third objective was to enhance the theoretical discussion of multi-regime interactions and the role of actors within the application of the multi-level perspective.

The research questions became as follows, under three headings:

1. Understand the nature of dematerialisation in the music industry through the enhancement of the methodological implementation of the multi-level perspective on socio-technological transitions.

    a. How do we enhance the methodological implementation of the multi-level perspective on socio-technical transitions to establish how socio-technical transitions in sound-carriers come about?

    b. How do multi-regime interactions shape technological change and what impact do these have in enabling socio-technical transitions?

    c. How do actors (e.g. entrepreneurs) lead or constrain (e.g. ‘the Cartel of Condemnation and Litigation’ consisting of Major Labels and their representatives) transitions within the pathways?

2. Determine the roles of actors in multi-regime interactions.

a. What impact do actors have on multi-regime interactions?

3. Determine the implications of dematerialisation.

    a. How do we develop a method that is sympathetic to a multi-level perspective of socio-technical transitions to measure materialisation and dematerialisation for the consumption of music?

    b. What are the processes of dematerialisation and how do they influence the personal consumption of music?

    c. What impact, if any, has technological convergence had on resource use?

1.4 Thesis Structure

The thesis is in eleven sections. These are: Introduction to the thesis, a Review of the Literature, a focus on existing methodology for the multi-level perspective on socio-technical transitions, defining and bounding the music industry, multi-regime co-operation, the emergence of dematerialised sound-carriers, the road to iTunes and legitimate dematerialised sound carriers, dematerialising systems, actor influence on transition pathways and the Conclusion.

Chapter one – this chapter, demonstrates the line of enquiry, purpose, aims and objectives as well as the format of the research.

Chapter Two – a review of the literature focuses initially on dematerialisation literature and pulls from different fields that have elements of dematerialisation to them. The multi-level perspective is investigated, alongside other transition perspectives. The multi-level perspective is critiqued and probed for areas where an original contribution can be made to the literature. Similarly, the MIPS methodology is examined alongside other material resource measurement tools. In doing so the strengths of the MIPS methodology are defined and areas of potential weakness identified. The chapter concludes by setting up the discussion in the methodology chapter as to how the three literatures can be brought together.

Chapter three – Focussing on existing methodology begins critiquing the multi-level perspective further, examining and suggesting solutions to the criticisms of the multi-level perspective's lack of clear methodological practices. It then goes on to define how this project tackles these criticisms and how the data for the construction of the historical narrative was collected and prepared for analysis. The MIPS methodology undergoes similar critique and reconstruction to create a tool for resource measurement suitable for music consumption. The chapter concludes with a brief discussion concerning the ethics of the research.

Chapter four – Provides the context of the music industry case study, it defines the music industry, discussing the regime's suitability as an area of study and begins to define the boundaries of the area of study in respect to dematerialisation. It serves as an additional literature review that focuses on existing definitions of the music industry and produces a discussion that seeks to make the music industry case study analytically useful for both a multi-level perspective analysis and a MIPS analysis.

Chapter five- An historical narrative which considers the many interacting and overlapping elements of the complex socio-technical transition in the music industry. The narrative begins by detailing the emergence of the Compact Disc which influenced developments in the emerging Personal Computer industry. In turn, the influence of the Personal Computer on personal music consumption is detailed along with its impact.

Chapter six - The emergence of the internet, file sharing and music downloads are considered alongside the emergence of new, specialised tools needed for dematerialised music consumption.

Chapter seven - Responses from the music industry and further responses from consumers and technologists which gave way to iTunes are analysed before further assessment of the transition towards streaming music away from downloaded music model is considered.

Chapters five through seven build upon the previous chapters which provided the boundaries of the case study and area for original research. These chapters addresses the first aim of the thesis by analysing the history of change in the music industry between 1989 and 2014. This chapter provides an analysis of an historical narrative whilst considering three questions, (a) How do we enhance the methodological implementation of the multi-level perspective on socio-technical transitions to establish how socio-technical transitions in sound-carriers come about?, (b) How do multi-regime interactions shape technological change and what impact do these have in enabling socio-technical transitions?, and (c) How do actors (e.g. entrepreneurs) lead or constrain (e.g. 'the Cartel of Condemnation and Litigation' consisting of Major Labels and their representatives) transitions within the pathways? These chapters for the most part are chronological so that the 'story' of transition is apparent, however as the chapter anticipates the multi-level perspective analysis and to better link to the research questions some events and actors are grouped together for discussion in Chapter 9. As a result, some time-periods are covered more than once in different sections so that details remain distinct and relevant to the novelties being addressed. This is particularly clear between the activity happening with MP3 that leads into "illegitimate" marketplaces in chapter 6 and the activity happening with copyright restricted sound-carriers in chapter 7 that leads to "legitimate" marketplaces being developed.

Chapter eight – the discussion focuses initially on the analysis of the material intensity of the different modes of music consumption prevalent today, as identified during the historical narrative. Between the two analyses much discussion is generated around the nature of dematerialisation, the resource implications and the way complex socio-technical transitions come about. The actor groups identified in the historical narrative are explored further as is their influence on transition. These groups include both technologists, consumers of music and industry actors.

Chapter nine – provides an analysis of the actor influences on the transition pathways that have led to the dematerialisation identified in chapter eight. The actors are identified based on their group behaviours in their approaches to the various technologies as identified during the historical analyses of chapters five, six and seven.

Chapter ten – the conclusion relates the discussions from the previous chapter to the research questions, aims and objectives, an overview of analysis and highlights areas of future research.

2 A review of the Literature

2.1 Introduction

The world faces difficult challenges relating to climate change impacts, resource use and energy demand coupled with continued demand for products and global competitive pressures for manufacturers (Skellern *et al.* 2016). Attempts to face up to these challenges had been confined to a few OECD countries for much of the 1990s and early 2000s (Truffer *et al.* 2015). Techniques such as ecological foot-printing are used to highlight the levels of resource consumption and issues surrounding resource extraction. One such report highlighted that if all 7 billion people were to consume resources at the level of average Europeans an extra two earths would be required to sustain them (Hails *et al.* 2006). Focus has fallen therefore, on resource inputs and the outputs of such rampant consumption. Baccini and Brunner (2012) claim that increases in material throughput and energy flows are the leading cause for the majority of environmental problems. Carbon dioxide, amongst others, is a key contributor to climate change. CO_2 levels are predicted to more than double 2012 levels by 2050 (IPCC 2013). Jackson (2009) claims that we require at least a reduction in CO_2 by a factor of ten in order to meet mandatory targets suggested by Stern (2007) and the IPCC. To meet these targets of keeping global warming within 2C, a UK resident would need to reduce emissions by 80% of what the average UK person emitted in 1990 (IPCC 2014). Prior to these mandatory targets, UNDESA (1992) had already highlighted issues around contemporary roles of production and consumption in developed countries as placing the greatest burden on the Earth's resource capacity to satisfy human needs and desires. Through the 1990s recognition of the problems associated with production and consumption would therefore become more targeted. This led to the development of a ten year framework of programs around Sustainable Consumption and Production (SCP) as part of the United Nations Environmental Program (UNDESA 2002). In preparation of the ten-year framework the European Union funded a major initiative: The Sustainable Consumption Research Exchanges (SCORE).

The SCORE initiative highlighted several strategies that targeted reductions in resource demands. These demands included the *greening of production* whereby end-of-pipe measures and technical changes in production methods should be adopted. The *greening of products and services,* where reduction strategies for material and energy use per unit could be implemented. *Intensifying use,* whereby products and services should be more efficiently used through behaviour modification such as car-pooling and tool-sharing initiatives. *Greening consumption patterns,* whereby consumers

purchase lower impact goods or service alternatives and reducing consumption volumes (Tukker *et al.* 2010). These routes to reducing environmental pressure all in some way seek to lower material demands (see Hertwich 2005b; Hofmann *et al.* 2016; Steen-Olsen *et al.* 2016; Tukker and Tischner 2006; Tukker 2006; UNEP 2011). Tukker *et al.* (2008) note that the implementation of SCP is often reduced to a process of dematerialisation claiming that such a strategy is flawed due to the rebound effect. Citing only two references (Binswanger (2001) and Hertwich (2005a)) Tukker *et al.* are quick to diminish the role of dematerialisation in consumption and production. Yet this is somewhat counter to the routes offered by proponents of SCP where reductions in material and resource use is inherent within such strategies one way or another. Fuchs and Lorek (2005) for example, see reduction as an essential element of strong sustainable consumption; similarly, Seuring and Muller (2008) in focusing on the greening of supply chains also see reduction in materiality as important. Further, as the literature review will show, such assessments of dematerialisation are based on whole economic systems, typically at a national level, whereas dematerialisation of production and consumption is under-theorised at the product level.

Key questions drive the literature review, in the first instance answers to the question of what dematerialisation is and how it has developed within the literature are attempted. This reveals issues around materiality and of measurement. It also shows several eco-efficiency potentials that might best be seen as sisters of dematerialisation that also play an important role in our understanding of processes of dematerialisation. The rebound effect is reconsidered in the context of the dematerialisation literature where it is more frequently referred to as rematerialisation. To better understand the processes that may lead to dematerialisation it is argued that dematerialisation should not be thought of as an event but as a socio-technical transition where in its impact and effects in relation to the wider system are considered. However, as the existing dematerialisation literature is not equipped epistemologically to analyse dematerialisation in this way the multi-level perspective on socio-technical transitions (multi-level perspective) is therefore proposed as a suitable lens of enquiry. The multi-level perspective is a framework specifically tailored for analysing socio-technical transitions and although it has been used previously for analysing several technologies it appears not to have been used to analyse socio-technical transitions relating to resource use changes because of technological innovation. Reviewing the multi-level perspective forms much of the discourse of the middle part of the literature review. There it is introduced more substantively, and its shortcomings addressed with discussion further focussing on how it promises to be a useful perspective for understanding transitions relating to resource changes, namely dematerialisation.

The literature review is structured thusly: an introduction to the concepts of dematerialisation and synonymous concepts with emphasis on reductions in materiality and resource use, a review of the

dematerialisation literature and the conceptualisation of dematerialisation as a socio-technical transition suitable for study. Building on this conceptualisation, a critical review of the multi-level perspective on socio-technical transitions as a perspective suitable for analysing dematerialisation is performed. The chapter is drawn to a close with a more substantive discussion of the literature review findings and addressing where a contribution to knowledge can be made.

2.2 Dematerialisation and synonymous concepts

The concept of dematerialisation can be found in sustainable development reports cited as both an indicator of resource use and as an approach to reaching sustainable development goals. Beyond this however, dematerialisation as a concept has received relatively little attention as an overt concept; instead, it is found implicitly within others. As a result of this, any review of dematerialisation literature demands the review of synonymous concepts by necessity and not just to give a fuller picture. Literature which discusses the decoupling of resource use with economic growth (see O'Rourke and Lollo 2015; Tapio and Vähätalo 2013 for recent examples) often highlights dematerialisation but rarely get to grips with it. Instead, it sits as a mostly uncited theory emphasising that there is no one body of dematerialisation literature nor one canonical framework for measuring and analysing it.

The basic processes of dematerialisation are expressed in the literature chiefly under three dominant banners: eco-efficiency, Factor *X* and decoupling (see Reijnders 1998). All three are found in an arena overloaded with concepts that align themselves with the sustainable development agenda. Each has a different point of origin and is promoted for different reasons within different discourses resulting in a fragmented group of literatures in which only the key resource reduction concept of dematerialisation is consistent. Despite often being used interchangeably there are differences between the three, the most notable of which is that eco-efficiency and Factor *X* are more than just the decoupling of resource use from economic growth. The 'more than' dematerialisation aspects of eco-efficiency are not particularly useful here, but Factor *X* offers important insights into the dematerialisation process.

Both eco-efficiency and Factor *X* tend to consider economic dematerialisation and dematerialisation of products as distinct but there is a degree of overlap. There are strong parallels between the two: economic dematerialisation sees a reduction (either absolute or relative) in the materials required to serve particular societal functions for economic purposes whereas dematerialisation of product sees a reduction in the material required to achieve the same functionality to the user for ecological purposes (Madlener and Alcott 2009; Sanne 2000). Essentially both require the supply chain to become considerably more efficient to reduce resource inputs (and outputs) without depriving the end user of a product or service. Given the similarity, it is understandable that some authors discuss

them as one and the same, as the difference, aside from original purpose, appears to be one of scale; it is also likely that a degree of overlap has been deliberate as the two can be combined to synergistic effect. Tapio *et al.* (2007) suggest the two concepts came together during the energy crisis of the 1970s which were fuelled by *Club of Rome* reports and the 'bad news' debate in the journal *Science* (Meadows *et al.* 1972; Mesarović and Pestel 1974; Simon 1980). Tapio *et al.* (2007) also note that the discourse has continued but it has been adopted and adapted by different fields where it has evolved and transformed whilst still essentially describing the same issue. This makes reviewing dematerialisation literature difficult. There is no linear progression of theoretical discussion for example. Instead, this literature review discusses the broad field of dematerialisation literature before focussing more specifically on two component interpretations, 'eco-efficiency' and Factor *X.* Both provide explicitly normative attention to dematerialisation and offer different ways of operationalizing the dematerialisation concept. It is a combination of the broader literature and the eco-efficiency and Factor *X* literatures that seeks to answer several questions to facilitate a more substantive discussion on dematerialisation in the succeeding section; primarily how is dematerialisation defined and operationalized and to what extent is sustainability achieved by dematerialisation alone?

2.2.1 Dematerialisation

The dematerialisation concept refers to a decline in the amount of material use per unit of output (De Bruyn 2002 p.209); such material reduction can result from technological and structural changes (Malenbaum 1978). Technological changes can alter material demand through improved manufacturing processes or product design. De Bruyn notes that structural changes result from changes in the composition of economic activities and states that:

> "Three types of structural changes are normally mixed in the literature. They refer to (a) a change in the structure of inputs, that is, a shift in the relative shares of capital, labor and various types of natural resources in production processes; (b) a change in the structure of production, that is, a shift in the relative shares of various sectors that make up the economy; and (c) a change in the structure of consumption, that is, a shift in the composition of consumption due to changes in life styles" (De Bruyn 2002 p.216).

Technological changes come from an implied increase in efficiency of material use. Both technological and structural changes can result from the interplay of many different variables including resource prices, consumer preference, government policy and business ethics. Dematerialisation, is broadly perceived to be a decoupling of environmental harm and material production where the quantity of materials undergoes absolute or relative reduction (Wernick *et al.* 1996).

The dematerialisation core concept is simple and it can be boiled down to eco-efficiency's by-line "doing more with less" (WBCSD 2005 p.16). However, the reality of dematerialisation sees several

complicating factors. Two attempts to apply a more normative dematerialisation offering are discussed below.

2.2.2 Eco-efficiency

The eco-efficiency concept was first described by Schaltegger and Sturm (1989) before being adopted by the World Business Council for Sustainable Development (WBSCD) in a 1992 publication, Changing Course, and continue to define it as:

> "eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the Earth's estimated carrying capacity"(WBCSD 2005 p.3).

Eco-efficiency is very much of the business domain where it finds a home in annual reports and business journals, promoting itself as a way for businesses to operationalize sustainable development objectives such as Sustainable Consumption and Production (SCP). However, within the literature the emphasis is on the importance of efficiency as it relates to the market and so the language of economics dominates and little is said about the environment nor of societal benefit beyond satisfying 'the human needs' of consumerism (Harrison 2000). Eco-efficiency literature promotes dematerialisation as the main means through which to achieve eco-efficiency by "creating more value with less impact" (WBCSD 2005 p.3). Eco-efficiency is an overwhelmingly prescriptive concept that promotes normative actions to enable businesses to work towards a sustainable development objective. Elsewhere it is a term that is used rather loosely but generally refers to dealing with natural resource input as well as outputs that are additional to the required product (wastes and emissions) (Reijnders 1998). Whilst it has been the subject of study, eco-efficiency is not a particularly specific way of investigating or analysing systematic material reduction. Very few studies exist that observe large scale eco-efficiency at a national or regional level (Huang *et al.* 2014; Mickwitz *et al.* 2006; Wang *et al.* 2015; Yu *et al.* 2013). More frequent however, is its use in observing production levels or firm's outputs (Basset-Mens *et al.* 2009; Bribián *et al.* 2011; Kerr and Ryan 2001; Koskela and Vehmas 2012; Michelsen *et al.* 2006). This is counter to dematerialisation literature more generally which tends to look at the national level of resource use (Barles *et al.* 2012; Hinterberger and Seifert 1997; Marra Campanale and Femia 2013; Prior *et al.* 2012; von Weizsäcker 1998). The eco-efficiency literature adds to the definition of dematerialisation but more importantly it provides lines of analysis for dematerialisation at a spatial level lower than national. The eco-efficiency literature provides useful definitions and concepts for a study of dematerialisation at a product level. The extended supply chain which is defined as "the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hand of the ultimate consumer" is indicative of the nature of the systems

that can be analysed and indicates that criteria selection and boundaries must be set (Christopher (1998) in Michelsen *et al.* 2006). Eco-efficiency analysis of products introduces some methodology to the dematerialisation concept, the identifying of system borders, selection of environmental performance indicators and assessment of performance are all valuable metrics through which to analyse the eco-efficiency of product. Importantly however, these metrics also allow for the analysis of whether dematerialisation is occurring in any explicit sense in products and services. These metrics are returned to in the methodology chapter (see section 3.3).

2.2.3 Factor *X*

The Club of Rome report *Factor Four: Doubling Wealth Halving Resource Use*, a product of the Wuppertal Institute, introduced the factor concept of reduction of resource throughput in the economy specifically targeting near-term possibilities for reduction (von Weizsäcker *et al.* 1997; Reijnders 1998). It provided numerous examples in which four times the wealth could potentially be extracted from energy and material resources utilising existing technologies. Arising from the same institute, Factor Ten builds on the Factor Four concept but calls for further reductions in resource use. Schmidt-Bleek's (1993; 1997) Factor Ten also focuses on materials but acknowledges the unbalanced nature of resource consumption between OECD countries and developing ones[1] seeking longer term changes over a 30-50 year period. Therefore, a reduction of 50% worldwide would require OECD countries to decrease material intensity by a factor of 10 to redress the imbalance. In attempting to decrease energy and material resources Schmidt-Bleek recognises that not all sectors can decrease by a factor of 10 but that also many areas can decrease by many more factors. Schmidt-Bleek acknowledged this with the Factor *X* concept, which is a direct benchmark for "the dematerialisation of industrialised countries needed to achieve sustainability" (Robèrt *et al.* 2002 p.208). The Factor *X* benchmark is a defining feature as it links dematerialisation to a required rate to reach the desired goal, in this way the Factor *X* is a benchmark which attempts to measure when a prescribed level of sustainability is reached or provides a scenario to facilitate reaching the sustainability goal.

Factor *X* utilises additional metrics of many activities that can reduce energy and resource throughput and as such Factor *X* is about how "a dematerialisation aspect of four system conditions[2] – higher resource efficiency to comply not only with ecological sustainability but also with social sustainability – can be addressed in a concrete way" (Robèrt *et al.* 2000 p.29). The two prominent metrics are total material requirement indicator (TMR) (Adriaanse *et al.* 1997) and the material intensity per unit service (MIPS) which Schmidt-Bleek uses to illustrate the Factor *X* concept. Both indicators give the

[1] At the time of the reports publication per capita consumption was about five times higher in OECD countries.
[2] Four system conditions: 1. A concentration of substances extracted from the Earth's crust; 2. Concentrations of substances produced by society; 3. Degradation by physical means; 4. Human needs are met worldwide

Factor *X* concept a greater quantitative measure of dematerialisation although neither adequately portrays the environmental impacts of the various materials entering the economy (Reijnders 1998).

2.2.4 Review of existing dematerialisation literature

Whilst the concept of dematerialisation is a simple one, several complicating factors have emerged from the different discourses. This section organises these factors thematically, while noting the links between them, as follows: depending on the discourse, issues surrounding what material is being dematerialised are dealt with in the *materiality* section; as a result of the different materials considered when discussing dematerialisation a number of competing tools for *measuring dematerialisation* are also found in the literature; in measuring dematerialisation it also becomes clear that there are a number of closely related *eco-efficiency potentials* that are considered to both be and not be dematerialisation depending on the host discourse; in addition to the eco-efficiency potentials there is considerable debate over whether dematerialisation is a long term reality or whether the long term pattern is a process of *dematerialisation and rematerialisation;* the penultimate section focuses more specifically on the *dematerialisation of product*; the final section summarises the dematerialisation literature whilst carving out an area where further research is needed.

2.2.4.1 *Materiality*

Since the dematerialisation concept started gaining traction in the late 1980s and 1990s the simple concept introduced above has been refined, accommodating additional factors that allow for a more useful and better-defined application of dematerialisation as a process amenable to analysis. Dominant in the sustainable development discourse is the issue of CO_2 and its reduction. Despite environmental harm being caused by any number of materials, CO_2 has also come to be the most prominent material discussed in the dematerialisation literature perhaps reflecting the wider climate change literature but also the need for a universal unit. Whilst it is still recognised that "dematerialisation refers to the decoupling of the specified environmental harm from material production" this is overwhelmingly expressed as CO_2 output to the point that dematerialisation is often determined by changes in the carbon intensity of energy production (CO_2 emissions / TPES) (Tapio and Vähätalo 2013 p.84). This shift has been driven by developments in both eco-efficiency and Factor *X* literature as well as attempts to measure dematerialisation elsewhere, particularly in Industrial Ecology literature. Consumption of materials cannot satisfactorily be recorded or reduced to a simple indicator and a kilo of one material does not equal another (Wernick *et al.* 1996). This, combined with the prevalence of CO_2 in sustainability literature has led to the prominence of CO_2 and energy as indicators used to ascertain whether dematerialisation is taking place. Despite the dominance of CO_2 and energy, the fact remains that dematerialisation can refer to any material. However, such studies need to rely on complex Life Cycle Analyses (LCA) and it is rare for these to be

repeated over time providing little indication of trends (Wernick *et al.* 1996). As such, several frameworks developed to measure and determine dematerialisation rely on CO_2 and energy as universal units out of necessity as this information is most readily available. However, other measurement frameworks, such as Factor *X* exist that attempt to include all materials used to produce a product or service without the same reduction of all materials to CO_2 and energy alone.

2.2.4.2 *Measuring dematerialisation*

Several frameworks have developed independently and are designed for measuring materials and identifying dematerialisation caused by dematerialisation arising in a number of fields of study rather than as deliberately competing frameworks (Huppes and Ishikawa 2005b). Despite this, one tool referred to as MIPS, has proved itself applicable to a broad range of research where the assessment of material flow is important particularly in the dematerialisation of production and consumption (Liedtke *et al.* 2014). Liedtke *et al.* (2014 sec.4.5) acknowledge however that "future assessments should have their first focus on processes, products, sectors, activities and lifestyles of high relevance and dematerialisation potential (such as living and housing, food and nutrition, mobility), […] in order to better address them"

A few measurement frameworks have already been introduced during this literature review. Eco-efficiency and Factor *X* both address dematerialisation in similar terms, whereby both see it as a reduction in materials but with Factor *X* requiring a 90% reduction in resource turn over specifically, and their measurement processes are also similar, on the surface at least. Although eco-efficiency does not provide a prescriptive, rigid framework, within the Industrial Ecology literature several attempts have been made to produce a framework capable of measuring eco-efficiency. As noted previously, eco-efficiency is more than dematerialisation in the sense that it seeks to operationalize a form of sustainable development across business using measures in addition to dematerialisation; a number of frameworks therefore work towards pre-emptive, prescriptive and often hypothetical eco-efficiency and as such provide little in the way of use for studying existing dematerialisation transitions in practice (see Huppes and Ishikawa 2005a; Tseng *et al.* 2013; Möller and Schaltegger 2005).

Schmidt-Bleek (1994) developed a number of measurement criteria used for measuring dematerialisation in Factor *X* (via Factor Four and Ten). MIPS (material input per unit of service) is the underlying calculation for estimating the Ecological Rucksack (Burger *et al.* 2009). Its theoretical basis is found in Material Flow Analysis (MFA) where production processes extract resources from nature where they are transformed into the desired products or services are measured which also considers undesirable outputs (waste, emissions, *et cetera*). The ability to quantify this process and establish ways to minimize physical exchanges between nature and humanity is why MFA was developed (Bringezu and Moriguchi 2002). MIPS calculates resource use from the point of extraction and is

applied to five categories: biotic (or renewable raw material), abiotic (or non-renewable raw material), water, air, and earth movement (in agriculture and silviculture) (Ritthoff *et al.* 2002). This considers all material used in manufacture, use and recycling/disposal and calculates various energy factors and transport. In measuring total inputs, MIPS calculations provide an estimation of the environmental impact potential. MIPS works under the assumption that all inputs eventually become an output, so a MIPS calculation also considers waste and emissions. The ecological rucksack includes the invisible material burden in recognition that the final product requires more natural material than found in its final form (Lettenmeier *et al.* 2009). MIPS has a number of benefits over other measurement methods such as LCA, virtual water and carbon foot-printing; MIPS is a comprehensive ecological indicator and covers the main environmental categories whilst also considering the broad life cycle of a product or service (Mancini *et al.* 2012). MIPS calculations, if they are to be done accurately, must also consider the pre-process-chain of materials. The Wuppertal Institute publish these to avoid recalculation each time.

MIPS can be used for both macro-economic (national and regional economies) and micro-economic (specific products or supply chains) evaluations (Mancini *et al.* 2012). Despite being broader in scope and analysis than other measurement frameworks MIPS are unable to accommodate environmental damage of specific resources and activities (such as toxicity) or measuring specific outputs. As such, MIPS "allows conclusions on the overall pressure on the environment (as any input into the human production-consumption system will become an output at some point in time) but not on specific environmental impacts (Mancini *et al.* 2012 p.781). Despite a lack of specific harm for a specific substance seemingly being a drawback, reductionism facilitates aggregation, measurement and comparison, with the side effect of obscuring the plural and incommensurable environmental impacts of production. As Hinterberger and Seifart note: "[t]o use material input (in kg) as a measure of anthropogenic impairments of nature has the advantage of being universally applicable. In that sense, material input (MI) can be regarded as a proxy measure of the human use of natural capital" (1997 p.79). MIPS by their own nature, highlight the complexity of trying to capture the multiplicity of ways in which human products pressure the environment counter to the intuitive clarity of eco-efficiency.

It is the overall pressure on the environment that a dematerialisation strategy seeks to reduce. As such one MIPS calculation in particular *MI [TMR[3]]=MI[abiotic]+MI[biotic]+MI[erosion]* can give a measurement for material use allowing for the comparison of one product or service with another (Ritthoff *et al.* 2002). Such a measurement can be used for both existing products as well as innovative new products taking into account the multi-level effects between the micro, meso and macro level of

[3] Total Material Requirement

economy (von Geibler *et al.* 2014); Lettenmeier *et al.* (2009) suggest a stepped approach to developing eco-innovation where an existing product is identified, its supply chain determined, the current status of the product assessed and its MIPS estimated and then optimized. The optimization process also allows for new alternatives to be considered to see if the product's MIPS measurement can be reduced. If the MIPS measurement can be reduced, then the product or service shows potential dematerialisation. Such measurements have been applied to a number of different areas in different studies including food (see Mancini *et al.* 2012), comparisons between low energy light bulbs versus incandescent light bulbs (Burger *et al.* 2009) and as a basis for the ongoing EU project MyEcoCost which seeks to inform all economic actors on environmentally relevant information (von Geibler *et al.* 2014). Von Geibler *et al.* note however that attempts to use MIPS to improve measuring resource consumption on the level of companies, consumers and households, is hindered by the lack of links with companies' reporting systems and lifestyles of consumer highlighting a need for research that seeks to address personal consumption.

2.2.4.3 *Eco-efficiency potentials*

Dematerialisation is one of four eco-efficiency potentials found in the literature With the others being immaterialisation, amaterialisation and decarbonisation. However, there is considerable confusion in the literature as to which term is applicable to any given instance. Dematerialisation is often used simply to refer to the reduction in material input, as with the MIPS measurement: any reduction in resource input is considered dematerialisation with no concern for the other three eco-efficiency potentials. Immaterialisation on the other hand, is given several definitions. Tapio and Vähätalo (2013 p.83) define immaterialisation as describing the process of "decoupling of material production and consumption from economic production" whilst acknowledging that this is also referred to as amaterialisation. Jurić and Vogel (2005) conflate immaterialisation with non-materialisation and claim that in consumptions purest form it does not require material goods, provided that basic needs have already been met. They give the example of the consumption of a classical concert where the instruments are needed as a basic requirement but that the enjoyment of the concert is non-material. Although elsewhere in the same paper, they acknowledge Hilty and Ruddy's (2002) definition of immaterialisation where a material product is replaced by an immaterial equivalent. They also note that Malaska *et al.* refer to this same process as amaterialisation. Hietanen (2010) gives an example of immaterialisation as keeping a car well serviced and driving it economically whereas he gives an example of amaterialisation as the substitution of the car and its physical movements for telepresence. Clearly there is confusion between the terms, although all provide a definition or at the least an example to qualify what they mean when they use the words immaterialisation and amaterialisation.

Decarbonisation, according to Tapio and Vähätalo is the combined effect of immaterialisation and dematerialisation which can be measured by CO_2 per economic output. Tapio and Vähätalo's definitions of dematerialisation, immaterialisation and decarbonisation are tied to GDP, energy and CO_2; other definitions are tied only to "material". It is interesting that the only term that features in the Factor *X* (and MIPS) literature is dematerialisation. No equivalent terms are used for immaterialisation and amaterialisation either[4]. This is perhaps because dematerialisation is used as an umbrella term; however, it seems more likely that the Factor *X* literature recognises the naivety of the other examples. Overwhelmingly, discussion of immaterialisation and amaterialisation are associated with Information Technology. The authors fail to recognise that bits and bytes have an impact too and require considerable resources to operate (Maxwell and Miller 2012). Factor *X* on the other hand, acknowledges the potential for reduction from a product to an IT based service but recognises that this service will still have an impact, hence using the term dematerialisation alone. Tapio and Vähätalo are outside this criticism, their definitions of dematerialisation, immaterialisation and decarbonisation can be seen to complement the Factor *X* MIPS measurements. The dis-coordinated definitions are likely the result of the separate literatures' overlapping developing of the comparable terms. The discussion around immaterialisation and amaterialisation is less optimistic than Factor *X* and eco-efficiency as such discussion contradicts the sustainability of the resource and economic decoupling proposed by the latter literatures.

2.2.4.4 *Dematerialisation and rematerialisation*

Throughout the literature there is a general optimism towards dematerialisation. Counter to this however, are a small number of critical voices that express doubt over whether dematerialisation can be maintained, at least at the economic level. Empirical evidence for dematerialisation was first identified in the 1980s but such dematerialisation "can be said to be applicable only to a select group of technologically inferior materials" (Labys 2002 p.202). Labys suggests that markets undergo transmaterialisation over periods of time where old materials are replaced with new; he is critical therefore, of literature that focuses on only a small number of old materials as the dematerialisation witnessed is part of a normal cycle of development in developed countries. Transmaterialisation, Labys suggests, is the more realistic model of dematerialisation where changes in the intensity of use of commodities are reflected as a shift from one group of materials to another in the long term.

De Bruyn (2002) suggests that transmaterialisation occurs as a result of rematerialisation after a period a temporary dematerialisation. De Bruyn identifies two different patterns: an inverted-U curve in which marginal changes allow for a gradual reduction in material intensity over time and an N

[4]Decarbonisation does not appear either, but this is because MIPS do not distinguish material inputs and outputs in this way.

shaped pattern where dematerialisation results from a dramatic shift in technological and institutional structures. However, over time the N shape might be recognised as part of a saw-tooth pattern in which developed economies experience radical changes in the technological and institutional paradigms; this disorientates the relationship between material throughput and income growth (decoupling/dematerialisation) after which the positive relationship between the two is likely to be restored (rematerialisation). What is less clear in the literature is whether similar processes apply to the level of product dematerialisation or indeed transitions between products and services. Certainly within the eco-efficiency literature some attempts have been made to predict dematerialisation such as the analysis of bread supply chains in France by Kulak *et al.* (2016). The anaylsis by Zhu *et al.* (2014) of pesticide use is more typical of this type of product analysis in which similar products are compared with conclusions drawn on their eco-efficiency potential with little consideration of upstream and downstream resource implications. This presents an opportunity to make an original contribution to the dematerialisation literature whereby a product-based analysis can assess the potential for dematerialisation and rematerialisation.

2.2.5 A more than linear analysis for dematerialisation

Despite the fractured nature of the dematerialisation literature it is apparent that the core concept of dematerialisation is consistent with a unified focus in establishing whether dematerialisation is occurring. There are those who claim that continued dematerialisation at a national level is a myth or is the result of moving certain industries overseas (Trainer 2001).

At the product level however, there are few examples which go beyond comparing one product with a revised version of that product. The absence of consideration for the wider context in which such a dematerialisation event has occurred is problematic. It remains unclear in most instances of product dematerialisation if true dematerialisation has occurred or if, as often is argued for the national level, a rematerialisation event has occurred elsewhere. The influence of the dematerialising of a single product or group of products on the system in which it is situated has been rarely considered amongst the existing dematerialisation literature. As such, the impacts on upstream and downstream sectors as well as structures/systems that have supported the dematerialisation of the product are unknown factors. As such, it is unclear if patterns of consumption observed at a national level are also found at the product level. Additionally, the increased material efficiency of the newly dematerialised product may lead to increased consumption of the product or other products negating the initial resource reduction; van der Voet *et al.* (2004 p.123) refer to this counter-productive shift in consumer behaviour as the “re-bound effect” such as consumers leaving energy saving lights on as they are no longer motivated to turn them off (Greening *et al.* 2000).

The research conducted by Van der Voet *et al.* (2004) into the materials that contributed the most to environmental problems in the Netherlands is particularly notable because it is one of the only dematerialisation studies to give detail about their methodology. Their reflections highlight three problems with attempting to ascertain whether dematerialisation is occurring. First, that boundaries are drawn around the product are too narrow and fail to consider the larger system. Second, and this appears to be true of the dematerialisation literature generally, it is unclear under what conditions a dematerialisation event may occur. Third, the focus is almost exclusively on the production of the product or service and thus the dematerialisation literature has thus far ignored the consumption of the product. Consumption of the product or service will impact on dematerialisation. The opposite is also true however as dematerialisation will have an impact on the consumer of the product or service: this is especially true when a product becomes a service. Other more recent studies have been more aware of these short comings however. Hochschorner *et al.* (2015) situate internet based movie distribution within a convincing boundary that includes both the network of computers used to deliver the movies as well as the audio-visual equipment required to watch them finding that it was primarily the consumer side equipment (TV and Computer) that continued to be the main contributor of environmental impact across the system. For the most part, such complex interacting relationships remain undiscussed in the existing dematerialisation literature. Ultimately, focus remains on system specific resource use and its associated economics and says little about the socio-technical context of dematerialisation and the literature has offered analytical frameworks that are largely incompatible with any attempt to consider changes in consumption because of changes in technology and how that relates to dematerialisation.

The eco-efficiency literature presents dematerialisation with an intuitive clarity yet as efforts to measure dematerialisation (such as Factor *X*) show, it is difficult to capture the multiplicity of ways in which human products pressure the environment. The dematerialisation literature has a focus on weight but as van der Voet *et al.* (2004 p.123) note "lighter materials are not necessarily more environmentally friendly than heavier materials". De Bruyn *et al.* (2002) concur, arguing that delinking would be the preferred indicator to measure reduction in environmental pressures. Such claims have methodological implications and are discussed further in chapter 3.

It is evident in reviewing the existing dematerialisation literature that several potential avenues are open for further research that would contribute to a better understanding of dematerialisation processes. Dematerialisation does not occur in isolation despite how it seems to be portrayed in the literature, there is a significant gap in knowledge when it comes to dematerialising a product and the effect that has on the rest of the system. There is scope therefore, for a study that expands the context of dematerialisation, locating it somewhere between an individual product and an entire economy.

Additionally, such a study could also consider a more temporal context of the event, as well as question issues of agency.The study could contribute to an area of dematerialisation that is currently under-theorised. However, as already noted the existing literature offers no framework suitable for such an analysis. The following section addresses this, highlighting that dematerialisation should be thought of as more than an event, locating it temporally as part of a transition within a socio-technical system.

2.3 Dematerialisation as socio-technical transition

Dematerialisation is advantageous for sustainable development. It can be seen as a special type of transition: a desired outcome of, as well as a contributory factor to, sustainable development (von Weizsäcker *et al.* 1997). With technology and structural changes reduction of material throughput in human societies not only contributes to sustainable development goals of reducing outputs such as CO_2 but also promotes a reduction of inputs like energy and mined materials which can have their own, wider ecological implications. This dematerialisation process can be considered, in Factor *X* terms, as a transition from one ecological rucksack to another reduced one. Such a transition should have a reduced environmental impact[5]. However, the existing dematerialisation literature views dematerialisation transition as a straight forward linear process of material reduction within a system. There is some indication in the literature that an analysis of such a transition only determines dematerialisation short term, indeed this is one of the main criticisms of the existing dematerialisation literature (Trainer 2001). In considering dematerialisation of product as part of a wider system it is possible to introduce several other avenues for analysis. Upstream and downstream sectors, as well as supporting technologies and structural changes, all have the potential to be impacted by the dematerialisation of a product. Beyond this, actors such as consumers, sales people and manufacturers will also likely be affected by, and constitutive of, a dematerialisation process. This is particularly true of transitions from goods to services and yet agency seems to be absent from the dematerialisation literature (Halme *et al.* 2004). In this sense, the analysis of the dematerialisation of a single product is too narrow to determine if dematerialisation has really occurred long-term; additionally, such an analysis also tells us nothing of the effects dematerialisation has on the socio-technical system of which the product is a part.

A socio-technical system is a complex "co-evolution of institutional and technological elements into a highly institutionalised configuration that enables the fulfilment of specific societal functions" (Fuenfschilling and Truffer 2016 p.298). Dematerialisation is something that influences technological

[5] Although it is noted in the literature that some materials are considerably more hazardous than others – this is particularly problematic when substitution occurs as a means of reducing material input (von Weizsäcker 1998)

elements and, by association, institutional elements. Within any socio-technical system change occurs but when either institutional and technological elements change significantly the institutionalised configuration can also change (Rip and Kemp 1998). Viewing dematerialisation as a socio-technical transition complements existing dematerialisation literature. Cleveland and Ruth (1998 p.17) state that "social, economic, technological, institutional and environmental forces" all play a role in dematerialisation, all of which constitute a socio-technical system. Indeed, a number of well documented examples exist that explore these forces, for example, technical improvements reduced metal use in drinks containers (Nappi 1990), communications (Key and Schlabach 1986) and car manufacture (Larson *et al.* 1986) whereas technical advances combined with reorganisation reduced paper use (Bellini *et al.* 2013). Whilst such studies typically identify some driving forces, they do so in limited contexts thus overlooking the factors that facilitate dematerialisation transitions and the factors that are altered by them. They also rarely analyse the long-term effects of dematerialisation on the socio-technical system, nor the structures that have supported it. There is considerable scope therefore, for a study of dematerialisation that encompasses these concerns.

In treating dematerialisation as a transition that occurs within a socio-technical system, as opposed to just an isolated event, the lens of enquiry can be refocused. In broadening the area of analysis, both spatially and temporally, a clearer picture of the process of dematerialisation within an expanded context can be obtained. As argued in section 2.2.1.2, analysis of dematerialisation would benefit from a broader temporal and spatial context. Indeed, given that many studies have thus far settled on the nation level of the spatial scale (Barles *et al.* 2012; Hinterberger and Seifert 1997; Marra Campanale and Femia 2013; Prior *et al.* 2012; von Weizsäcker 1998), the rebound effect (rematerialisation) is often observed but what remains unclear from the small number of studies that focus on product is if this is a typical trend throughout the spatial scale.

In theorising dematerialisation in a more than linear event manner, dematerialisation is no longer something that happens in isolation. Instead, the possibility to see effects of dematerialisation on the rest of the socio-technical system and the effects socio-technical systems have on dematerialisation becomes possible whilst retaining explanatory factors from the existing (and synonymous) literature. If dematerialisation literature has so far focused on conceptualisation, measurement and identification of component steps then it is possible, in redefining dematerialisation as a socio-technical transition, to analyse the socio-technical system in which the transition occurs whilst retaining methods of analysing changes in material throughput. The socio-technical literature is well established theoretically, providing several perspectives and frameworks suitable for studying socio-technical transitions. As noted by Geels and Kemp, a "socio-technical approach to transitions conceptualises […] a configuration of elements that include technology, policy, markets, consumer

practices, infrastructure, cultural meaning and scientific knowledge" (2012 p.49). Such an approach offers a broader perspective than dematerialisation alone which has hitherto analysed only a limited set of dimensions. In particular, the multi-level perspective was developed to analyse and understand transitions and regime shifts happening within socio-technical systems (see Rip and Kemp 1998; Schot *et al.* 1994; Geels 2002; Geels 2005c).

2.4 Multi-level perspective on dematerialisation transitions

Ontologically, the multi-level perspective developed within the sociology of technology literature in which three inter-related dimensions were identified: socio-technical systems which contain the tangible elements required for society to function; social groups who maintain the socio-technical systems; and rules, which guide the social groups activities (Geels and Kemp 2007). The three elements co-structure and influence each other. The social groups contain actors, who conform to the regulative, normative and cognitive rules whilst also creating and promoting their existence; such actors include: companies, who react to problems with existing technology; products that are part of consumption patterns, either because of cultural meaning or embedded through routine; consumers who have certain lifestyles apply certain cultural meaning to products. These rules are semi-coherent and Rip and Kemp (1998) developed the rules into 'technological regimes' expanding the work of Nelson and Winter (1982) who coined the term. "A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems – all of them embedded in institutions and infrastructures" (Rip and Kemp 1998 p.338). This section further explores the multi-level perspective literature whilst demonstrating how the perspective may benefit a study of dematerialisation transitions. The multi-level perspective consists of three levels: the socio-technical regime, niches and the socio-technical landscape.

The multi-level perspective offers several distinctive features that whilst not necessarily unique, have been brought together in a unique way that makes the multi-level perspective a particularly viable start-point for the study of dematerialisation transitions. As argued above (section 2.3), dematerialisation of product needs to be considered in broader temporal and spatial contexts to assess whether dematerialisation has occurred or if the dematerialisation of the product has caused a rebound effect. The multi-level perspective offers a longitudinal approach to studying transitions which might be better considered as historical analyses of transitions (Geels 2002). Such an approach allows the researcher to identify an incumbent regime and to detail the effects that a transition has on it over time.

As recognised in sections 2.2.3 and 2.3 existing dematerialisation studies focus little on agency. This can lead to questions over the social groups responsible for dematerialisation and in the eco-efficiency (see section 2.2.1.2) and Factor *X* (see section 2.2.1.3) scenarios where agency lies regarding the development of the technology that leads to dematerialisation. The multi-level perspective allows for an agency based approach (section 2.4.5.1) because it assumes that the alignments and trajectories of the transition are always enacted by social groups (Geels 2011). Further, the structural levels (discussed below) that are theorised are reproduced and enacted by actors (Geels 2004; Geels and Schot 2007; Geels and Schot 2010). Further to these features, the multi-level perspective offers several other advantageous conceptual elements for the study of dematerialisation transition which are discussed below. In defining the conceptual components of the multi-level perspective, further consideration is given to the ways in which the multi-level perspective can enable a thorough analysis of dematerialisation transition beyond those afforded by typical dematerialisation studies. The following section is structured in a manner that both introduces the multi-level perspective as well as attempts to show how such an analytical tool could work for dematerialisation transitions. As such it introduces the three levels found within the multi-level perspective, the regime (2.4.1), the landscape (2.4.2), the niche (2.4.3), the concepts of transition patterns and mechanisms (2.4.4), criticisms of the multi-level perspective (2.4.5) and closes with concluding remarks on what the multi-level perspective as an analytical tool means for the study of dematerialisation transitions (2.4.6).

2.4.1 Socio-technical Regime

Geels (2004) widened technological regimes into 'socio-technical regimes' in order to show the inter-organisational community as a unit of analysis. By broadening the regime definition it overcame the tendency found in innovation studies to view manufacturers as the key actors to the detriment of other potential key actors (Geels and Kemp 2012). This is particularly helpful in studying dematerialisation as it enables us to see beyond the dematerialisation to the where the agency lies.

The social groups within a socio-technical regime are largely autonomous but the socio-technical system is not itself autonomous and is coordinated by human actors. These groups are capable of interpenetrating one another without losing their identity or autonomy (Geels and Kemp 2012). This meta-coordination of technological regimes, user and market regimes, socio-cultural regimes, policy regimes and science regimes create rules which are linked not just within regimes, but also between regimes. In studying dematerialisation transition, this meta-coordination allows for the analysis of outside factors on the operationalisation of dematerialisation; going beyond the manufacturer it opens many possible new driving forces such as changes in other technical regimes or consumer preference in facilitating or initiating a dematerialisation transition.

Socio-technical regimes are inherently stable as the social groups maintain and reproduce the system elements according to deep structural rules (Giddens 1984). A stable socio-technical regime should not be regarded as a static regime however, change still occurs but innovation is usually predictable and incremental "because of lock in mechanisms and path dependency" (Geels and Kemp 2012 p.54). Dematerialisation transitions have the potential to occur within static regimes in a manner that has little effect on the wider regime, in particular where dematerialisation is the result of predictable efficiency improvements such as in the automotive sector (Miller *et al.* 2000).

The socio-technical regime is considered the meso-level of the multi-level perspective. However, the multi-level perspective does not predefine what this level consists of. The scope of analysis relies on the boundaries drawn by the researcher (Geels 2011), as such, the meso-level can range in size and concept dependent on the topic of study. This can range from entire sectors such as the automobility sector (Geels *et al.* 2012), to smaller seed supply systems (Li *et al.* 2013) and the implementation of a biogas digester (Campbell and Sallis 2013). Indeed, what may be considered the whole socio-technical regime in one study may be considered just a component in another (Geels 2011). Although this has been criticised by Berkhout *et al.* who argued that "it is unclear how these conceptual levels should be applied empirically" (2004 p.54), Geels (2011) retorts that this is a typical boundary and topic definition problem; indeed, the same issues or boundary occur in the eco-efficiency literature (see section 2.2.1.2) and broader dematerialisation literature (see section 2.2.3). For the study of a dematerialisation transition however this fluidity is beneficial. The dematerialisation literature spans from the dematerialisation of a single product to that of national economies and so there is no conflict between the multi-level perspective and dematerialisation literature regarding the unit of analysis. The only requirement that the multi-level perspective stipulates is that the unit of analysis and its boundaries are well defined as such components/boundaries are integral to explanation entailing the identification of key actors and their linkages. Additionally, where the dematerialisation literature is limited in analysing drivers towards and consequences of transition the socio-technical regime considers all aspects of an inter-organisational community.

2.4.2 Socio-technical landscape(s)

The socio-technical landscape is an exogenous environment that sits beyond the influence of actors found in the socio-technical regime and niche levels. In some respects the socio-technical landscape is "everything else" but one has to be wary of treating it as a dumping ground for external influence as this is one of the key criticisms levelled at the multi-level perspective (Geels 2011 p.36). However, it frequently includes "aspects such as economic growth, broad political coalitions, cultural and normative values, environmental problems and resource scarcities" and it is used to "emphasise the large-scale material context of society, e.g. the material and spatial arrangements of cities [and]

pervasive technologies that affect all of society" (Geels and Kemp 2007 p.443). Socio-technical landscape(s) add a level of structuration as they are largely beyond the influence of individual actors. It is often changes in socio-technical landscape(s) that enable niche novelties (discussed below) to develop and alter the socio-technical regime. For dematerialisation transitions, such a change might provide either an opportunity or a driver for change such as change in legislation. Such change would facilitate a niche novelty to destabilise the incumbent socio-technical regime.

2.4.3 Niches

Niches are home to actor arrangements and may be coordinated geographically. They give rise to noveltiessuch as a new technology or a new practice (Geels and Kemp 2012). Niches act as "incubation spaces dominated by uncertainty and experimental disorder" (Coenen *et al.* 2012 p.971) and are "protected spaces in which actors learn about novel technologies and their uses" (Geels 2002 p.365). In the instance of a dematerialisation transition a new technology may be developed that significantly reduces material input of a product. However, this new technology will be shaped by external forces as well as exerting its own influence on individuals and companies' expectations. Geels and Kemp (2012 p.53) note that the literature has distinguished three social processes that happen within niches:

- "The articulation (and adjustment) of *expectations* or *visions*, which on the one hand provide guidance and direction to the internal innovation activities and on the other hand aim to attract attention and funding from external actors
- The building of social networks and the enrolment of more actors, which expand social and resource base of niche-innovations
- Learning processes on various dimensions, about imperfections of technology and how they may be overcome, issues of organization, market demand, user behaviour, infrastructure requirements, policy instruments and symbolic meanings".

Social processes shape the transition potential of the niche and its trajectory in destabilising the existing arrangements of the socio-technical regime (Geels 2002).

The socio-technical regime, socio-technical landscape(s) and niches form the main analytical framework which encompass the entire transition, "like a helicopter view" (Geels and Kemp 2012 p.59). They allow for the study of a dematerialisation transition from start to finish but they provide only a basic framework of long-term events. Alone, they do not incorporate the shorter-term mechanisms and patterns that are required to flesh out the multi-level perspective. The multi-level perspective literature identifies several transition patterns and actor-related transition mechanisms.

2.4.4 Transition patterns and transition mechanisms

Transition patterns and mechanisms within structural transformations are important to the study of dematerialisation transition. The multi-level approach is good at detailing the overall technological transition but less so at broader shifts in behaviour and societal change (Bergman, Haxeltine, *et al.* 2008). Conceptualising a more detailed point of analysis, transition patterns and mechanisms allow for the study of changes that happen intra-structurally. Further, the introduction of transition patterns and mechanisms allows researchers to determine what, if any, influence such changes have on the scope and direction of transformative change as well as allowing for a finer temporal analysis of the transitions within the over-arching transition (Walrave and Raven 2016). As Geels and Kemp (2012 p.59) put it "these patterns and mechanisms help to put more flesh on the bones of the multi-level perspective". In adding this flesh, the causal links at play in a dematerialisation transition should become conceptually clearer. By articulating and exploring how these factors can lead to both stability and change within the system, it is possible to identify transition patterns and mechanisms which highlight the precursors, dynamics and complexities of navigating the contours of the socio-technical landscape (Avelino 2009; Weaver and Rotmans 2006; Whitmarsh 2012). Several studies have already utilised this more in-depth approach on empirical case studies. These include the transition to sustainable housing in the UK (Bergman *et al.* 2007; Bergman, Whitmarsh, *et al.* 2008), comparisons between electricity transitions in Germany and the UK (Geels *et al.* 2016) and transitioning to vehicles powered by hydrogen or electricity (van Bree *et al.* 2010). The potential for such analysis of transition patterns and mechanisms in dematerialisation transitions follows. It utilises the latter two studies which are of note here given that they deal with transitions specifically related to the use of environmental resources.

Both the Geels *et al.* (2016) and van Bree *et al.* (2010) studies analyse actors and their institutionalised relationships within transitions related to electric automotive technologies and how these relate conceptually to the broader socio-technical context. In doing so, both studies take Geels and Schot's (2007) original conceptualisation of four transition pathways (transformation, de-alignment and re-alignment, technological substitution and reconfiguration) and seek to reconceptualise them. All the pathways were originally conceptualised to account for incremental adjustments that lead to transition. In broadening the analysis of transition pathways further Geels *et al.* (2016) borrowed concepts from neo-institutional literature notably the work of Thelen (2003) and Mahoney and Thelen (2009). The *layering* of new institutions atop of existing arrangements and *drift,* in which implementation on the ground sees a gradual change in policies being used with no official decision being made, are like the existing incremental change conceptualisations of transition. *Conversion,* in which goals but not instruments are changed and *displacement*, in which new institutions overtake

old ones are conceptualisations of far more significant change. In reformulating transition pathways Geels *et al.* highlight these more significant changes as demonstrating "conflicts between incumbents, subversives and other actors". Through such reformulation, the transition pathway concept becomes more sensitive to agency and therefore more conceptually useful to the study of dematerialisation.

The conceptual usefulness of the reformulated substitution pathway in analysing agency can be illustrated further. The substitution pathway was originally conceptualised as a pathway through which niche and regime technologies developed separately and were carried by different actor groups. In the 'normal' substitution pathway new actors struggle against established actors (new firms against established firms) wherein innovation is in part driven by the conceptualisation of a David verse Goliath duality. However, more recent thinking about such technological substitution sees a far greater array of potential actors driving innovation in a far more pluralistic conceptualisation. Seyfang and Smith (2007) note that certain types of radical sustainability innovations may be developed and deployed by outsiders such as social movements, activists or citizens with normative motivations. Geels *et al.* (2016), add that new entry may come from incumbents in other sectors such as internet companies diversifying and moving into these sectors. The potential therefore for actors to disseminate their technologies from outside of the sector and having a direct impact on the incumbent actors and regimes is revealed through this reconsidered approach to the substitution transition pathway.

There is great relevance of this approach to dematerialisation transition studies. The interplay between the many types of actors and the emergence of new actors outside of the established regime, or new entrants to it, are significant. The potential for actors to emerge outside of the sector is real and any study must account for this in analysing the finer detail of the transition and the mechanisms through which such transitions may come about.

Actor related transition mechanisms allow for the analysis and conceptualisation of the rationale of actor behaviours both in the regime and the niche (Geels and Kemp 2012). Specific to the analysis at hand there is far less attempt made within the multi-level perspective literature to ground such concepts in other literatures. Instead, actor-related transition mechanisms are illustrative and metaphorical tools to group actors together by their apparently similar behaviours identified during analysis. Such an approach is similarly advantageous to a study of dematerialisation transitions in the same manner as the conceptualisation of transition patterns; as a means through which to further understand agency, actor motivation and actor behaviours *inter alia*. The more recent reformulation of transition patterns and the increasing number of actor-related transition mechanisms that have been identified seek to respond to criticism of the multi-level perspective that suggests it had

previously not been attentive enough to agency during analysis. The salience of this criticism and others levelled at the multi-level perspective have relevance to a new study that intends to utilise the multi-level perspective as a means of analysis. The criticisms considered pertinent to a study of dematerialisation transitions are reviewed and discussed in the following section to illustrate this relevance.

2.4.5 Criticisms of the multi-level perspective

The multi-level perspective is still a relatively new framework for analysing transitions. In some ways, it is controversial and is the subject of several criticisms from within the extended transition literature. These criticisms include (a) a lack of agency (Smith *et al.* 2005; Genus and Coles 2008), (b) operationalization of regimes (Berkhout *et al.* 2004; Genus and Coles 2008; Markard and Truffer 2008), (c) bias towards bottom-up change models (Berkhout *et al.* 2004), (d) epistemology and explanatory style (Genus and Coles 2008), (e) treating socio-technical landscape(s) as a residual category (Geels 2011), (f) a flawed use of secondary data sources (Genus and Coles 2008), and (g) that the multi-level perspective promotes and consists of hierarchical levels (Shove and Walker 2010). It is not necessary to engage with all these criticisms as they have been answered elsewhere in the multi-level perspective literature specifically by Geels (2011) but also Jørgensen (2012), Raven *et al.* (2012) *inter alia*. However, the issues surrounding agency, the operationalisation of regimes and the use of secondary sources are worth engaging further here as these criticisms directly affect a study of dematerialisation transitions. Agency has already been highlighted as absent from the dematerialisation literature (see section 2.3) and so to engage the multi-level perspective as an analytical tool with the intention of gaining an understanding of agency as it relates to dematerialisation transitions without further addressing these existing concerns seems unwise. In addressing the existing criticisms of agency in relation to the multi-level perspective at this juncture, the criticisms and responses to them can inform the research design so the same criticisms cannot be levelled at the resulting analysis. Further, where questions remain over the efficacy of the response it may be possible for these to be incorporated so that the research offers an original contribution to the multi-level perspective literature as opposed to only taking from it.

2.4.5.1 Agency

Smith *et al.* (2005 p.1492) complain that multi-level perspective approaches "tend to be too descriptive and structural, leaving room for greater analysis of *agency* as a means to more informed, deliberate and effective processes of regime transformation". They specifically seek to encourage greater attention to agency within regimes. Similarly Genus and Coles (2008) claim that:

> "the making or unmaking of the various types of rules constraining or enabling actions and the reproduction of related practices central to maintenance or transformation has not been an explicit object of systematic study in multi-level perspective research—not in case study histories, and certainly not in any contemporaneous analysis." (Genus and Coles 2008 p.1442)

To remedy this apparent lack of agency Genus and Coles suggest the inclusion of approaches such as Actor-Network Theory. However, given that Actor-Network Theory has its own language to describe the complex associations between the social, technological and natural (see Sarker *et al.* 2006), as well as being itself controversial (see Latour 1999; Latour 2005), the combination of both the multi-level perspective and Actor-Network Theory would prove unnecessarily complex in part due to their specific languages but mainly because as Geels (2011) points out Actor-Network Theory is ontologically flat. Additionally, though it helps to explain how certain actions hold together over space and time and others fall apart, Actor-Network Theory too is weak on issues of human intentionality (Elder-Vass 2008).

Geels (2011) also claims that there is a dissonance between the criticism made by Smith *et al.* and Genus and Coles and the actuality of the multi-level perspective literature in so much as agency is not an absent feature of the multi-level perspective. Although he acknowledges that "certain *types* of agency are less developed, e.g. rational choice, power struggles, cultural-discursive activities" he claims that proponents of the multi-level perspective have always felt that agency was present (Geels 2011 p.29 his emphasis). The multi-level perspective developed from STS and so "accommodates agency in the form of bounded rationality" (Geels 2011 p.29).

Geels further argues that the multi-level perspective distinguishes between (a) actors and social groups, (b) rules and institutions, (c) technologies and socio-technical systems and articulated dynamic interactions. Although the criticisms of Genus & Coles (2008) and Smith *et al.* (2005) called for further focus on actors and social groups within regimes the multi-level perspective literature already had or moved to explicitly address these concerns beyond the structural focus of the earliest contributions (see Geels 2004).

The response was taken further by Geels and Schot (2007) who distinguished links between agents and trajectories occurring within the field. Geels and Schot conceptualised such a trajectory around agency as a sequence of linked events. The (a) conditioning of actors by the existing structures' rules and institutions, (b) social interactions between actors, (c) structural elaboration through, for example, the reproduction of rules and institutions and (d) externalisation and institutionalisation. Such a conceptualisation reveals that trajectories are enacted and those that are stable require actors to continually to reproduce them. This conceptualisation of agency within the multi-level perspective formed the basis of the reformulated transition pathways devised by Geels *et al.* (2016) (see section

2.4.4) although it remains that any approach to agency within the multi-level perspective has not necessarily been consistent. The response from Geels (2011) treated such criticisms about the lack of agency as a cosmetic issue in which he demonstrated that the multi-level perspective dealt with agency all along but that perhaps it should have been semantically clearer. However, problems with agency remain.

It is still not clear from the literature how the contribution of actors to transitions can be captured, nor what those contributions may be, nor what such influence agents might have on the transition process. Pesch (2015) suggests that the agency related problems stem from the number of theoretical frameworks brought together to shape and inform the multi-level perspective (at least seven different ontologies (Geels 2010)) each bringing with it its own implications for agency. The focus has therefore been on the reproduction of meanings, institutions, regimes and practices to the detriment of the new which have gone largely unarticulated. Some historical analyses have had some focus on these new practices and regimes but have focused on the simplified alignments and realignments between niches and regimes which have provided little in the way of analytical insight into how such processes are invigorated (Geels 2005d). Pesch argues that the focus on the reproduction of rules connects people to their institutional roles. In this way, they become representatives for their industry, political interests, *inter alia* to the exclusion of their own individual decisions and motivations. This can be seen in the nature of the agency as analysed by Geels (2011) and Geels and Schot (2007), as discussed above, whereby actors are grouped into "political groups and social movements" despite others arguing that the root of agency resides with individual actors (Garud and Karnøe 2003). Further, Shove and Walker (2010) highlighted the importance of "consumers and practitioners […] as and vital to change" in the same was as a producers and promoters within regimes. Consumers and practitioners however, are typically outside regimes in the transition literature yet have the potential to be relevant actors in the development of technical change along with other outsiders (Poel 2000). The role of practitioners and consumers seems to be particularly pertinent to the study of dematerialisation transitions, where the adoption of dematerialised goods and services relies heavily on being adopted by home users, as discussed in section 2.2.3.

This extended criticism of the lack of agency in the multi-level perspective highlights additional areas for analysis in which dematerialisation may be enacted. The broadening of the analytical context of the multi-level perspective when applied to dematerialisation transitions, and indeed to socio-technical transitions, more generally, helps the researcher find appropriate information about how transitions are enacted so that change processes can be analysed and explained in as coherent and full a manner as possible. In grouping actors within the regime, the multi-level perspective has so far failed to analyse agency at a level below that of a group of a subset of actors despite that apparent

importance of such individuals. This may in part be linked to another one of the criticisms of the multi-level perspective, that of the operationalisation of the multi-level perspective structure.

2.4.5.2 Operationalization of multi-level perspective levels

Several criticisms are found in the literature on the operationalization of regimes; some criticisms have been responded to and appear settled whereas other criticisms remain an on-going concern. Berkhout *et al.* (2004) were concerned that the multi-level perspective did not prescribe what the various conceptual levels were and how they should be applied empirically. Whilst this criticism has implications for methodology and analysis, according to Geels (2011 p.31) this is "the normal problem of drawing boundaries and defining the topic of analysis" and that "[t]he scope of the empirical topic will have implications for the operationalization of the regime concept (e.g. the number of actors, their relationships and the coordinating rules/institutions)". However, the criticism is broader than just the operationalisation of the regime, as the levels of the multi-level perspective represent different degrees of structuration and differ regarding their potential to influence actors and their activities. Despite their key roles in the multi-level perspective, the niche, regime and landscape levels are all too often assumed rather than their empirical application made explicit (for further criticism of this see Berkhout *et al.* 2004; Genus and Coles 2008; Markard and Truffer 2008; Shove and Walker 2010; Smith *et al.* 2005). This is a concern when taken alongside the criticism above (section 2.4.5.1), as it can be inferred that the failure point for the lack of agency may be that the point of analysis was incorrectly considered as assumptions are made about regimes that apply a congruity they may lack.

The risk in conveying assumptions is true in all structures of the multi-level perspective. As Fuenfschilling and Truffer (2016) note, most multi-level perspective studies delineate niches and regimes based on assumptions on the maturity of the technology and actors rather than empirical assessment. Similarly, most studies do not provide any form of description of the structures of the socio-technical system. This in turn leads to a lack of explicit discussion about the analysis of the conflicts, tensions and debates within the systems and as such this leads to the tendency to portray regimes as too harmonious and homogenous in empirical accounts. In doing so, transitions are depicted as small innovations overthrowing a unified regime actor or block of actors and their established technologies. In taking a more analytical interest in the structure and structuration of the subject of study and assessing the technologies and actors empirically the operationalisation of the multi-level perspective levels has the potential to provide a clearer analytical output for strengthening our understanding of transition dynamics.

An additional concern highlighted by Geels (2011) is the overwhelming focus on a single regime when he believes that for sustainability transitions it might be better to consider *multi-regime* interactions

as discussed and illustrated by Raven (2007) and Konrad *et al.* (2008). As such, the operationalisation of the multi-level perspective's levels is of even greater analytic importance here if additional regimes are to be brought into the analysis. As already identified in reviewing the dematerialisation literature (see sections 2.2 to 2.4) dematerialisation happens across different sectors and as such are likely to benefit from an analysis of multi-regime interactions. Whilst the multi-level perspective has yet to be utilised for dematerialisation transitions a number of sustainability transitions have been analysed, several of which have shown how certain niche innovations "requires interactions between two (or more) regimes" (Geels 2011 p.32) due to the "interrelated transformation dynamics in production, consumption and governance" (Konrad *et al.* 2008 p.1190). As such, an analysis of dematerialisation transitions may also be able to contribute to an understanding of the positive and negative influences transitions have on other regimes which Geels notes is "an understudied but promising topic" (2011 p.32).

2.4.5.3 Use of secondary sources

Much of the early multi-level perspective literature is written to illustrate the potential of the multi-level perspective as a tool for analysis rather than specifically to provide an historical analysis of certain case studies. As a result of this focus however, the reliance on secondary and tertiary sources went unchallenged until Genus and Coles (2008 p.1441) called into question the "flawed use of secondary data sources".

Genus and Coles found that previous research employed an evolutionary historical case study method "without acknowledging the debates surrounding the presentation, and use, of such data" (Genus and Coles 2008 p.1441). Indeed, much if not all, of the multi-level perspective literature never even stated what the source of the historical narrative was; whether it was constructed from multiple primary and secondary sources, collected tertiary works or even pop culture accounts of historical events are known only to the original authors. Whilst Geels claimed Genus and Coles' original criticism is underspecified as no particular error was highlighted, Genus and Coles extrapolate their concern further in the foot notes citing Carr's What Is History? where Carr claims "the facts of history never come to us 'pure' since they do not and cannot exist in pure form: they are always refracted through the eyes of the researcher'" (Carr 1961 p. 22 in Genus and Coles 2008). Whilst the inference that each researcher has added their own impurity to the narrative in some way it is understandable why Geels is perhaps slightly dismissive of the criticism. At the core is a criticism that can be levelled at all interpretive methodologies although Geels acknowledged that "transition case studies" had so far "aimed more at illustration and exploration that at systematic research" (Geels 2011 p.36). Despite this defence Genus and Coles criticism was not without merit. It is important to understand the presentation and use of secondary and tertiary data. If data has passed through multiple researchers,

it is important for the reader to know how impure the data is. Whilst it was ultimately inconsequential in illustrating the potential of the multi-level perspective when multi-level perspective studies began using the multi-level perspective as a tool for analysis the data was once again the most important element. The methodological importance of this criticism for transition studies, and by extension dematerialisation transition studies, is that a far greater transparency must be given to the origin of the sources when synthesising data into a comprehensive interpretation suitable for multi-level perspective analysis. More recent analyses have begun given some detail as to where their sources of data originate, although this is still often not referenced as rigorously as academic articles (see Acheampong *et al.* 2016; Nilsson and Nykvist 2016; Cowell *et al.* 2017 for recent examples with explicit discussion of sources).

2.4.6 Summary discussion on the use of the multi-level perspective for dematerialisation transitions

The review and discussion of the multi-level perspective literature above seeks to highlight the many ways in which the multi-level perspective could enhance analysis of dematerialisation transitions. Dematerialisation studies have largely been confined to numerically ascertaining dematerialisation status and little in the way of research into the socio-influence on or resulting from such transitions. If we take dematerialisation to be defined as the reduction of material use per unit resulting from technological and structural changes then that are very explicit links between dematerialisation as transition and other sustainability transitions to which the multi-level perspective has already proven to be a valuable analytical tool. Beyond this however, the multi-level perspective as an adaptive analytical tool shows the potential to allow for the analysis of dematerialisation transitions in a far more analytically detailed and robust way than has happened previously. Across the gamut, from a socio-technical perspective, the introduction of the multi-level perspective to dematerialisation transition should provide a far more contextually rich and finer detailed analysis of dematerialisation transitions giving far greater insight into the drivers and impacts of such transitions.

The discussion by De Bruyn (section 2.2.1.1) highlighted the importance of structuration to the analysis of dematerialisation, a concept synonymous to the operationalisation of the levels of the multi-level perspective. The dematerialisation and multi-level perspective literatures both use case studies for analysis. As the multi-level perspective is responsive to the researcher's needs the system boundaries can be drawn to suit the context of the dematerialisation transitions. The operationalisation of the multi-level perspective and by extension the dematerialisation transition being studied is of great benefit as it forces the researcher to better define the system boundaries of the dematerialisation process which forces a greater consideration of the wider context of dematerialisation, its impact and the possibility of rematerialisation (see section 2.2.3). The operationalisation of the multi-level

perspective also provides a far better explicit structure for the analysis of the various structures of production of the different economic sectors that may be affected by or contribute to dematerialisation – something the dematerialisation literature had only done implicitly as part of some analyses (see von Weizsäcker *et al.* 1997). Further, assuming the criticism of the operationalisation of the multi-level perspective's levels is adhered to (see section 2.4.5.2) the multi-level perspective encourages the researcher to approach the dematerialisation transition without a priori assumptions about existing structures and instead ascertain these through empirical application.

The multi-level perspective further helps the researcher to identify additional areas in which dematerialisation may be enacted enabling the researcher to find appropriate information. Dematerialisation transitions have been limited to analysing drivers towards and consequences of transitions. The multi-level perspective allows for analytical interrogation of the entire inter-organisation community. Again, assuming the criticisms above are observed (see section 2.4.5.1) the interplay between the many types of actors including new ones emerging from outside of the sector can be observed and analysed, something that is not done in existing dematerialisation studies. The role of the individual has been underplayed in the multi-level perspective literature today and is seemingly absent in the dematerialisation literature although the discussion on agency above highlighted the potential of the individual as an additional area of analysis within the multi-level perspective and therefore in gaining further insights into dematerialisation transitions.

2.5 Conclusion

The proposed reductions in emissions were linked to reduced resource use in the literature as evidenced by the EU funded SCORE initiative (Sustainable Consumption Research Exchange). The SCORE initiative cited several routes to reduce environmental pressure through the lowering of material demands in consumption and production. Whilst some such as Fuchs and Loreki (2005) saw reduction as essential to strong visions of sustainable development others were dismissive of the potential of the long term potential of dematerialisation.

It was clear from the existing literature that dematerialisation had received relatively little attention as an overt concept despite the apparent importance given to it, or at least the concept of it, in sustainable development literature.

In bringing together synonymous concepts it was possible to define dematerialisation and to determine several ways in which it may be measured. However, in doing so it highlighted the extent to which the various dematerialisation literatures had focussed on the national level of shifts in materiality. That is, few examples exist that consider dematerialisation at a product level and as such

how such an outcome might affect the wider social context in which it is occurring. The upstream and downstream factors are also rarely considered. In exploring and probing dematerialisation literature, further it became increasingly evident it should be thought of as more than a single event. The boundaries of the system that contained it needed to be expanded so that a deeper conceptualisation of dematerialisation could be formed. Although some examples of this were identified for the most part they remain scarce in the literature (see section 2.3). Dematerialisation in its simplest terms is something going from one state with a prescribed amount of material to another state with less material. This material reduction occurs, not as a linear event, but as a set of transitional processes brought about through innovation. As section 2.3 argues, dematerialisation should be thought of as more than a linear event if we are to further understand dematerialisation. It is important to analyse the complex socio-technical system in which the dematerialisation transitions are occurring. Doing so responds to one of the main criticisms of the dematerialisation literatures, that the short time frames and narrow system boundaries typically involved mean that dematerialisation is identified short term but the long term picture and implications are unobserved (Trainer 2001). In this way, the previously unobserved aspects of dematerialisation are observed and analysed in a way that offers a contribution to the dematerialisation literature by offering a 'more than event' narrative, a greater understanding of the socio-technical context which leads to dematerialisation and the impacts of dematerialisation on that same socio-technical system and perhaps beyond its boundaries.

In conceptualising dematerialisation as a complex socio-technical transition the multi-level perspective on sustainability transitions was put forward as a framework which could be adapted for use as an analytical tool to make such a conceptualisation analytically useful. Both the existing dematerialisation literature and multi-level perspective literature take a system as a point of analysis and both have an inherent focus on technology and innovation as a driver for change within those systems. However, as previously discussed the dematerialisation literature rarely considers, at least in any comprehensive way, the processes that have led to the event under observation, the effects that occur because of the event, nor the elements that come together for such an event to occur. Short-comings in the definitions of the system boundaries also make it difficult to ascertain upstream and downstream effects of a dematerialisation event which leaves little evidence for analysis of possible rematerialisation and other similar outcomes. The multi-level-perspective, and indeed innovation studies more generally, considers the wider context in which events occur. The multi-level perspective is a concept developed specifically to analyse complex socio-technical transitions. What becomes clear therefore is that the multi-level perspective, assuming the current criticisms over agency, operationalisation of levels and boundaries and it's use of secondary sources are considered, offers the potential to offer a great deal of analytical clarity to a dematerialisation event. What remains

therefore, is the selection of a case study that satisfies the criteria of both literatures, one in which a dematerialisation event appears to have occurred but also offers new knowledge to both literatures. A gap exists in the dematerialisation literature (see section 2.2.2), where individual products are assessed on one level and national economies on the other. By changing the scope of the analysis of the single product and redefining the system boundaries it is possible to begin closing such a gap. Additionally, the multi-level perspective would benefit from a study that focusses on multi-regime interactions. As such, a case study that focusses on production and consumption as two inter-related socio-technical regimes would satisfy both requirements. Further rationalisation of the case study as well as methodological implications borne out of discussion in the literature review are discussed in depth in the methodology chapter.

3 A focus on existing methodology for the Multi-Level Perspective for socio-technical transitions and determining dematerialisation

3.1 Introduction

This chapter describes both the nature of the investigative structure of the thesis and its practice. Typically it is the research questions that dictate the research strategy (O'Leary 2014); yet, as the research questions were informed and shaped by the literature review, the specific literatures offer the greatest contribution to the strategy. The literature review has problematised areas for further research, either through the absence of existing research and knowledge or through prescribing types of knowledge acquisition. Therefore, the methodology has emerged to meets the demands of the existing literature, the gaps in the existing literature, the research strategy set in place and the research questions that were developed and refined because of the literature review and as part of a reiterative refinement of the research process itself.

The first part is written, like the rest of the thesis, in the passive present voice. It provides the theoretical justification for the methodological approach taken. The second part of the methodology chapter is written in the past tense first person as it details what I did in the production and analysis of the thesis. The initial focus of the chapter is on the research strategy employed which is informed by findings from the literature review. It focuses on the problems inherent within the multi-level perspective, notably the absence of methodological discussion, before discussing the precautions taken in collecting data suitable for analysis. It then seeks to address the ontological complications of problem rather than paradigm driven research. The methodology chapter introduces the MIPS methodology as a means through which to collect and analyse quantitative data on resource use. The methodology chapter then moves into its second part, detailing what I did to execute the theoretical. It closes with an overview of the ethical considerations of the research project and a brief conclusion.

3.2 Multi-level perspective

The multi-level perspective, introduced and discussed substantially in the literature review (see section 2.4) is constructivist in nature and provides a framework on which the narrative of technological transition can be structured. However, much of the multi-level perspective literature attests to the usefulness of the multi-level perspective with the express purpose of developing it as an analytical tool and as a means of investigating complex socio-technical transitions. As such, it is the more recent literature that has sought to utilise the multi-level perspective in the manner intimated in the first decade or so of multi-level perspective theoretical development (see section 2.4). The

outcome of this initial focus has been that no single methodology has emerged or been associated with the multi-level perspective. However, even the more recent literature barely spares more than a sentence or two to cover the methodology of data collection nor the operationalisation of the multi-level perspective as a tool for analysis. The purpose of this section therefore, is to address the lack of substantive discussion of the multi-level perspective's methodology with a view to rationalising the methodology chosen and detailing how it was practiced.

3.2.1 What methodology?

There is a lack of commitment from multi-level perspective proponents in addressing methodology and relating data collection to analysis. This has led to a state of confusion where some proponents introduce the multi-level perspective as a methodology and proceed to describe the framework (see van Bree *et al.* 2010; Raven 2004). Elsewhere the same overview is utilised to define the multi-level perspective as an analytical framework (see Geels 2011; Geels and Kemp 2007; Geels 2004; Berkhout *et al.* 2004). What is clear in the literature, regardless of whether the multi-level perspective is being treated as a framework or as a methodology, is that there is scant methodological discussion. This is to be expected. If as treated here, the multi-level perspective is a framework it should be silent on method in terms of things like data collection. However, there is a broader criticism about the lack of methodological discussion that runs as a common theme through the literature which makes ascertaining the robustness and rigour of multi-level perspective studies difficult. The surrounding debate in the literature has generated an amount of discussion and further criticism which is of interest as it highlights issues which can be implemented into new research to increase robustness as well as providing an opportunity to deduce possible methods from other multi-level perspective proponents.

The lack of consistency in defining the multi-level perspective as framework or methodology has led to criticisms in which others have argued that the multi-level perspective defined as the former lacks robustness when conflated with the latter. As the criticisms from Genus and Coles (2008) and Berkhout *et al.* (2004) (see sections 2.4.5.2 & 2.4.5.3) indicated the focus of the multi-level perspective literature has been on development of the multi-level perspective rather than the realisation of case studies utilising the multi-level perspective. There are methodological shortcomings with the multi-level perspective whether interpreted as a framework or method. Geels (2011), in his response to Genus and Coles' (2008) criticism that multi-level perspective case studies do not set out adequately the research methods for data collection and analysis, takes their criticism to mean that the multi-level perspective lacks rigour. He argues that the multi-level perspective does not need to "emphasize method (e.g. rigorous procedures for data gathering, data analysis, replication)" in the same way mainstream social science tends to (Geels 2011 p.36) because the multi-level perspective is a process

theory that should not be forced through a variance theory strait-jacket. Geels' (2011 p.36) concern that the multi-level perspective would become "a mechanical procedure" if it was forced to engage with such criticisms is difficult to reconcile with the actual criticisms of multi-level perspective methodology presented by Genus and Coles (2008). On one hand, Genus and Coles are calling for a clearer account of methodology and the addressing of rigour and similar concerns and on the other Geels responds by claiming he does not want the multi-level perspective forced into a prescriptive methodology. Whilst this is an understandable justification it is less clear why the multi-level perspective literature should be removed the normal disciplines of social science research. Genus and Coles are calling for greater rigour and clarity in Geels' chosen methodology not demanding that the multi-level perspective adopt a methodology. As the multi-level perspective is an analytical framework several methods are applicable when producing the data for analysis. This is Geels' (2011 p.36) mistake, deliberate or otherwise in "aim[ing] more at illustration and exploration than at systematic research". There is no real reason why, when one discusses their chosen methodology that, they cannot provide a clear account of what they did. Nor is there a reason to avoid engaging with concerns of rigour when discussing that methodology. Geels' concern that the multi-level perspective would be somehow weakened is unfounded. The application of the multi-level perspective through many rigorous methodologies can only strengthen it. Perhaps in addressing this it will allow for methodology to catch up with ontology rather than the continuation of "our ontologies" to "outrun both our methodologies and standard views of explanation" in the multi-level perspective literature (Hall, 2003:387 in Geels 2011 p.36).

Similarly, the issue over the use of undisclosed and seemingly uncritically accepted secondary sources (see section 2.4.5.3), risks undermining the rest of a multi-level perspective analysis. The absence of any substantive discussion on methodology means that potential flaws are difficult, if not impossible, to detect. For example as part of his defence, Geels notes that others have used primary sources citing van Driel & Schot (2005), Raven (2004) and Smith (2007). However, the three papers do not contain any useful discussion on their methodology. All three use a mixture of both primary and secondary sources in their analyses. More recent literature goes further in highlighting where it sources data but as highlighted in the literature review, this falls short of even the most basic standards of academic referencing. Essentially, the literature sought to promote the multi-level perspective's vigour to the detriment of its rigour. Raven's (2004) methodological discussion is typical of early literature. His article discusses the multi-level perspective as a methodological guide in which he introduces the key concepts of the multi-level perspective but not methods of data collection or analysis. This changes in later publications where he states his "analysis is based on primary sources including government publications, research reports, waste magazines, annual reports and secondary sources including

publications in scientific journals and dissertations" (Raven 2007 p.2200). This revised style of loosely sourcing data used for analysis remains the current manner in which the literature details the origin of the evidence (see Piterou and Steward 2011; Simmie *et al.* 2014; Wells and Nieuwenhuis 2012 for examples of this). Some exceptions do exist however, such as Rosenbloom (2017) who gives details of the data collection process going so far as to include search strings in the foot notes. Without a clear discussion of methodology this use of mixed sources becomes problematic as one cannot be distinguished from the other. The extent to which uncritically accepted secondary sources influence the overall analysis is unknown. Given the nature of sustainability transitions they tend to be used to inform policy and as such the omission of source and methodology is particularly problematic when recommendations are based on unaccountable evidence. The consequence of such an omission is to shift the reader's critical focus from the argument the multi-level perspective literature is making to the sources of the analytical claims being made to the detriment of the analysis. An awareness of such criticisms must lead to stronger referencing of sources so that the nature of the source is apparent to aid the reader in determiningvalidity of the claims made.

3.2.2 Multi-level perspective methods

Although, as discussed above, the multi-level perspective when treated as a framework does not prescribe a specific methodology, certain criteria must be accommodated to produce data suitable for analysis. The multi-level perspective explains outcomes in terms of events and as such traces processes as they "unfold to allow for the analysis of event sequences, timing and conjunctures of event chains" (Geels 2011 p.34). Any method chosen must be amenable to tracing such events and several process theories steer towards narrative explanation. This has led to narrative explanation as the default explanatory tool for the multi-level perspective. More specifically, causal narratives must be developed, and the multi-level perspective is used as a heuristic device and framework in which plausible causal pathways are constructed.

Several methods are suitable for this narrative reconstruction. Existing multi-level perspective literature can be divided into either historic or contemporary case studies with some overlap between them. Whilst historic case studies (see Driel and Schot 2005; Raven 2007; Geels 2005a; Raven 2004 inter alia) typically reconstruct events from primary and (overwhelmingly) secondary documentary sources more contemporary case studies such as Marsden (2013) have also utilised interviewing and scenario development, whereas others such as Elzen *et al.* (2012) have incorporated key informant studies as a means to capture transitions in the making in the pork industry. The methods used, although not always specific, construct "narratives [that] can capture complex interactions between agency and changing contexts, time, event sequences, making moves in games, and changing identities" and hence construct the causal pathways of transition (Geels 2011 p.35). As such, it is for

the researcher to select a method that meets the requirements as necessitated by the subject of the research and whether the socio-technical transition of interest can be determined to have completed or be ongoing. For dematerialisation transitions determining the nature of the transition requires a more nuanced application of data. As a dematerialisation transition can be determined numerically, in terms of changes in the resources used, a method for capturing resource use is also required.

3.3 Material Intensity Per Service (MIPS) Methodology

As detailed in section 2.2.4.2, the MIPS methodology was theoretically based in material flow analysis. It measures resource use from the point of extraction and produces a simple comparison between either products or snapshots of defined systems. Although similar methodologies exist (see section 2.2.4.1 to 2.2.4.3), they tend to concentrate on one component such as CO_2 or energy as a proxy for materiality and therefore lack the comprehensiveness of MIPS which gives a fuller report of the materials of the subject under observation. MIPS can be calculated merely with a calculator and pencil in a sequential manner. However, such a technique provides a difficult work flow when dealing with multiple subjects. A spreadsheet approach such as with Excel is also problematic. Such a method has been criticised for having potential inconsistencies across the different calculations (Ritthoff *et al.* 2002). Spreadsheet based calculations show a maturation of the process over the 'pencil' technique however. It is simple and remains popular. Both methods follow the same seven steps shown in Figure 1. The process begins by defining the product system (cradle to product boundaries). This includes both the use and end of life phases. The remaining steps represent manifesting the process chain, compiling the data, expressing the material input (MI) per mass unit of product (material intensity MIT) and/or per unit of service (MIPS).

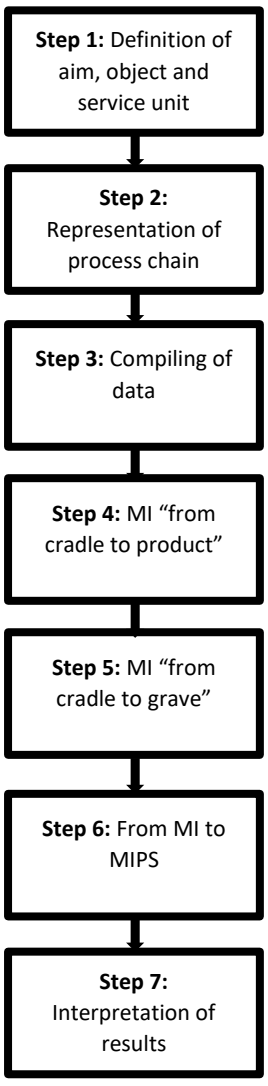


Figure 1: MIPS calculation in seven steps (adapted from Ritthoff *et al.* 2002:16)

More recent literature, either specifically on the MIPS methodology or making use of it, has turned to a more software based approach through the use of eco-auditing software (Saurat and Ritthoff 2013). Such software improves both workflow and consistency and the overall picture of the project, but it was an option closed off to this project by its associated costs. Eco-auditing software that can be adapted to be useful to the MIPS process is also expensive. Further, the "ecoinvent database or the built-in GaBi database provides no unused extraction flows" and so must be entered by hand and these too have an associated cost (Saurat and Ritthoff 2013 p.584). The eco-auditing software approach serves to detach the researcher from the

calculation process for several of the MIPS' steps, it is also cost prohibitive and invalidates comparisons with existing studies such as Türk *et al.* (2003). This introduces the potential for error of a similar nature levelled at the spreadsheet methodology. Errors in calculations may be missed by the researcher the more removed they become from the calculation process. The use of eco-auditing software for MIPS calculation is still in its infancy. This too is problematic as it demands that the researcher adapt existing software to produce results that it was not intended to. The use of eco-auditing software which outputs many more but unrelated results which have the potential to cloud out the useful data seems like an unnecessary compromise as there are few benefits and as such criticisms of this approach are not outweighed by the criticisms of the eco-auditing route.

A more detailed explanation of the MIPS methodology as it related specifically to the research is given in section 3.5.3. The following section discusses the ontological and epistemological implications of utilising two very different methodologies within the thesis and what that means practically for the research.

3.4 Mixed methods or mixing methodologies?

Denscombe (2008) in his meta review of mixed methods studies synthesised five broad rationales for undertaking mixed methods research. Some researchers (a) utilise a mixed methods approach to improve the accuracy of the data whereas, others (b) use mixed methods to produce a more complete picture by combining information from complementary kinds of data or sources. Some (c) mixed methods approaches are chosen as a response to avoiding biases found intrinsically within some single method approaches and (d) some mixed methods approaches are used as a way of developing the analysis further using contrasting types of data or methods. Additionally, mixed methods approaches have been used (e) as an aid to sampling such to screen potential participants. There are those who believe that quantitative and qualitative methodologies can only be used in tandem as the introduction of a second methodology which has a very different set of epistemological demands could, according to Lincoln and Guba (2000), create a project with two irreconcilable ontologies as they are too incompatible (see also Brewer and Hunter 1989; Morse 2003). Such irreconcilable differences supposedly stem from the emergence of qualitative inquiry as a response to the short comings found in quantitative inquiry (Vidich and Lyman 2000). However, as Geertz (1988) predicted in the late 1980s there has been a "blurring of genres", although mixed methods approaches are still seen as somewhat "controversial" (Creswell 2011). Those who see a more common ground, highlighting similarities between the two approaches (see Hardy and Bryman 2004; Onwuegbuzie and Leech 2005 inter alia), show that there is a degree of pragmatism in opting for a methodology which combines quantitative and qualitative methods.

Pragmatism distinguishes the approach from purely qualitative approaches which are based on a philosophy of interpretivism or constructivism and quantitative approaches which are based on a philosophy of positivism. Denscombe (2008) highlights four overlapping features of pragmatism found in mixed methods approaches. In research designs where (a) neither quantitative nor qualitative methods alone will provide adequate results for the research at hand, pragmatism provides a basis for a mixed methods approach (Tashakkori and Creswell 2007; Johnson *et al.* 2007; Vidich and Lyman 2000). This contrasts with research designs where (b) a pragmatic approach is chosen specifically around the belief that a mixed methods approach is a desirable means through which to perform good social science research in order to provide an adequate answer (Greene *et al.* 2001; Greene *et al.* 2005; Rocco *et al.* 2003). Pragmatism also provides (c) a fusion of approaches that deal with the unproductive dualisms of the quantitative / qualitative divide (Datta 1994; Tashakkori and Teddlie 2003) and (d) can be considered in a common sense way as "anything goes" that should not be associated with a mixed methods approach to research design.

The discussion on dematerialisation (see section 2.3) revealed the problems inherent in trying to capture the wider context beyond the dematerialisation event, therefore the multi-level perspective was proposed. The methods for identifying dematerialisation events are (post)positivist. Using the multi-level perspective, a constructivist methodology, as a means of analysing a dematerialisation transition, alongside MIPS, a (post)positivist methodology, intended to determine if that transition has taken place is a pragmatic solution to the research problem. The multi-level perspective allows for a far more detailed analysis of the dematerialisation context and in this instance the MIPS methodology is the methodology chosen to discern the dematerialisation events. The use of two distinctive methodologies is an attempt to answer the questions raised by the problem rather than something pre-defined by discipline or epistemological perspective and as such the choice to use them is a pragmatic response to neither methodology being sufficient in scope to resolve the problems at hand. In constructing a narrative of dematerialisation transition for analysis the (post)positivist approach of determining resource use is co-opted into that narrative. These pragmatic mixed methods, in which more adequate findings are likely to be produced than by either a quantitative focus on an isolated dematerialisation event or the qualitative analysis of a socio-technical transition could provide, was improved still further towards the end of the research. The research design proved more synergistic than anticipated as the multi-level perspective analysis allowed for the formation of additional scenarios for the MIPS methodology and analysis; the synergetic relationship is discussed in the following section where I detail the practical aspects of how I performed the research and analysis.

3.5 Collection and analysis

This section details the processes I went through in collecting and analysing data to ensure such processes were as rigorous as possible. The way I collected the data and substantiated it is dealt with first before turning my attention to coding the archive I had developed to make the information it contained analytically useful. This section also covers the use of the MIPS methodology which required that I collected data in a different manner to that of the main archive, as well as a very different type of analysis as discussed in section 3.3.

3.5.1 Ensuring rigour

When I first began the research, the research questions were focussed on the specific areas highlighted during the literature review that could be enhanced through further empirical study. That is, there was a specific focus on dematerialisation as a socio-technical transition and the impacts of dematerialisation on the socio-technical system. As the project became more focussed, with a socio-technical system for study being selected, I revised the questions tailoring them and making them more targeted to the specifics of the research.

Intent on answering these questions I set about performing desk-based research. Having selected the area of research, I set about researching the music industry by performing an additional literature review presented in chapter 4. I did this so that I could begin to define the boundaries of the project as well as determine which areas could be answered from existing knowledge and which areas needed further research. The music industry specific literature review was also used to generate search terms that could be used for the collection of documents suitable for analysis. These search terms such as MP3, iPod, “compressed audio” etc. are discussed further in section 3.5.2.

I performed systematic research that was intended to reveal new information about the topic. As such I opted for a more rigorous approach to data collection than is typically found in the multi-level perspective literature (see section 2.4.5.3). In establishing a methodology that went beyond a simple reliance on secondary and tertiary sources I adopted appropriate measures from methodologies outside of multi-level perspective case studies. It is worth distinguishing here between the different ways in which validity is at play in the multi-level perspective and constructivist inquiries more generally. There is a criteria for validity found in the processes and outcomes of inquiry that typically surpasses the application of methods (Lincoln *et al.* 2011) and there is some yet undecided criteria for sources utilised in constructing narratives in the multi-level perspective. The multi-level perspective literature has so far, for the most part, only shown off its outcomes (see section 2.2.2). The sources of data and the processes of analysis that lead to such outcomes are intimately linked but need greater validation. This concern for validation stems from a lack of transparency concerning the use of sources in constructing the narrative, in particular the uncritical acceptance of secondary sources (see Genus

and Coles (2008)), used for the multi-level perspective analysis. I wanted to demonstrate the validity of my analysis by properly sourcing my primary and secondary sources. With these concerns in mind I set about appropriating suitable methodologies for data collection of primary sources when constructing my own historical narrative. The multi-level perspective literature only showed concern for sources' applicability in the narrative's construction; in finding methods that would be useful, I explored case study research further but found that although case studies can be a form of methodology they are not a useful approach for addressing source rigour. This is in part because of the wide ranging application of case studies and because the case study literature has been preoccupied in defending case studies as valid in their own right (Flyvbjerg 2011; Stake 2003; Yin 2008). Additionally, as a methodology, it is one that generally demands the use of other complimentary methodologies.

In the case of the multi-level perspective these methodologies must allow for a systematic construction of narrative. These typically take the form of historical analysis, even if it is an analysis of relatively recent transitions. Historical analysis overwhelmingly relies on primary and secondary sources. Benjamin (2006) provides a number of rules that should be applied to primary evidence. In an example, pertinent, if not wholly relevant, to the research she addresses the primary evidence of the famous "Sarnoff Music Box". David Sarnoff claimed that he had written a memo in 1915 predicting the advent of radio broadcasting "I have in mind a plan of development which would make radio a 'household utility' in the same sense as the piano or phonograph. The idea is to bring music into the house by wireless" (Sarnoff 1968). Sarnoff became RCA's president in 1930 and his "celebrity grew to mythic stature" (Benjamin 2006 p.29). The inclusion of the memo in Archer's (1938) *A History of Radio to 1926* saw it introduced to other textbooks over a fifty year period. However, when investigated further in the 1990s the memo was determined to have originated in 1920 as part of a larger 28-page document. By 2002 this had been revised again as although the original memo was never found two contributory notes echoing the memo were found in Sarnoff's personal effects dated to 1916. This suggested that Sarnoff did indeed conceive the idea of a wireless 'music box'. It is worth noting that Geels' (2007) used Leblebici *et al.* (1991) in his case study on "the breakthrough of rock 'n' roll". Leblebici *et al.* had in turn used Archer's work to inform their own. This error had no impact on Geels' findings because Geels' case study applied to the years 1930-1970 but this anecdote serves to highlight the importance of validating one's sources and the problem in relying on secondary sources alone. With this in mind, I utilised questions as defined by Benjamin (2006) who in turn based them on the work of Marwick (1989) for determining the validity of the primary sources. Marwick's *The Nature of History*, remains influential because of his advocacy of professional standards in research (see Canning

2017; Lodhi 2016; Porra *et al.* 2014 for recent examples). It is these questions that Benjamin (1993) asked of the Sarnoff Music Box memo:

1. "What is the document's surface content?
2. How is it arranged?
3. What are its major points?
4. What might the document have said but did not?
5. What intellectual worlds lie behind its words?
6. Who were the audiences addressed in the document?
7. How does it function within a special social situation?
8. What is its contemporary context?
9. Where did the source come from?
10. Where was it originally found?
11. What type of source is it: a private letter, an internal corporate memorandum, minutes of a meeting, published accounts of that same meeting, and so forth?
12. Who created it, and for whom was it created?
13. What are the author's basic attitudes, prejudices, vested interests?
14. How, and for what purposes, did it come into existence?" (Benjamin 2006 p.29)

As such, when it came time to collecting my own sources I kept the rigorousness of these questions in mind in determining the legitimacy of primary sources. The most important questions asked of a primary source are from where it originated and whether it could have been amended. This is an issue across all sources but is particularly problematic with internet sources wherein amendments can be made easily and without trace unless specialist websites are used such as those discussed in section 3.5.2.

In utilising external evidence, such as the organisation's reputation and comparative evidence, I authenticated a source by establishing its integrity. For example, the work published by MPEG (the Moving Picture Experts Group who developed the MP3 standard) was well documented across many sources. The organisation is a highly regarded Joint Technical Committee formed by ISO and IEC in 1988. Its accounts of development can be corroborated against its own well documented 'Meeting notes' (MPEG 2010) and the final published standards. As primary sources of information on the development of MP3 and associated formats, information published by MPEG is very credible, although I always checked that any claims made in their secondary accounts of development could be corroborated by their own original accounts.

A great deal of effort went into legitimising the primary sources used. Secondary sources have a hierarchy "running from the academic monograph at the top to the sensationalised popular work at the bottom" (Marwick 1989 p.137). It is not clear what type of secondary sources multi-level perspective proponents used. Popularisations tend to be reliant on secondary sources and do not pass muster as secondary authorities. It is possible however, that Geels (and others) used sources of this type as they present an established narrative which would fit Geels' (2011) admission that systematic research has not been the aim of multi-level perspective case studies so far. Yet, secondary sources such as periodical literature, official histories, monographs, major historical studies and biographies (Startt and Sloan 1989) would in this case be acceptable if they provide "general information, substantiation, description, alternative interpretations, and understanding of the topic" (Benjamin 2006 p.28). When I used secondary sources which are cited in the analysis they were used in the manner suggested by Marwick (1989) and latterly Benjamin.

3.5.2 Collecting, Collating and Coding

I put boundaries on the sources I collected for the archive. Firstly, I limited the collection period to four months to avoid project creep and the risk of diminishing returns wherein the information that continued being collected was covering the same areas as information already collected. The initial deskwork phase took place between February 2014 and May 2014. Secondly, the sources had to be related to the key search terms that were being collected and fitted within the period of interest. Outside of these boundaries I followed Marwick (1989) in constructing the narrative. I undertook four tasks: (1) finding the sources, (2) applying the techniques and knowledge described above, (3) producing an interpretation and (4) communicating this interpretation in the form of written analysis. Task two is not discussed again having been dealt with in he preceding section.

As Barraclough (1955 p.2) noted history is "the attempt to recreate the significant features of the past on the basis of imperfect and fragmentary evidence". The evidence for transition in the music industry was certainly fragmented. However, the transition period coincided with the growth of the internet, indeed the two are related as the analysis shows. This resulted in a significant amount of documentary evidence created and stored on the internet much of which is still available. Such evidence included reviews of new hardware, which gives detail not only of launch dates but opinion on how well such hardware was received. I found it was possible to access forums which show the spread of software such as Napster as new users were introduced to it. All such data could be utilised and appended to the multi-level perspective framework. In addition, the often-controversial nature of the new technology meant that the spread of technology and software such as Napster was well documented in news reports and other similar secondary sources. Magazines and music industry specific newspapers such as BillBoard also proved to be important sources of information.

Work began by collecting and collating documents from all over the web. Google was used as the main search site, with the google book search tool (books.google.co.uk) allowing access to many digitised magazines and for them to be searched for my specific key words and phrases. Such a method replicates the work of manually searching through old magazines and newspapers but in a faster and more efficient manner. Of use was the “wayback machine”, a tool developed by the internet archive (archive.org). This tool has access to an archive of websites dating back to 1996 and has archived about 510-billion-time stamped web captures. These web captures form archival histories of web sites that are no longer hosted. Websites change frequently with their content being amended or removed. However, with the time stamped web captures I can access information that no longer exists on the domain. For example, many of the articles published on MP3.com by Michael Robertson in 1997 through to 1999 at the height of its infamy are archived. In this manner, they can be considered primary sources as archive.org host the original website snapshots with no additional editorial. Without the archive site, the content would have otherwise been lost. Other general searches were included of the entire World Wide Web as well as website targeting searches of news providers such as the BBC and Guardian along with technology blogs and forums. To begin, product histories of the largest technology companies were utilised to generate search terms. These included search terms such as “CD” or “Compact Disc”, “iPod”, “minidisk” and “mp3”. New search terms were added in the first wave of document collection as deemed appropriate. This allowed me to create a spider-like search for documents. The content was of course important, and documents were only made part of the archive if they were clearly relevant and met the criteria for primary and secondary sources. Additionally, if a document could not satisfy questions of validity asked of them they were flagged as being of dubious of quality within the archive. If a more suitable document was found containing the same information the first document was substituted. This kept the quality of the sources high. A total of 1236 online documents remained in the final archive. Further offline documents were also utilised although these offline documents were limited to books used for substantiation.

I assembled the archive in Microsoft OneNote. OneNote has a distinct advantage over other systems such as NVivo and Atlas.ti. It’s Optical Text Recognition (OCR) functions far better than other CAQDAS systems whose implementation I found awkward and unhelpful in producing a clean workflow. The efficient OCR of OneNote meant that keywords could be searched for and identified quickly without having to go through each document manually. I utilised OneNote in a manner like CAQDAS software, whereby it allowed me to organise the qualitative data and analyse it. It allowed me to link documents through hyperlinks, nest notes between documents and the chronological arrangement of the documents. OneNote also enabled the inclusion of PDF documents, Images, Videos and spreadsheets *inter alia*. Further, videos which were obtained from YouTube, such as Steve Jobs’ introduction of the

iPod, came with transcriptions which were also embedded into OneNote which increased the ease of searching for relevant information. Ultimately, it was my existing familiarity with the software and a feeling of discontent with the features offered by existing CAQDAS solutions that led to the use of OneNote.

The data assembled in the archive remained as entered as this allowed me to always retrieve information that showed what the original source said, should it be required, at any stage of the analysis and subsequent write up (Merry 2011). I expanded each record, for each source, in the archive which contained a standardised form of the information contained within the original source. The standardised records contained expanded acronyms and abbreviations (CD was stored as compact disc for example), dates were standardised, company names were normalised (LiquidAudio was often found as Liquid Audio, LA or LQA, across different sources). I performed the standardisation as the archive was compiled as this allowed me to standardise globally in an efficient manner.

It became clear to me towards the end of the field period that the time allowed to collect the data had been slightly too generous and so although four months had been allowed a total of around fifteen weeks were spent collecting sources. The information collected started to overlap and as such most avenues felt exhausted. Having standardised the archive as I went along I reviewed it once more upon the close of source collection. I did this to ensure that the way I had standardised was consistent throughout and that the archive was ready to start being coded.

Although coding became popular as the technique at the heart of grounded theory (Glaser and Strauss 1967) it has since become a dis-embedded general approach to qualitative data analysis (Coffey *et al.* 1996). The purpose of coding is to indicate what is talked about in any given segment of text. I also used it to ensure that the text was properly dated. This allowed me to group the texts both thematically and temporally. I felt this was important for a historical analysis, particularly one of technology development as it allowed me to determine what events were occurring within the same time durations. There were some theoretical considerations that came from the multi-level perspective literature and I was mindful of this as the coding occurred. As the coding categories emerged it was possible to consolidate some, dropping others that were not useful and otherwise edit the coding during a second stage. It was during this stage that I started mapping events and codes to the multi-level perspective's framework. As I had an idea of the narratives that were emerging having read through all the sources once during standardisation and coding, I could begin to synthesise parts of the analysis. During the second stage of coding, I began to delineate and assign multi-level perspective dimensions as codes moving beyond the relatively simple coding of the first pass-through such as, for example, whether something was within a niche or whether it was more appropriate to

place them within the regime. Similarly, at this stage certain potential transition mechanisms started to emerge. Although these were not fully fleshed out I began coding them with the intention of refining them further on a third round of coding. For example, I noticed a pattern of resentment to the new technologies from established parties. This indicated two things to me, firstly that they are probably part of the incumbent regime (although not always, some emergent actors were also resentful of certain types of emergent technologies) but secondly and most importantly that this resentment was being born out in several ways that were worthy of further analysis and that these transition mechanisms were likely shaping the transition. I discuss these topics further in the analysis (section 5.4.4 specifically). On the third pass-through for coding therefore, I was refining the codes of the earlier two stages. I explored the tentative relationships I felt had emerged in stage 2 and refined these where it seemed appropriate. A fourth round of coding saw the further emergence of theorisation. For example, an amount of different data focussed on the timing of the adoption of the MP3 format and event sequences that could be drawn out from the abstracted coding as well as the chronological nature of the documents. Elsewhere, patterns began to emerge around the role of individual actors, for example technologists by stage 2 of coding. By stage 4 of coding the role of the disruptive entrepreneur concept based on the initials observations of the way certain technologists behaved had emerged (see section 6.5.1).

Over the course of the coding I identified transition dynamics, causal agents, causal mechanism's timings, conjunctures and event sequences as well as roles and contexts. All of this was done in anticipation of the analysis to make the archive analytically useful as well as to position the real-world events within the context of a multi-level perspective narrative. As there was little in the existing literature to guide me during this process specifically in relation to the multi-level perspective it felt at times that it was perhaps an experimental way in which to perform the research. Always, however, I was guided by a sense of what seemed to be the most logical way to make the wealth of information more abstract and thus make patterns more exaggerated in a way that has typically benefited qualitative analysis (Boyatzis 1998; Denzin and Lincoln 2011; Holsti 1969; Saldaña 2015).

The coding, therefore, allowed me to take preconceived theoretical concepts from the existing literature and codify many new sources. The function of this enabled me to assign actors to specific (non-hierarchical) levels of the multi-level perspective as well as identify areas related to resource use. Further rounds of coding, as I became more theoretically sensitive, allowed refinement of that initial coding which allowed for the emergence of clearer patterns of transition as well as individual actors, actor groups, transition patterns and dynamics. Once I completed this coding and I had started to tease out the theoretical considerations the archive was ready for analysis as defined in chapters 5 through 7.

The initial stage of analysis was focussed on the data collected for the archive. One of the aims of this analysis was to establish contemporary listening habits from which I could devise listening scenarios suitable for analysis. In doing so, I hoped to reveal the changes in resource demands between the different ways in which people consumed music to satisfy the research questions.

3.5.3 MIPS Methodology.

To make the comparisons between the different models of music consumption I opted for the MIPS (Material Input Per Service unit[6]) methodology as a way of measuring and quantifying the use of resources from their point of extraction from the environment. As all inputs eventually become outputs, MIPS indirectly accounts for outputs too (Ritthoff *et al.* 2002). The MIPS concept allowed me to assess individual products and to determine their "ecological rucksack" as it has shown its potential for measuring resource use at both the macro and micro levels (Liedtke *et al.* 2014). The ecological rucksack is a "comprehensive view of life-cycle-wide resource consumption" (Ritthoff *et al.* 2002 p.10). The MIPS literature is particularly prescriptive about methodology; the Türk *et al.* (2003) study utilised the MIPS methodology which in turn was based on the work of Ritthoff *et al.* (2002) which detailed the Wuppertal Institute's process. One key difference between the two studies however was that Türk *et al.* focussed exclusively on the delivery of music, placing consumption outside the scope of their study. Additionally, the Türk *et al.* study is now over a decade old. The CD element was based on data taken from EMI's Uden Plant in the Netherlands which was sold to MediaMotion in 2004. The justifications made by Türk *et al.* for the modes of delivery they selected were also based on the state of music consumption in 2002-2003. Although they were aware of the potential for streaming sound carriers they chose not to include them as, at the time, they did not consider it to be a significant way of consuming music. Thus, although the methods are identical some aspects defy direct comparison. Further, Turk *et al.* chose not to explore the hardware that is required to listen to music. As such, I wanted to use their study as a starting point in terms of service unit but to develop it to allow for further analysis. The purpose of doing so was to allow for a reference point to substantiate and calibrate my own results and to also allow me to tie my results to the existing literature.

There is a risk here of getting ahead of the analysis in discussing the specific reasons for opting for the listening scenarios chosen. This forms part of the discussion in section 6.2. Instead the focus is on methodological specifics. In overview, there are seven steps involved in the MIPS methodology. Step one was a definitional step. I have outlined the key difference between the two units below as well as highlighted the further way the service unit I devised deviates from the service unit found in the existing literature. All numerical values of the MIPS calculation are referred to the service units. In step

[6] MI/S

two I established the process chain and how each process related to one another; the process chain provided the structure of the overall MIPS calculation. Step three gathered together inputs and outputs into a process picture. I recorded this information in a data-sheet in preparation of step four: the calculation of the Material Input (MI) by linking together the MI factors. In step five I calculated the Material Input paying attention to the use and recycling phases of the life cycle. In step six I calculated the MIPS unit. In step seven which I do not detail below I interpreted the MIPS results, this analysis appears in Chapter 6. Steps 1 through 6 are given further attention here. For each scenario, the process was essentially the same whether it related to the production or consumption service unit. As such my discussion of the methodology below is typical of each scenario rather than specific to a scenario.

3.5.3.1 *Step 1: Service Units*

The MIPS methodology introduces the concept of the service unit. The definition of the service unit is important as it must be applicable across all the scenarios. As Türk *et al.* (2003) had already determined an applicable service unit it seemed sensible to carry this forward for the reasons outlined above. Three criteria must be met when selecting a service unit:

a. "The unit allows comparison of many different product or service alternatives. Hence it should be phrased in a generic way;
b. The unit reflects all important usage aspects of the product/service;
c. The measure of the unit is understandable and applicable for a broad audience." (Türk *et al.* 2003 p.6)

For the purposes of the research, I felt that using only the delivery service unit was insufficient. I redefined the way in which the service unit is used by adding an additional dimension that incorporated the hardware used to listen to music. The two service units are discussed below.

3.5.3.1.1 Delivery Service Unit

Two alternative service units were considered by Türk *et al.* before they settled on their chosen service unit. First, an *x* number of megabytes. This was discounted because they felt it conflicted with criteria (b) and (c). I too, discounted the *x* megabytes as the service unit. Since the study, many other sound carrier formats have emerged which further complicate meeting criterion (a). Sound quality varies across these different sound carriers and so some require a greater or lesser number of megabytes to fulfil the same role. Further, older types of music carrier such as tape and vinyl records (analogue sound carriers) are not thought of in terms of the amount of data they store in terms of megabytes. Additionally, I felt that a service unit defined in this way would be difficult to translate into a consumption service unit that would benefit the analysis.

Another alternative was to base the service unit on an individual song. This too was rejected as Türk *et al.* felt it conflicted was criterion (b). Türk *et al.* (2003 p.6) suggested that "customers tend to purchase albums or singles rather than individual song files". Purchasing habits have changed since the release of the original case study. The singles market has overwhelmingly shifted to digital sales, a fact that is considered in more detail in the analysis (see section 5.5.4.2) (IFPI 2012). However, there has never been an equivalent in physical media. Singles often came backed with additional songs which I felt would have its own problems when it came to calculate the MIPS.

Therefore, to fulfil all three criteria, I decided that the most applicable service unit was the music stored on one CD. Türk *et al.* took the average playing time of a CD produced by EMI[7] as 56 minutes. This too is problematic for older formats, especially vinyl which was incapable of holding more than around 40 minutes without compromising sound quality. Workarounds included releasing double vinyl albums which again frustrates calculations as technically any calculation for a vinyl record with must be doubled to accommodate 56 minutes of music. The weight of a vinyl record also varies and so its resource input can vary dependent on the "quality" (weight) of the product. However, whilst the service unit of a provision of 56 minutes of music to the consumer does not satisfactorily fulfil criterion (a) for vinyl records, sales of these within the period of interest are very small and so for the purposes of this case study, vinyl records fall outside the scope of the research.

3.5.3.1.2 A consumption service unit

There are many ways of consuming music. I decided to opt only for the most popular methods of consumption as identified during the analysis of the archive. In order to satisfy the three criteria set out by Türk *et al.* (2003) for their delivery service unit and to link the consumption service unit to the delivery service unit I decided that the consumption service unit should be a device capable of playing 56 minutes of music. In this way, several scenarios could be developed around the consumption of music based on delivery and usage. However, conventionally MIPS includes all the hardware resources required to produce the final product proportioned by the number of individual products the hardware could produce of its lifetime. Many hardware devices used for listening to music and not dedicated only to music consumption, as such I had to develop a modified MIPS unit that took account of this.

3.5.3.1.3 Developing MIPLS

The service unit remains a fixed constant. If a Hi-Fi is required to listen to a CD, treating the backpacks in the manner typically found in the MIPS literature would result in the Material Intensity (MI) of a CD plus the MI of the Hi-Fi forming the overall Material Intensity Per Service unit. Therefore, the MIPS of

[7] The case study was based around EMI's operations.

consuming music must include the footprint of the HiFi. Ordinarily in MIPS, the hardware used to produce something is divided by the number of products it can produce to add its resource backpack to the final MIPS of the product. For example, a newspaper press would be divided by the total number of newspapers it was capable of printing in its service lifetime and added to the other materials required to make a newspaper. However, for a product such as a PC where use for music is somewhat transient I developed a different equation. The MIPS methodology is utilised instead to develop a "listening session" figure. Each listening session consisting of 112 minutes is considered alongside the typical life cycle of the hardware. As hardware is typically used multiple times several listening sessions are assumed to occur over a set period. Therefore, if a consumer purchases both 24 CDs over the course of a year and a Hi-Fi with a life-cycle of four years, the overall MI for the Hi-Fi can be divided into more discrete listening session units. Such a figure allows for comparison of typical usage across the different modes of consumption. Each of the scenarios in sections 6.2.1 - 6.2.3 describe in greater detail how a typical Material Intensity Per Listening Session (MIPLS) was derived. The benefit of using the derived MIPLS figure is that it allowed me far greater understanding of resource consumption for listening related activities. Further it allowed me to compare hardware, some of which is converged and multifunctional, which MIPS alone fails to grasp. Additionally, MIPS had for the most part only previously delivered results which focused on end-products and not the ways in which these products were consumed. There is an appreciable difference between the resources required that result in a product such as a CD or an MP3 file (as shown initially by Türk *et al.* (2003) and updated here in section 6.2.1) but without consideration for the hardware required to consume such products as part of normal listening activities it is not possible to state which method of consuming music is actually more resource intensive. In taking into consideration how supporting hardware is used for the different consumption scenarios it allowed a move away from static and constant material intensities which make comparison of modes of consumption more difficult.

3.5.3.2 *Step 2: Representation of the process chain*

In step two I developed the life cycle of the product/service. Ideally, such a life cycle should represent all processes that are necessary for the manufacture, use and disposal of production (Türk *et al.* 2003; Ritthoff *et al.* 2002). The life cycle chains were checked to see if existing MI factors were present. If they were I summarised these. For example, the MIs of transporting and displaying a CD in store was already known and so did not require additional calculation.

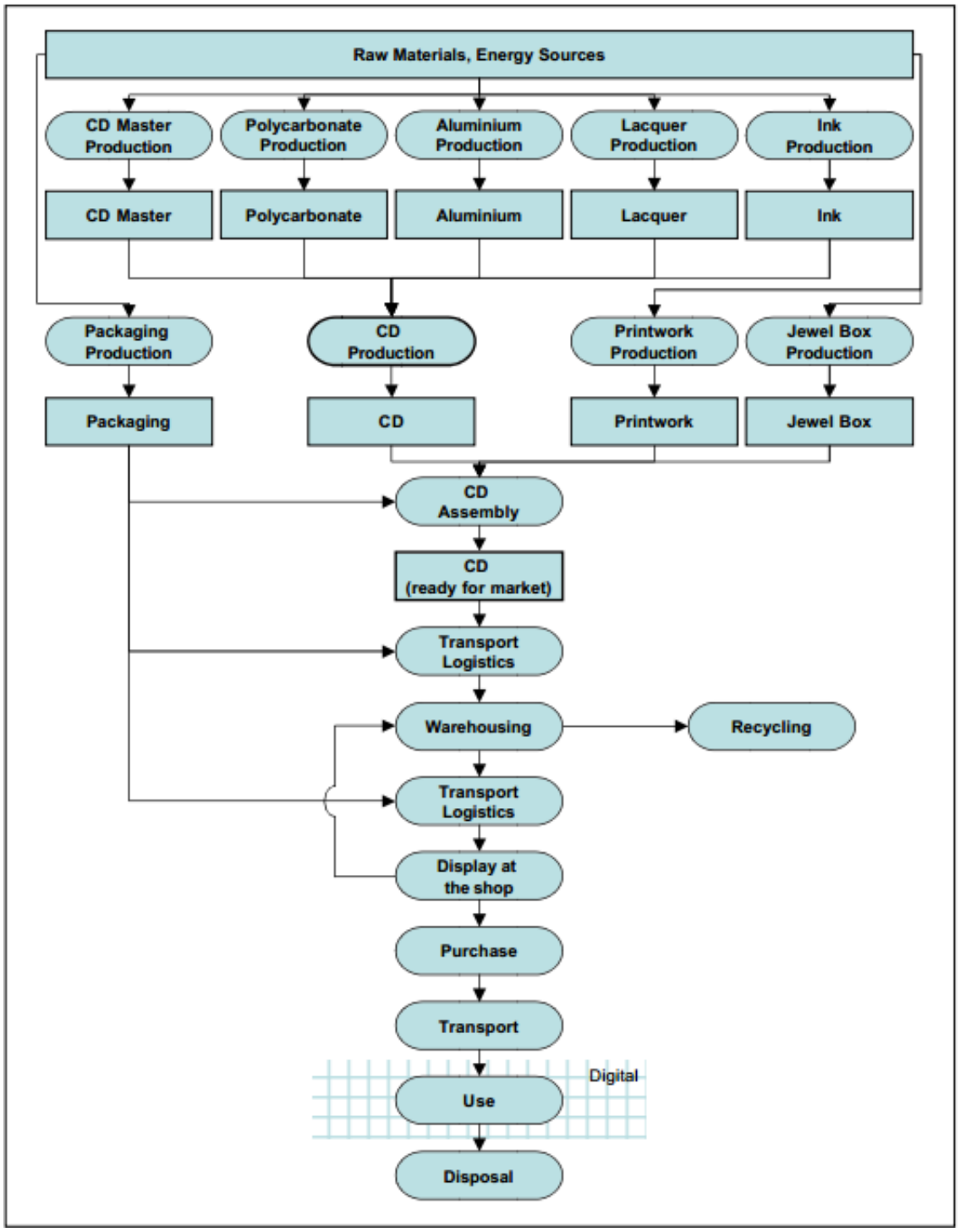


Figure 2: Process flow chart for physical sound carrier (CD)

These life cycles took existing life cycle analysis from the literature as its starting point. Newer life cycles for products not yet explored in the literature were informed by primary sources obtained from manufacturers and technology companies as well as informed by LCA literature. The existing work conducted by Turk *et al.* formed a substantial part of these life cycle constructions. In addition to this I utilised Life Cycle Analysis literature made available by manufacturers and technology companies as well as secondary literature sources that had made an analysis of the products/services but for

different purposes. I conducted a systematic search for each of the scenarios and its product to produce the most complete process flow chart. Such a search included googling specific search terms such as the name of the product/service with the addition of "LCA" for example. The outcome of this stage was a series of process chains indicating which processes are necessary for the manufacture of products or the execution of the services of interest.

3.5.3.3 *Step 3: Compiling of data*

Once I had identified the process chains, that is, the raw material to usage chain, for each of the various methods of consumption I gathered data for each of the processes within the chain and recorded in data sheets obtained from the Wuppertal Institute website. For manymethods of consumption the processes were identical and so I could consolidate searches for processes found in chains. The literature demands that all sources are well documented, the analysis section records these sources. Information came from two sources: direct measurements and literature references. Of these direct measurements, which offer a by weight break down of the materials, are the most reliable whereas literature references allowed me to acquire further information about procedures.

It was unfortunate that not all information was available from these sources. This was to be expected, however, and the literature guidance acknowledges these gaps in which "qualified estimations" must be made (Saurat and Ritthoff 2013; Ritthoff *et al.* 2002). Where I estimated I made both minimum and maximum estimates. The literature guidelines provided several rules that I followed when compiling data, the most important of which are summarised here:

- Material flows must be stated in an appropriate weight
- Primary raw materials are listed first under Input
- Main products and by-products are listed under Output
- Not all inputs and Outputs need to be recorded – these depended on system boundaries (Ritthoff *et al.* 2002 p.23).

The result of this third step was to have an overall view of the material and energetic inputs and outputs of the various processes found in the process chains. Any gaps had been estimated with minimum and maximum estimates.

3.5.3.4 *Step 4: Calculating the Material Input (cradle to product)*

As highlighted in step two some Material Inputs were already available (Wuppertal Institute for Climate, Environment and Energy 2014). However, I needed to calculate other Material Inputs utilising the data compiled in step three. I calculated the Material Input by multiplying the individual input quantities by the specific Material Intensities (MIT) of the input substances (Ritthoff *et al.* 2002). Adding these together resulted in the MI of the relevant intermediary product. Material Intensity was

recorded using the unit Kg/Kg except for weightless items such as electricity which I recorded as Kg/kWh. The outcome of this stage was to have the Material Input per Product calculated with a breakdown of the resource consumption. Again, a calculation sheet was used which combined the relevant Material Inputs of the five data categories.

3.5.3.5 *Step 5: Calculating the Material Input (cradle to grave)*

In step four I calculated resource use right up the complete product. Further resource expenditure had to be determined for the product during normal function. I calculated these separately from the manufacture in this step. Step five therefore included the calculation of usage and disposal resulting in the Material Input of a product which assumed usage through all life cycle phases.

3.5.3.6 *Step 6: Material Input to MIPS*

I achieved the actual MIPS calculation by dividing the Material Input by the number of service units. This calculation allowed me to compare the different sound carriers as the service unit was unified for all by calculating the MIPLS figure.

3.5.3.7 *Step 7: Interpreting the results*

The final seventh step was to interpret the results; this formed a significant section of the discussion chapter (see section 6.2.4).

3.6 Ethics

The research followed the six key principles of the ESRC (Economic and Social Research Council 2010) to ensure current best practice. No children or vulnerable groups were included. There were no interviewees. The data archive from which the historical narrative was created was curated from publicly available documents. Where opinion was presented it was done so in a manner which best represented what the original author had intended to say. The purpose of such measures was to avoid harming any person (Flick 2007). There was no conflict of interest in conducting this research.

3.7 Conclusion

The research strategy employed for this research emerged as a response to answering the specific problems identified during the literature review and the gaps in knowledge the review identified. The methodology needed consideration because the multi-level perspective is a process theory and as such provides an analytical framework on which to construct an analysis but does not produce a prescriptive methodology. In many ways, this freed me as a researcher to select the methods I felt best suited the evidence I knew was available whilst still meeting the requirements and expectations dictated by the literature. This led me to select and detail the method of historical narrative construction as it applied to the multi-level perspective and the way I ensured rigour throughout the process whilst collecting and collating data. It also led me to elaborate on the nature of the sources used whilst highlighting the importance of the criticism from Genus and Coles (2008) on the uncritical

acceptance of sources. Further it allowed me to adopt a second methodology to provide data for a different type of analysis that helped answer a more quantitative set of research questions. In doing so, the research strategy developed complementary methodologies that addressed the research questions in a manner that built on existing work but is also distinct from it.

The MIPS discussion highlighted the way in which I developed MIPS and utilised it in a way that it has not previously been used for allowing me to establish a metric (MIPLS) for comparing the production and consumption of different products in a more holistic manner. In this way, upstream and downstream sectors could be more roundly appreciated in terms of their contribution to resource demands and as such a far better understanding of the impacts of technology transition on resource use can be brought to the fore during the analysis and subsequent discussion.

The chapter also provided the theoretical justifications for the methods' selection and a description of their practical implementation in anticipation of defining and discussing the topic of research and the analysis in the succeeding chapters. The analysis is split, essentially, into three distinct sections. Chapter 4 is a literature review that explores the concept of "the music industry" which seeks to define it and produce boundaries to the scope of inquiry. Chapters 5 through 7 contain the historical analysis, utilising the multi-level perspective as a skeleton on which to flesh out the story of socio-technical transition within the music industry. Chapter 6 focuses on the dematerialised consumption making use of the MIPS methodology to produce illustrative examples of how changes in the way music is listened to have resulted in material changes in terms of the resources used.

4 Defining and bounding the Music Industry

Both the dematerialisation literature and the multi-level perspective literature call for the use of well-defined case studies. Within the dematerialisation literature the case study typically takes the form of a comparison, either between two different products, or two different snapshots in time in which resource use can be compared and analysed. For the multi-level perspective, the case study is typically defined as a system over a period, with a technology or transition of interest to be analysed. Many examples of such multi-level perspective case studies exist including the transition from sailing ships to steamships between 1780-1900 (Geels 2002), from fossil fuel to wind energy (Bagherian and Lettice 2014) and the development of smart (electricity) grids in Korea (Ngar-yin Mah *et al.* 2012). In both literatures therefore, the case study is used to compare change between states of a thing, area or sector inter alia in which it is the transition which is of interest. The purpose of this chapter therefore is to define what is meant by the term "music industry" as well as to provide definitional borders of what is and is not included within the scope of inquiry.

Defining and bounding the music industry is a necessary step in contextualising the socio-technical transition of interest and its movement from one state to another. In doing so, the complex patterns can be properly analysed using the multi-level perspective. In defining what constitutes the music industry and understanding how it has changed through the existing literature the intention here is to begin to define the existing regime and to explore socio-technical transitions that have already occurred. In doing so this literature review can feed in to the more substantial analysis of the succeeding chapters.

As with all definitions of something as colossal as the music industry, there is a degree of interpretation involved so, although in performing the literature review the intention is to go with the consensus of what constitutes the industry there are likely conflicting definitions. As such, the definitional endpoint here is something that is both recognisable as the music industry but also analytically useful within the scope of inquiry. Given its limited presence in the literature ultimately any study of the music industry is likely to be explorative. Propositions are to some degree absent in the music industry literature; Yin claims when no propositions are present an "explanatory study should state its purpose" (2014 p.30). Whilst the aim of the research may be to explore, the scant music industry literature as well as the multi-level perspective and dematerialisation literatures have created many propositions around the basic point of exploration. It is these propositions that are borne out in the research questions which have in turn shaped the research design. There is considerable uncertainty around the nature of dematerialisation transitions not least their origin as well as their development over time. Relating this specifically to the music industry questions 1a through 1c were formulated (see 1.3). Similarly, the implications of dematerialisation found in the literature were rather singular;

after a stage of dematerialisation rematerialisation occurs. However, few studies, if any, supported this assumption and such an assumption was based more widely on events occurring over the whole economy rather than industry clusters. Therefore, there was a focus on the results of dematerialisation events in questions 3a to 3c. The final proposition is based around the criticism of the multi-level perspective and the nature of its methodological practice. Responding to this criticism shaped the research design considerably, in part because the root criticism is a lack of clarity and openness about methodology.

The unit of analysis for case study research relates very specifically to how the case study is defined and bounded (Yin 2014). The case study in this instance is more easily defined than it is bounded. Temporal bounding is not discussed in the literature of the multi-level perspective. Given the reliance on secondary sources it is possible temporal bounding is decided by the original authors of the secondary works and multi-level perspective proponents adopt these boundaries. Any analysis of technology transitions in the music industry is innovative and so there are no pre-existing boundaries defined in the literature. This isproblematic in the sense that the researcher defies the boundary as they see fit but also beneficial for the same reason. In this instance, the bounding of the case study was informed by evidence as well as specific events which define the temporal boundaries.

The transition of interest is the move away from CD as the incumbent sound carrier to 2014 (see Figure 3). Although the CD was launched in 1982, the transition away from it begins later. The CD was itself a challenger to the incumbent regime of the LP/EP vinyl sound carrier. The beginning of the case study therefore begins around 1989. Two things happened in this year of relevance to bounding the case study. The vinyl sound carrier format was declared ‘dead’ and Karlheinz Bradenburg completed his doctoral thesis on how people perceive music. His thesis lay the groundwork for most of the audio compression formats used today, particularly MPEG-1 Layer 3 (mp3). Although the temporal bounding of the case study begins in 1989, the timeline around this can offer much to our understanding, the development of the CD for example offered up useful information for understanding the later transition. As such, the case study can be defined in two parts, firstly that the transition of interest occurs between 1989 to the present but this transition sits in the context of a longer timeline with a primary focus on the music industry.

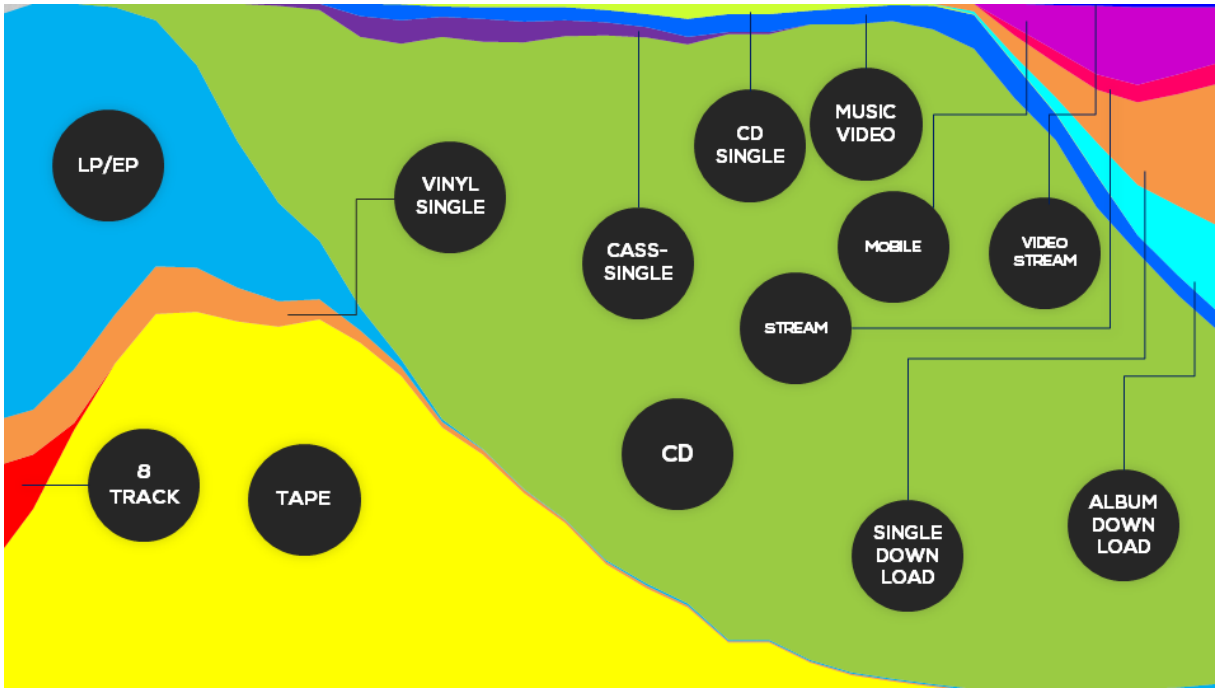


Figure 3 Music media transition from 1976 to 2010

There is inevitably with transition studies a secondary focus on contributory sectors. The multi-level perspective allows for different transitions aside from the one of interest to be considered as part of the socio-technical landscape. A degree of interplay and overlap exists between these other regimes – the rise of home computing, for example, was integral to the spread of MP3 technology. Data collection and analysis focussed on music specific changes. So, changes in the home computing market were acknowledged in the socio-technical landscape but were kept and analysed in more abstract terms. One of the key questions kept in mind when collecting data was how relevant it was to the act of listening to music. In this way a fuzzy border was kept in place determining the scope of the case study that allowed for the bounding of the "concrete manifestation" of the case study – transitions in music carriers away from the CD (Yin 2014).

The MIPS element of the research design came very specifically from the existing literature on music sound carriers. The Türk *et al.* (2003) study used the MIPS methodology to explore the environmental impacts of various music carriers. However, the research, though theoretically sound, did not explore streaming technologies. Additionally, given the increased efficiency of the supporting hardware analysed and the subsequent changes in listening habits the study's data is out of date. In utilising the same methodology and applying it to some of the same listening practices (as well as new ones) it was possible to tie the research to the literature. Further it provided a point for comparison to test resource efficiency claims. For MIPS, therefore the case study provides a context in which to ground

the listening habits, or ways of consuming music, that are both informed by the case study boundaries and the subsequent analysis

4.1 The music industry case study

The music industry is home to significant technological change. Since the invention of the phonograph by Thomas Edison in 1877, technology has both shaped and been shaped by the industry that developed around it. Indeed, in the second decade of the 21st Century many different technologies exist that allow end users to consume music. Vinyl gave way to CDs and CDs currently compete alongside MP3s and streaming services as a way of delivering music to us. Vinyl, considered finished in 1989 has seen a resurgence over the last decade. The music industry can be seen as a highly complex socio-technical system, rich in dematerialisation and rematerialisation transitions. Its core product has become smaller, from "2 Ounces of Plastic with A Hole in the Middle"[8] to a few thousand largely intangible bits. These technology transitions have considerable implications for the industry, as well as for consumers, producers and manufacturers alike. Such transitions also have environmental implications that are under studied, at least at a cross-industry level, with impacts that are barely acknowledged and poorly understood.

The music industry is of a considerable size and in the parlance of the multi-level perspective it could be credibly split into at least three socio-technical regimes: live music, recorded music and music publishing (Wikström 2010). However, this is to get ahead. As a case study, there is an expectation to define the subject of study in a way that is analytically useful with properly delineated boundaries so that the regimes can be properly operationalized. Unlike many other industries which produce physical products is it true to say that music industry produces music in the same way the car industry produces cars, or the steel industry produces steel? What the music industry's 'core product' is, is as important to the question of dematerialisation, as to how the industry is defined. Both questions are intertwined and responses to them can be carved out from the existing literature to an extent. It is the answers to these questions that drive the following literature review of the music industry.

4.2 Defining the industry more broadly

The nature of the existing literature is problematic in the sense that it is small and scattershot. Rarely is the music industry given explicit focus in academia; books on the subject are usually written by journalists and as such not given significant weight or consideration academically. Musicology rarely considers the industry that is so entwined with it. As the music industry has only been central to a small number of studies, the literature is temporally dispersed and, coupled with the continually developing and changing nature of the industry results, in a literature that is frequently disparate.

[8] According to Welsh prog/psych-rockers Man

Some authors build on the ideas of others, but they rarely agree with them. There have however, been several attempts to ascertain what constitutes the music industry. Several conceptual models exist but there is difficulty in reconciling the existing models with the multi-level perspective. In determining what constitutes the music industry it is possible to strip away and compartmentalise those areas of it that would serve only to complicate an analysis of dematerialisation transitions. This section seeks to define the music industry but also to dissect and delineate it so that it can be analysed via the multi-level perspective framework.

Paul Hirsch (1969) made one of the first notable attempts to define the Popular Music Industry. Hirsch's primary focus was on the symbiotic relationship of the recording and radio industries working together, but with different aims, to produce a cultural Popular Music Industry identity. The music industry of the 1950s and 1960s appears to have changed considerably since Hirsch first attempted to define it, yet the core operations of the industry identified by later scholars were already in place. To consider only the recording industry and the radio industry as representing the music industry is wrong today; Hirsch was attempting to define the Popular Music Industry in the sense of an industry that produced top 40 records. Hirsch appears not to have considered live music alongside the other two sub-industries despite the heavily reported raucous live shows of high profile acts such as Elvis Presley and the Beatles because live performances were not industrialised to the same extent as recording and publishing. Although the music industry was born of the live setting as identified by Attali (1985), live shows remained within the control of individual artists and their managers; live shows were more akin to small family businesses than an industry despite their contribution to the music economy.

Attali (1985), in his cultural historiography *Noise*, developed several distribution models[9] of music networks which he felt best represented the music economy: sacrificial, representation, repetition and composition. The sacrificial network is not necessarily relevant in a discussion of the modern music industry as Attali saw it as being a network where music was distributed through ceremonial processes and patronised by the aristocracy. In this sense, the distribution network was in the oral/aural tradition of "myths, and religious, social or economic relations of symbolic societies" and was funded but not monetised (Attali 1985: 31). Attali argued that composition, representation and repetition are musical networks that "are both emblematic and constitutive of distinctive types of social and economic relations within human society" (Leyshon 2001: 58). The representation network, originally somewhat exclusive, experienced a transformation because as society became less feudal and more capitalistic, musical performance transitioned from "popular festival and private concern at

[9] Attali's distribution models were attempts to analyse and conceptualise the various methods in which music was disseminated at different points in history

court" to more widely accessible "concert hall performances" because of economic and social developments afforded by a society in which wealth started to become more evenly distributed (Attali 1985: 46–47). The network of repetition emerged at the beginning of the 20th Century with the creation of technology that allowed for sound to be recorded and reproduced. This network captured the sounds generated in the network of representation initially, but soon became a "new organisational network for the economy of music" (Attali 1985: 32). The final network, the network of composition, sees Attali predict that eventually music will be performed for the artist's own enjoyment; shunning the other networks he believes music will be produced only for one's own pleasure "as something fundamentally outside all communication, as self-transcendence, a solitary, egotistical, non-commercial act" (Attali 1985: 32). Attali's prediction ignores that this non-commercial private act has a long history and indeed, playing for pleasure at home helped fuel the very earliest forms of music industry distribution, that of sheet music. The criticism here is a serious one: Attali's distribution models suggest that change occurs in stages, but this appears to be Attali poorly fitting evidence to preconceived ideas of change[10]. Leyshon (2001) is critical of this also, identifying that Attali's work is heavily influenced by a Marxist legacy with its "economic logic of succession" (Attali 1985 p.41). Much of Attali's *Noise* is convoluted, ideological and overblown with little in the way of actual evidence to back it up; one of his central claims is that changes in music be a presage for historical events and he uses attractive but ultimately questionable comparisons such as individuals stockpiling music and nations stockpiling weapons to draw out the awkward metaphor that noise is violence further. It is unlikely music has ever predicted a revolution, though it may have sound-tracked a few. It is the confidence of Attali's argument that sees it cited as an important work for those interested in the music industry. Whilst the book is not totally without merit, the parts that are relevant here are over stated and conceptually flawed. That Leyshon (2001) used *Noise* up on which to base some of his own analysis says more about the paucity of existing literature than it does about the strength of Attali's analysis.

In Leyshon's study on the reorganisation of the music industry because of new software formats Leyshon (2001) takes Attali's conceptual networks and modifies them, almost beyond recognition, to better understand the economy of music by aligning them with concepts of time and space found within geographical networks. Leyshon's modifications are based on the criticism of the succession of the models suggested by Attali, arguing that these models frequently overlap. Leyshon identifies the recording studio as a space in which the networks of composition, of representation and of replication must surely exist together as a space of performance, composition and replication. Leyshon's

[10] Attali recognises this himself when he claims these modes "interpenetrate in time and space" so it seems odd that he still insists that it is possible to discern such a succession (Attali 1985 p.41).

modification sees composition, performance and recording subsumed into a broader network of creativity (2001: 59). Attali's primary focus was of production rather than consumption and as such the role of consumer is overlooked; Leyshon notes that much greater attention on consumption is required, especially as the role has become increasingly powerful. Leyshon also argues that Attali's work has been superseded by work on the cultural industries which align the flow of cultural products with commodity chains. To compensate, Leyshon draws on Sadler's (1997) work, who in turn had drawn on that of Aksoy (1992). Sadler identified four distinctive processes: "(1) production - innovation - creation; (2) packaging - publishing - reproduction; (3) distribution - transmission - diffusion; and (4) facilitation - integration - servicing" (Leyshon 2001: 59). Stages 1 and 2 are like the networks already identified by Leyshon but stage 3 highlights the importance of distribution. In conceptually overhauling Attali's original networks Leyshon produced four distinctive musical networks that he believes comprise the music industry. Leyshon notes that "this framework is particularly useful in analysing the impacts of software formats within the music industry given the potential some advocates would suggest they have to `dematerialise' the musical economy" as it

"offers the possibility of analysing the various functions necessary for the reproduction of the musical

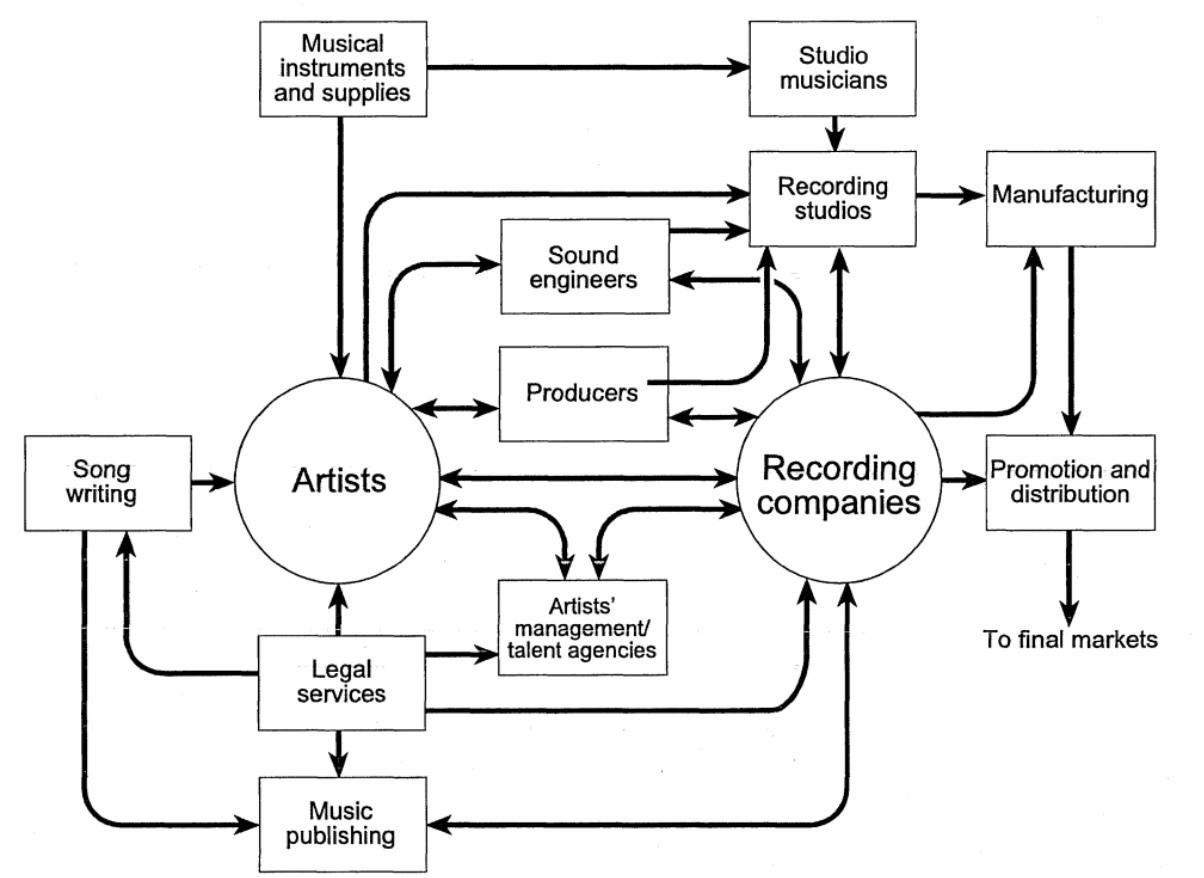


Figure 4: Scott's (1999) schematic overview of specialised activities in the recorded music industry.

economy, while addressing its complex and often messy organisational structure" (Leyshon 2001 p.60). The framework offered by Leyshon here appears to be conceptually useful as stated, but it offers only an abstract of how the music industry is organised and defined.

Leyshon used his conceptual framework to map the music industry's spatial organisation by drawing on Scott (1999) asthe spatial organisation of the industry was still of considerable importance; the music infrastructure was concentrated near major labels (Leyshon 2009). This tied musicians spatially to major label centres such as Nashville, New York and Los Angeles in America and London in the UK (Hracs 2012). Scott's schematic overview positions artists and record companies as central to the music industry which seems to be a reasonable assessment. The recording contracts between the two helps organise the "constellation of distinctive economic and culture-producing functions ranging from song writing and the provision of music instruments on the one side, to manufacturing and promotion – distribution on the other" (Scott 1999: 1968). Scott's original schematic overview of the recorded music industry is presented in Figure 4. Leyshon modified Figure 1 so that the various functions are allocated to the four musical networks he had previously adapted from Attali's work as shown in Figure 5.

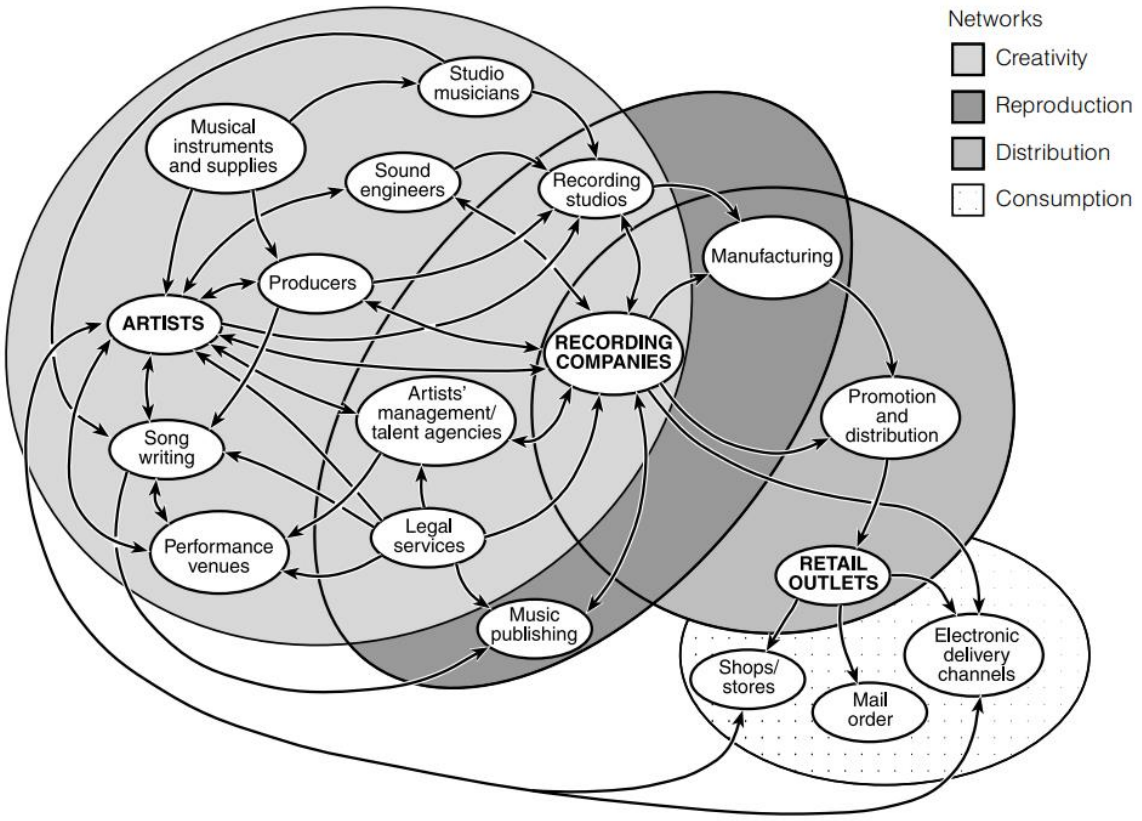


Figure 5: Music networks (Leyshon 2001).

What becomes clear from Figure 2 is that only the creativity network is network like (Wikström 2010); the networks of reproduction, distribution and consumption have more in common with the "networks" found in Actor Network Theory in that they are an alignment of "interests, including people, organisations and standards" (Walsham & Sahay 1999: 42). The creativity network is wide ranging, Wikström suggests too wide ranging, in defining the music industry. Leyshon's model emphasises spatial distribution as a dynamic that holds the networks together. Leyshon's model, in relying on spatial organisation, seems to overlook that certain actors interact with others without coming into physical contact with them. Additionally, Scott's model of the music industry is one of production only, consumption is considered only in terms of "final markets". Leyshon's model expands on this, indicating three retail outlets for the music industry as the network of consumption. However, listening equipment which allows the consumer to interact with the various sound carriers is not considered. Yet, consumption is of interest in analysing a dematerialisation transition. Leyshon's model falls short of this, which in some respects is strange given that his purpose for modelling the music industry in the first place was because of his interesting in the changes that new technologies

would have on the music industry, especially as these new technologies affected the way consumers consumed music.

Burnett (1996) developed an alternative conceptualisation of the music industry in his analysis of the global music industry. There are several similarities with Leyshon's model that suggest the models might complement each other but Burnett's model is fundamentally different in that he builds his model around "loosely coupled systems" which he believes may characterise the production and consumption of culture in a more general sense than just the music industry (see Glassman (1973); March & Olsen (1979); Simon (1996); Meyer & Rowan (1978); Ouchi (1978); Simon & Ando (1961); Fisher (1961)). Wikström utilises an earlier model produced by Burnett in conjunction with Weber (Burnett & Weber 1989) but Figure 6 shows a more refined version taken from a later publication (Burnett 1996: 71). Burnett's model suggests that two largely separate complex systems exist: the production of popular music and the consumption of popular music. These two systems are loosely coupled and are analytically if not factually distinct systems. Unlike Leyshon's model they pay less heed to spatial structuring of the industry. The result is that the emphasis is on connections within the systems which are substantially stronger than the connections between the systems. Burnett suggests the strongest of these weaker connections are the media connections, concert (live music) connections and the act of purchasing; because of this interplay each system weakly influences the other. Although analytically different, Leyshon's model and Burnett's model show several commonalities which suggest that production in the music industry is predominantly made up of three inter-related industries: the recording industry, the publishing industry and the live performance industry. However, it is the difference between the two models that is of greater interest when considering the operationalization of regimes. Burnett's model implies that at least two distinct socio-technical regimes exist, that of production and that of consumption which have interrelated transformation dynamics. Burnett has further split aesthetic production from material production whereas Leyshon's model considers all production to be part of the creativity network. Leyshon's model has more in common with how the music industry is typically defined as seen in policy documents, than Burnett's model does.

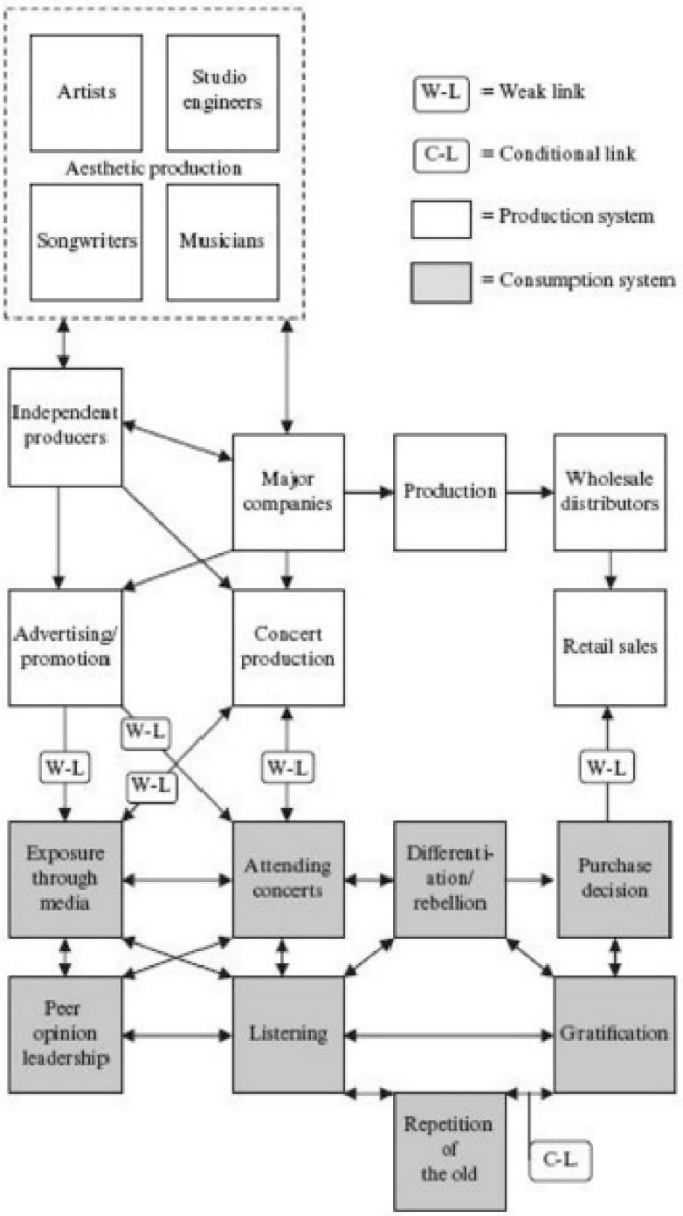


Figure 6: Production and Consumption systems of popular music (Burnett and Weber 1989)

The British Department for Culture, Media and Sport states that the "core music business activities [are] live performances, the production and sale of sound recordings and printed music, and the administration of copyright in compositions and recordings" (DCMS 1998: 67). The mapping document has become the de facto worldwide policy standard for defining the creative industries; few if any amendments have been made although the most recent mapping of the creative industries document notes that there are inconsistencies in the document which are linked back to problems of defining creativity (Bakhsi *et al.* 2012). This is further complicated by the fact non-creative jobs are also a part of the creative sector. As Anderton *et al.* (2013) note the music industries are multiple and range from the very small to the very large with a varied output of product; this is a complicating factor in defining

the music industry as ultimately it depends on where one is willing to draw the boundary of what is and is not. Inevitably, the nature of defining a boundary for a creative industry is complicated by several factors and as such an exact definition is not easily formulated.

In attempting to reconcile these definitions with the multi-level perspective the existing models of the music industry become particularly problematic. Depending on where one wishes to draw boundaries several socio-technical regimes can be conceptualised. Feasibly, each of Leyshon's networks could be defined as their own socio-technical regimes, albeit ones that are interrelated. However, Leyshon's model lacks focus on consumption. The DCMS (1998) document shows five core activities, that the authors consider part of the music industry yet they too severely underplay the role of consumption. Burnett's model is perhaps the most useful as it gives greater clarity to the two parallel networks.

Therefore, the traditional definition of the music industry, an industry that subsumes the recording industry, the publishing industry and live performance industry as they are distinguished in the literature is analytically unhelpful. To reconcile the music industry, technological change, dematerialisation and the multi-level perspective a different organisational structure may be necessary. Wikström suggests that the music industry should be considered a copyright industry. In this sense, the music industry is defined around its control and exploitation of copyright. Such a claim compliments the models proposed by Leyshon and Burnett. The relationships, and therefore the structure of, the music industry exist the way they do so that copyrighted works are created, controlled, promoted and sold. Such a definition includes major record labels and independent record labels as well as signed and unsigned artists. Importantly it also includes distribution channels that up until the last decade or so did not exist whilst also maintaining existing distribution models. Copyright is the organisational nuclei around which the music industry is based. Creation of copyright fuels production and exploitation of copyright fuels consumption however to define the music industry in terms of copyright is to get ahead. The following section explores copyright further, the commodification process, as a greater understanding of the music industry's product is of value in defining the music industry.

4.3 Lost in the supermarket – the commodification of music

The commodification of culture and the resulting culture industries have a long academic history. The commodification of music has fuelled much of this discussion, despite often being discussed implicitly as a part of culture. Pessimistic arguments about the commodification of culture can be traced back to neo-Marxist ideas found in the Frankfurt School particularly Horkheimer and Adorno (1944). The two wrote a critique of the USA's capitalist society Dialektik der Aufklärung (Dialectic of

Enlightenment) where the phrase the Culture Industry was taken from one of the book's chapter's The Culture Industry: Enlightenment as Mass Deception. As Hemsondhalgh (2007) notes the phrase became particularly prominent with French sociologists who pluralised the term. This conversion was in response to a criticism of the singularity of the Horkheimer and Adorno term in which a unified field of cultural production was implied as opposed to the complexity of cultural production identified by the likes of Miege (1987). The Culture Industries literature is considerable and given the often-implicit nature of the inclusion of the music industry great swathes of the literature are irrelevant here. However, the question of commodification is somewhat central to arguments found in the culture industries' literature and is therefore important to an understanding of product within the music industry.

The work of Horkheimer and Adorno, though the basis for much qualitative music sociology, has been heavily criticised. Miege rejected the pessimism of Horkheimer and Adorno towards the commodification of culture as commodification also allowed for innovation. Elsewhere Lovering (1998: 32) referred to Horkheimer and Adorno's analysis as "an impoverished version of Marxist economic theory" which wrote "off jazz and other popular forms as mere capitalist dope for the masses". Whether one agrees with the implications of the commodification of culture (read music) in terms of loss of expression Horkheimer and Adorno's work remains important, as Hesmondhalgh notes it is the "fullest and most intelligent version of the extreme, pessimistic view of the industrialisation of culture". They see the music industry as commoditising something and selling it "through a small group of giant companies with 'global reach'" (Lovering 1998: 32). However, the term commodification is somewhat misused by cultural studies writers (and sometimes economists and Marxist political economists). It is not clear if commodification is even the most appropriate term for the music industry's business model. In a strict sense, a commodity is a product which cannot be differentiated from another. This is not particularly true of the music industry but fitted the pessimism of Horkheimer and Adorno whose use of the term was likely influenced by Benjamin's (1936) Das Kunstwerk im Zeitalter seiner technischen Reproduzierbarkeit (The Work of Art in the Age of Mechanical Reproduction). As a result of the engagement with their critique, the phrase has stuck, and it now permeates most academic work relating to the cultural industries. This has resulted in a different meaning of the term when discussing culture. Hesmondhalgh (2007) identifies it as a more extreme form of industrialisation whilst acknowledging Lacroix and Tremblay's observation that authors do not typically define either term. He further argues that commodification is a long-term but ambivalent process and that it should not be seen "as a fall from grace from a non-commodified state of culture" (2007: 57).

The stages in which culture has become commoditised follow the same stages by which copyright legislation came to apply to original works. Copyright allowed for the commodification of music and as a result an industry developed around it. Others have suggested alternatives but as the stages of commodification have progressed so to have the ideas surrounding the actual commodity. It's at the heart of a question like Eisernberg's (2005) "is music a thing?" and it is copyright that defines what consumers actually own.

Wikström too, argues that music is commodified through copyright legislation. His classification of music as a copyright industry is not unique, the term has some history in policy documents from several institutions including the OECD (2005), IFPI (2004) and Congress of the United States (CBO 2004). The term has much to recommend it, it is clearer than a term like "culture industries" which Wikström notes is "more useful during analyses of the dynamics of these firms and industries" (2010 p.17). It is unnecessary to recount the history of copyright here, as this has been done well elsewhere (see Geller 2000; Loewenstein 2002; Wikström 2010). However, copyright has several characteristics that Wikström has identified that are worth reviewing to better understand product in the music industry as copyright is unlike products found in other industries.

Copyright is essentially a nonmaterial good, one that needs to be experienced before a consumer can decide if they enjoy it. Many thousands of new songs are written every year but this "wealth of information creates a poverty of attention" (Simon 1971 p.40). Wikström notes that "the audience is consequently unable to make well-informed decisions regarding its consumption of copyright products" (2010 p.22). Hirsch also recognises how different copyright product is from other industries which results in "the number of already available goods far exceed[ing] the number that can be successfully marketed" (Hirsch 1969 p.5). As a result of this one of the primary functions of the music industry is as a filter, which Hirsch terms "preselection systems". Should a copyrighted song successfully navigate the various gate keepers and is to be released another notable characteristic of copyright becomes important.

Copyright controls information, which allows for interaction with a copyright product at several stages. Shapiro and Varian argue that "baseball scores, books, databases, magazines, movies, music, stock quotes, and Web pages are all *information goods*" (1998 p.3 their emphasis). This intangible information is commodified through control of copyright. When a person purchases a song, they are not purchasing the copyright, but access to the sound recording which continues to be controlled by the copyright holder under licence limiting the ways the consumer can lawfully interact with it. There is an important distinction to be made: to the layman the music industry's product, or products, might be thought of as vinyl records, CD albums and MP3s. However, these are better considered, to borrow

the term from Lovering (1998), sound carriers. These sound carriers allow the music industry to control access to the copyrighted material by consumers. Shapiro and Varian discuss information in terms of option values. Different sound carriers have different option values. Shapiro and Varian discuss the difference between a song heard on the radio which is "presented in an inconvenient form" whereas with a CD "you can exercise the option to play it where and when you want" (1998 p.87). The music industry controls their copyright through offering items with different option values. Traditionally, a radio DJ would play a song which had a low option value to promote the purchase of the same song with a higher option value on CD allowing for copyright to be monetised in several ways. The act of dematerialisation is technically attributable only to the sound carriers; however, the act of dematerialisation affects the option value of the product and therefore the commodification process itself. MP3s, CDs and streaming services all have different option values both to the copyright owner and the listener of the sound carrier.

Copyright products have a high level of uncertainty, even those that have successfully navigated the preselection systems. Indeed, just because a copyright product with a low option value is available to consumers does not guarantee that the consumers will be willing to purchase a higher option value of the copyright product (Shapiro and Varian 1998); not every new song played on the radio becomes a hit. Negus attributes this uncertainty to the "unpredictable social processes and diversity of human behaviour" (1999 p.31). Thus, despite some complex filtering process copyright products are riddled with uncertainty. Wikström identifies several possibilities for this and these are considered and embellished here (2010 pp.23–24). Almost all industries, creative or otherwise, must forecast success. A car manufacturer will already have an idea of the established market and the specifications that interest consumers. However, copyright products must be produced first before a consumer can evaluate it only then will knowledge of existing markets and market research become relevant. Even established artists can become irrelevant when the zeitgeist shifts. A common way to overcome this in the music industry is to use the principles of portfolio theory. By investing in diverse markets risk is reduced and an aggregate on return provides some stability. Wikström notes that Hesmondhalgh (2002) refers to this strategy as throwing mud to see what sticks, similarly, Negus (1999 p.34) references throwing "mud against the wall" in reference to the large number of releases made each year in which few releases will prove financially viable. This overproduction is the result of the expectation that only one in eight of all released records cover the cost of production (Negus 1999 p.32). In the US during 1998 only 2% of albums released sold more than 50,000 copies (Wolf 1999 p.89). In traditional distribution models this would suggest that there is huge inefficiency leading to considerable material waste: if copyright products are manufactured and made available through various sound carriers what happens if they do not sell?

From an economic point of view this is unlikely to concern the music industry perhaps as much as it should. Wikström (2010 p.24) points out that "the dominant portion of the costs in copyright industries is attributed to the production of 'the first copy' and the marketing of the title in question. This is to say that, once the first copy or design has been made, most of the project costs have been paid". This has implications for new sound carriers such as MP3s sold through iTunes. Whilst it might be expected that a dematerialised sound carrier is cheaper to produce, these costs traditionally have only ever been a small percentage of the total cost of the copyright product. As such, high production costs are common amongst all sound carriers and are not unique to physical media. Potentially therefore, despite dematerialisation in the music industry, economies of scale remain largely unchanged. However, Wikström's argument here neglects changes in business practices within record labels. If production costs represent the greatest share of a copyright product has there been a move towards copyright product releases where these sunk costs can be reduced, i.e. where songs have already been produced and recorded? This could potentially lead to an even greater number of releases being made available.

The commodification of culture has several implications for a study of dematerialisation in the music industry. Copyright is essentially a government backed lease (it expires eventually) on a creative work that creates a product quite unlike anything found in other industries. Without it, music could be reproduced freely and without compensation to the creator lawfully. As it is, the creator of the copyrighted work, or the owner of the copyrighted work, can license the copyright product as they see fit. Given the intangible nature of copyright product a sound carrier is employed to give physicality to it. These sound carriers allow the consumer to interact with the copyright product under strict licensing conditions, as a result, sound carriers can have different value options. What is not clear from the existing literature is how value options have changed because of transition within the industry especially as newer technologies can be as intangible as the copyright product it contains. What is also unknown is the impact newer intangible sound carriers have on efficiency of production. The sound carriers remain important: they represent music 'the thing' as a tangible product, something that can be traded and coveted. They are the vessel that allows for music to be held, commoditized. If production of copyrighted work remains the same, it is the translation of commodities into real-world products that is in transition. The effects of a dematerialisation transition in the music industry remain unclear although potential avenues of analysis have been highlighted within the literature. Sound carriers are changing, and each has its own environmental impacts. It is to a comparison of the various sound carriers that we now turn.

4.4 The stylus and the damage done

It is easy to claim the music industry is in a dematerialisation transition and has been for several decades simply because sound carriers have been getting physically smaller. A vinyl record is larger than a CD, so in typical dematerialisation parlance, the transition from a vinyl record to a CD is a dematerialisation transition. An MP3 is intangible and so must be 'smaller' than a CD – another dematerialisation transition. The dematerialisation literature generally focuses on the weight of the product to ascertain dematerialisation. Additionally, it does so in a narrow context. To better understand dematerialisation in the music industry, and dematerialisation more broadly, additional factors must be considered. MIPS show us that it is not the weight of the final product that should be considered but the weight of its environmental rucksack. Further, the process of dematerialising one product may result in increases in materials used elsewhere, either as materials required to support the dematerialisation of the product, or because of increased demand for the new product. Neither does such a statement take into consideration that materials may be employed that are more environmental harmful than those they are replacing. To accommodate these criticisms when considering sound carriers, it is not enough to look just at the individual sound carrier's weight. Although much of this criticism will fuel the analysis of dematerialisation in the music industry, the literature already includes a scant number of studies that have tried to grapple with these issues.

Two studies are useful in illustrating the potential of the dematerialisation transitions, but both have faults. Weber *et al.* (2010) consider the energy demands and climate change implications of a number of sound carriers but they do not include more recent streaming technology in their analysis nor do they consider materials beyond CO_2 reduction. Türk *et al.* (2003) apply the MIPS framework to a number of sound carriers but the data on which it is based is now over a decade old, though they consider streaming technologies such technology was in its infancy, YouTube, one of the earliest streaming services (for video as well as music) was not launched until 2005 for example. Despite these criticisms both studies form the basis for the following section allowing for the environmental impact of music consumption to be more thoroughly understood, as well as the potential for dematerialisation transitions.

Weber *et al.* provide three scenarios for physical CD albums and three scenarios for MP3 albums. Over half the energy demand and CO_2 output of the traditional retail route is comprised solely of customer transport based on the assumption that customers drive to purchase an album (and nothing else). However, since the release of the study several large music retailers have collapsed, and supermarkets now supply physical music media to consumers. This suggests that driving to purchase only one CD may no longer be a realistic scenario. Two further scenarios are also considered, physical media delivered from an e-tailer (such as Amazon) on a light-weight truck and a physical album delivered

from an e-tailer by express air. The express air scenario is specific to the US and so it is the light truck scenario that I will use to illustrate the potential environmental impacts of physical media. Two of the three MP3 scenarios presented are also perhaps outmoded. Both include downloading an MP3 and burning it to disk, the difference between the two is that the third scenario also includes a slim-line jewel storage case. However, since the study there has been considerable growth in the tablet market as well as in notebook computers and smartphones. These products do not have the ability to burn CDs. As this is illustrative, the first scenario has been chosen as it considers only MP3 downloading.. Weber *et al.* calculated that in 2008 it took approximately 7kWh to download a gigabyte of data. This equates to 7MJ per downloaded album and 36MJ per purchased CD album. Similarly, a downloaded album produces approximately 400g of CO_2 and a purchased CD approximately 2050g CO_2.

The Türk *et al.* (2003) study highlighted the key differences between the three scenarios of physical retail, online shopping and digital delivery (Table 1). Türk *et al.* (2003) found that digital distribution appears to be beneficial as it had an approximate 50% resource compared to the other two scenarios. However, they noted that the material benefits of digital distribution depended on the underlying assumptions made about the support upstream equipment, that is in an equivalent scenario in which they increased the time it took to download an album digital delivery could potentially exceed the material intensity of the physical scenarios many times over. This finding highlights the need for further research into the technologies that support the digital only scenario.

Table 1: Summary overview of the three highest contributors to total material intensity (Turk *et al.*, 2003)

	Physical Retail	Online Shopping	Digital Distribution (Partial capacity)	Digital distribution (slow download)
	Abiotic(kg)	Abiotic(kg)	Abiotic(kg)	Abiotic(kg)
CD/CD-R	0.77	0.77	0.05	0.05
Production Site				
NDC/Warehouse				
CD shop / Retailer shop	0.43			
Transport goods				
Transport by consumer	0.28			
Consumer PC materials		0.14	0.14	1.28
Download		0.25	0.46	4.14
CD burning				
Disposal				
Total	1.56	1.31	0.67	5.50

Table 2 shows how the amount of CO_2 produced and energy required increased for digital album sales as the number of digital albums sold has more than doubled in the UK between 2008 and 2011. It also shows the decrease in CO_2 produced and a decrease in the amount of energy required in the same period. However, despite the growth in digital album sales, CD albums have declined meaning the total sold has also declined which would have reduced CO_2 production and energy demands over the same period. Considering this, Table 3 produces a hypothetical comparison point in which digital and CD sales are combined and treated as if they were all CD albums. This accounts for the decline in sales whilst still demonstrating a reduction in CO_2 production and energy demands. The graph in figure 5 shows over a four-year period the amount of CO_2 prevented from being produced has decreased from 273,625 tonnes to 231,421 tonnes, a reduction of 15.5%, and energy demand has decreased from 4,798,800 GJ to 4,060,800 a reduction of 15%.

Table 2: Total (approximate) Metric Tonnes of CO2 and Gigajoules of energy reductions caused by album format transition (data calculated from (IFPI 2013) and (Türk *et al.* 2003))

	Album Sales (Million)		CO_2 produced		Energy	
	Digital	CD	Digital	CD	Digital	CD
2008	*10.3*	*123.0*	*4,120*	*252,150*	*72,100*	*4,428,000*
2009	*16.1*	*112.5*	*6,440*	*230,625*	*112,700*	*4,050,000*
2010	*21.0*	*98.5*	*8,400*	*201,925*	*147,000*	*3,546,000*
2011	*26.6*	*86.2*	*10,640*	*176,710*	*182,000*	*3,103,200*

Table 3: Metric Tonnes of CO2 and Gigajoules of energy reduction compared to all album sales as CD format to account for drop in album sales (data calculated from (IFPI 2013) and (Türk *et al.* 2003))

	CD & Digital Albums combined (Million)		Total album sales as CD albums		Reduction	
	CO_2	Energy	CO_2	Energy	CO_2	Energy
2008	*256,270*	*4,500,100*	*273,625*	*4,798,800*	*16,905*	*298,700*
2009	*237,065*	*4,162,700*	*263,630*	*4,629,600*	*26,565*	*466,900*
2010	*210,325*	*3,603,000*	*244,975*	*4,302,000*	*34,650*	*699,000*
2011	*187,350*	*3,285,200*	*231,240*	*4,060,800*	*43,890*	*775,600*

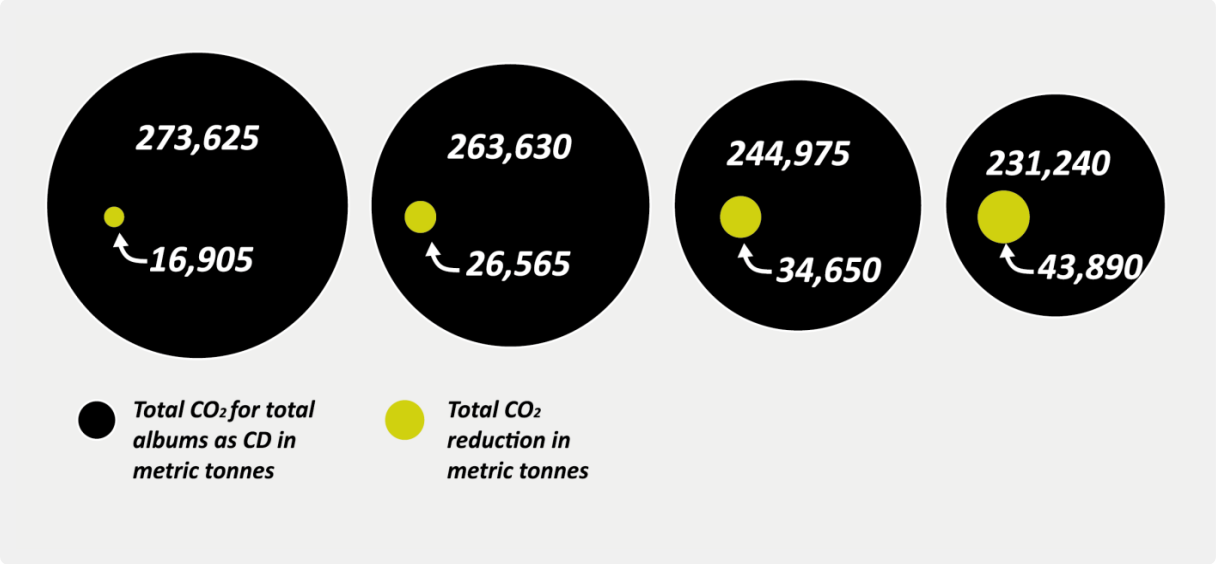


Figure 7: The total bar shows the Metric Tonnes of CO2 produced hypothetically if all albums were CDs. The green portion shows the reduction in CO2 because of the format transition (data calculated from (IFPI 2013) and (Türk *et al.* 2003)).

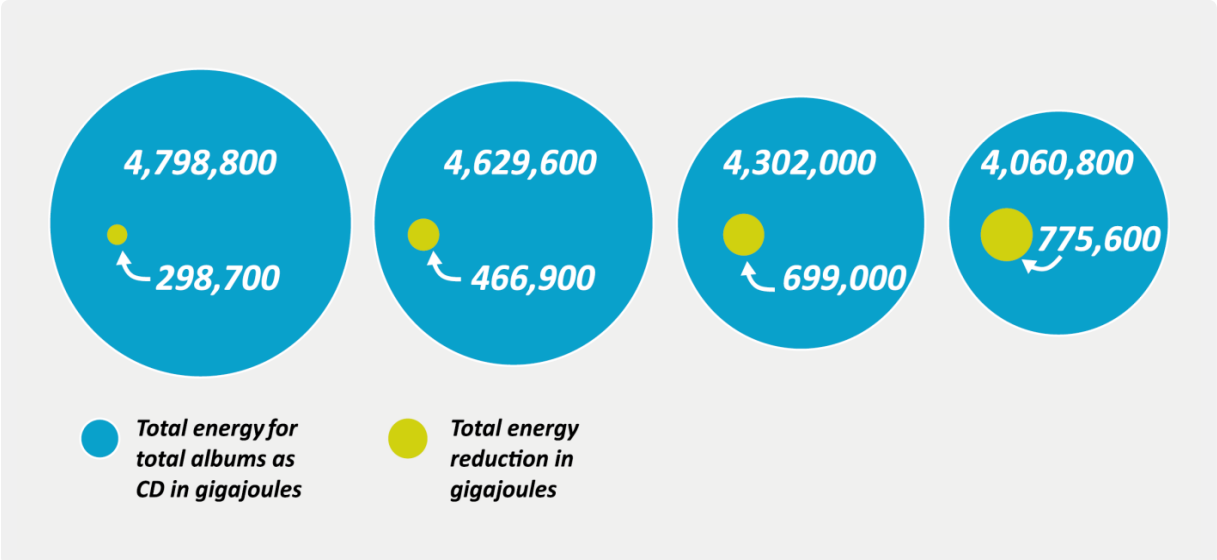


Figure 2: The total bar shows the gigajoules of energy produced hypothetically if all albums were CDs. The green portion shows the reduction in gigajoules as a result of the format transition (data calculated from (IFPI 2013) and (Türk et al. 2003))

Although this is only an illustrative example, the numbers are grounded in real figures. The actual reduction in CO_2 and energy demand is likely to be greater given that the calculated amount of energy

used of 7kWh per gigabyte was artificially frozen. Weber *et al.* predicted that the actual energy used per gigabyte would halve approximately every two years.

As already noted there are several limitations to this example, including an absence of 'streaming technology' due to insufficient data being available. Streaming uses approximately the same energy demands as downloading an album does but the data downloaded is not typically stored locally on the computer. This means that to listen to the same album again doubles its CO_2 emissions and energy demands (Haupt 2012). Further, it only accounts for legally obtained albums; the number of illegally obtained albums through newsgroups, torrents and peer to peer sharing networks is difficult to estimate (Barker 2012; Piolatto and Schuett 2012; Smith and Telang 2012). Also, there is no recognition of the effects on CO_2 emissions and energy demands in upstream and downstream sectors caused by the transition. Gains in the transition may well be offset by the technology required to engage with the digital culture such as MP3 players.

Türk *et al.*(2003) focuses on three different scenarios and attempted to employ a life cycle wide approach to each in line with MIPS methodology. They too selected physical retail, online shopping (e-tail) and digital distribution. They found that digital distribution was beneficial with a 50 per cent reduction in resource consumption than the other two scenarios. They found that the online shopping and physical retail scenarios were similar which is similar to the findings of Weber *et al.* (2009). Although they do not analyse streaming services in detail, they do note that streaming technology is unfavourable compared to downloading digital media in terms of material intensity and as such models that encourage users to be selective and preferable.

Both the Weber *et al.* (2009) and Türk *et al.* studies highlight the dematerialisation potential of transition in the music industry. However, they also highlight several unknowns that align with the dematerialisation literature. Notably Turk *et al.* are unsure of the effects of streaming but suggest they could be more materially intense. This could be an example of the transmaterialisation highlighted by De Bruyn (2002) where a period of rematerialisation occurs have a period of dematerialisation. However, De Bruyn's analysis was on the wider economy, but the potential dematerialisation highlighted in these two studies suggests that the music industry provides an opportunity to establish whether these dematerialisation patterns are found at the product level where goods transition to services.

Neither study properly considers supporting technology. Weber *et al.* chose to ignore products such as iPods entirely as they felt they were broadly like Discman type products and as such further analysis was not required as the focus was on the delivery method rather than the consumption method.

Similarly, Turk *et al.* do not consider such technology as this too was outside the focus of their study. This is disappointing as the demand for supporting technology (hardware) provides an important piece of the puzzle as to the nature of dematerialisation in the music industry. Whilst it is possible to claim that dematerialisation transitions are occurring in the industry based on the studies by Weber *et al.* and Turk *et al.*, the picture is far from clear. Like the dematerialisation literature generally, without the wider context such an analysis is incomplete.

4.5 Conclusion

At the beginning of the chapter questions were posed about the definition of the music industry, where its boundaries are and what its core product is. Several studies had attempted to produce an encompassing definition with the work of the Leyshon and Wikström highlighting the complexity of such an undertaking. Central to Leyshon's network model was the relationship between production and consumption that occurs within the reproduction, distribution and consumption networks. There are several forms of production in the overall music industry but here production is limited to the production of a commodity post creation. This more limited definition of the music industry creates a bounded case more suitable to use with the framework of the multi-level perspective as the focus is narrowed in a way that does not amend the analysis of the transitions within the production and consumption regimes. The literal production of music from conception to recording is separate from the production of the sound carriers for consumption. Looking again at Leyshon's four network model and removing creativity we are left with the commodity-based part of the music industry. This is the part that takes copyrighted products created in the creativity network and processes them for consumption. The result of the literature review therefore is to acknowledge the four networks that intertwine to encapsulate the music industry: creativity, reproduction, distribution and consumption. Creativity is excluded from the case study as Attali suggested it would occur independently anyway, as a means of satisfying self-transcendence and is an inherently non-commercial act. The border of the case study here then is the point at which the artist finishes creating a copyrighted work. The music industry regime commodifies that creative work; packaging the creative in such a way that it can be consumed. Its product is a piece of aural copyright distributed to the consumer through any number of sound carrier channels. As such, in multi-level perspective parlance, the production of Compact Discs as a way of disseminating musical works became in the dominant regime in 1989. The incumbent regime through the 1990s was one that sought to control copyright through the production and consumption of physical plastic discs and to a lesser extent, cassette tapes. The creative and performance are beyond the scope of inquiry of this research.

The existing literature on the music industry, as discussed in section 4.4, highlighted the apparent changes that have occurred in distribution of the copyrighted works but was unable to cover changes

in upstream and downstream sectors, nor did the existing literature contain sufficient information to explain how such changes came about and the catalysts for such change. In addition to seeking clarification for these questions understanding how the regime's core activity of copyright control and distribution has changed over time will be central to the subsequent analysis.

5 Multi-regime co-operation – the development of new sound-carrier technologies by disparate actors

5.1. Introduction

This chapter's primary focus is on the multi-regime interactivity that occurs in the development of the Compact Disc Digital Audio (CD-DA) technology and the subsequent innovations of the MPEG standard because of the breakthrough of the CD-DA technology as a result of actor activity and enrolment. It is intended to contextualise the socio-technical regime of the mid-1990s from which dematerialised sound carriers began to be adopted. This is achieved by highlighting the key multi-regime actors, their influence on the socio-technical transitions and transition patterns that influenced the later developments in the music industry regime and on dematerialised sound carriers using historical narrative and analysis of the interactions that occur.

The chapter first focusses on the CD-DA and its development from earlier laser based analogue technologies and the actions taken by special interest actors in forming symbiotic relationships between the record industry and technology companies to transition to the new CD-DA technology from existing physical analogue technologies (section 5.2). The chapter then focusses on the further actor enrolment from other regimes who sought ways to adapt and adopt the CD-DA technology and innovations that emerged as part of this and the influence they had on developments and in specially created protective niches such as MPEG (section 5.3). The closing section (5.4) provides a summary discussion with a specific focus on the multi-regime interactions of the different actors and actor groups in steering the socio-technical transitions that occurred during this time period.

5.2. The development of the CD-DA and how the record industry positioned it as the technologically superior sound format

The CD-DA was a technological phenomenon; a project co-developed between European and Asian competitors and launched into an uncertain market with declining album sales. Other optical disc-based products had fared badly, and adoption was far from guaranteed. Yet within just a few years, CD-DA had not only squashed sales of vinyl records but reduced compact cassettes' momentum, positioning it instead as a subaltern-regime with CD-DA as the dominant sound-carrier. The following subsection provides a narrative and analytical overview of the elements that came together at the niche level through the design, launch and marketing of the CD-DA that led to a significant re-adjustment of the existing socio-technical regime and its impact on the wider socio-technical landscape.

5.2.1. The creation of a shiny new plastic novelty

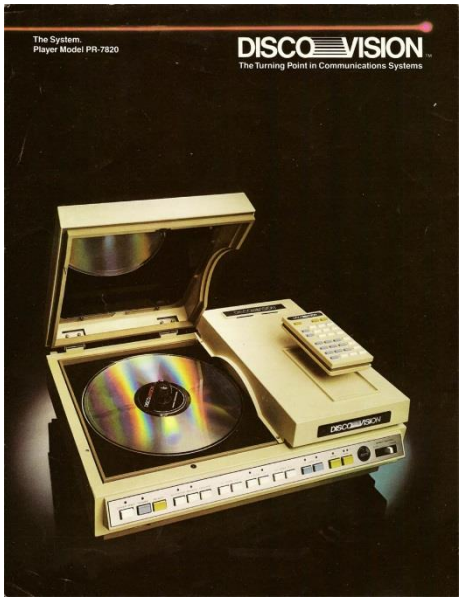


Figure 3: The MCA DiscoVision PR-7820 was the first mass produced laserdisc player.

LaserDisc was co-developed by MCA and Philips and was the first commercial optical disc storage medium. Aimed primarily at home video users (Figure 10), it offered superior quality audio and video compared to cassette-based products but saw only limited popularity. The LaserDisc provided early learning opportunities for Philips, through several dimensions. The lack of market demand, caused in part by high player costs as well as other competing technologies and formats[11] all vying for a similar user base, demonstrated that it was not enough to be technologically superior. As development had been costly and penetration of the technology low, other attempts were made to further develop optical technology by Philips[12] (McGahan 1991).

Philips' engineers tasked specifically with evolving LaserDisc technology and developing a technology with superior sound quality to vinyl records by Philips' management sought produce a digital rather than analogue[13] format. They established a laboratory specifically to develop their optical disc prototype in 1977, the type of protected space in which novelties are allowed to be developed and eventually emerge (Immink 1998). Sony, having recently developed the Digital Audio Tape (DAT) and aware of the work that was happening at Philips also began work on optical discs as an extension of Pulse-Code Modulation (PCM) used in DAT. Both companies having demonstrated their prototypes, which served to attract the attention of external actors, Philips' management decided in 1978 that the project merited a worldwide standard agreeing to collaborate with Sony.

This enrolment of actors is an important social process in the development of the CD-DA. As an innovation within the niche it allowed for Philips and Sony to significantly expand their respective resource bases (Kemp *et al.* 1998; Hoogma *et al.* 2002). Further, the process of standardisation was important as it provided the engineers with guidance and direction that created an opportunity to link

[11] VHS and Betamax were already competing for the home video market, locking users in to these formats. They also offered home recording which Laserdisc lacked despite its higher cost.
[12] Pioneer purchased the majority stake in the Laserdisc format in 1980 and rebranded it.
[13] The Compact Cassette, Vinyl Record, LaserDisc, VHS and Betamax systems were all analogue formats.

together different technologies with engineers selecting the best elements based on the specifications set by managers.

Several external landscape pressures also influenced the CD-DA developments. Sony was still rapidly losing ground in the home video cassette market with its technically superior Betamax system to JVC's VHS. Similarly, Philips had introduced one of four incompatible and competing audio cassette formats in the 1960s which had taken a long time to penetrate the market despite also having clear advantages to the dominant 8-track systems[14] (see Figure 10). These earlier precedents of competing consumer technologies concerned management, especially as Philips and Sony were not alone in developing digital capable discs in the 1970s[15].

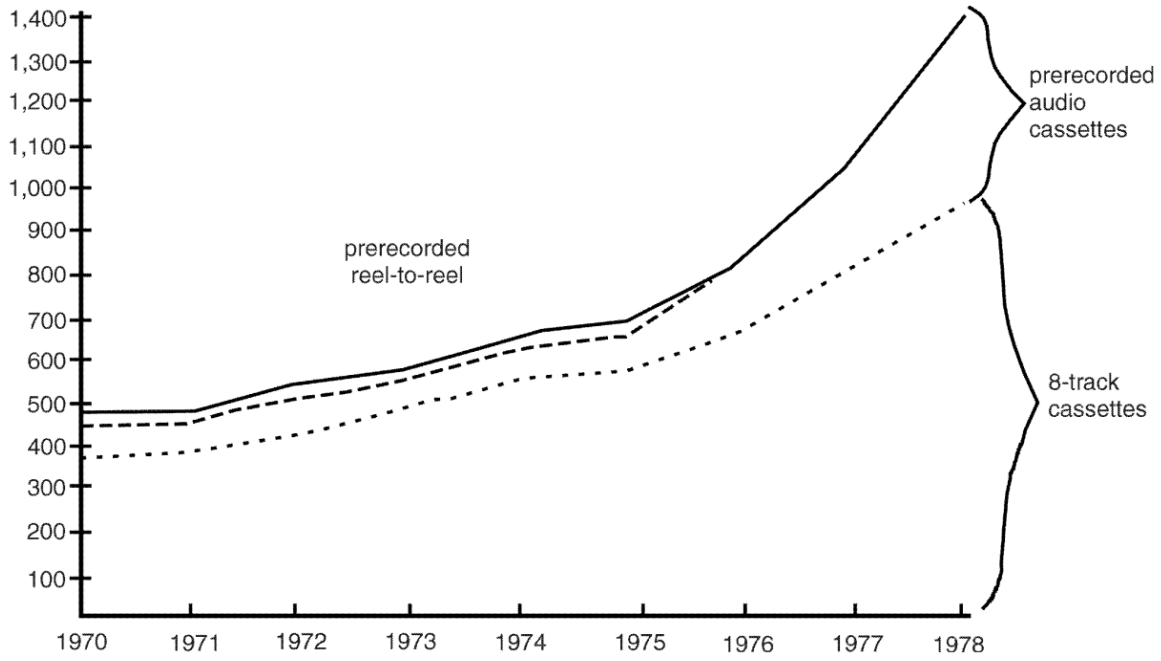


Figure 10: U.S. Retail Sales of Pre-recorded Music on Tape by Format (millions of dollars) (Liebowitz 2004)

5.2.2. Enrolling rival actors through standardisation

In combining the two systems, Philips' and Sony's engineers had to collaborate and discussions centred on parameters such as sample rates, disc size and sound resolution. Some parameters were dictated by existing analogue technologies and the digital interaction with them, others were chosen

[14] 8 tracks had playback only capability

[15] The Berlin based Telefunken and the Japanese JVC were at the time also developing incompatible discs as evolutions of products originally designed to display video. Telefunken's bore a strong resemblance to conventional phonograph players as it used a groove-based mechanism whereas JVC's prototype was based on an electronically charged disc that operated in a manner similar to Sony's digital cassette without the recording capability.

by management whilst others were left to the engineers to factor. Size was perhaps the most important as all other factors were traded off against that. Immink (1998 p.60) notes that the prototype Philips had developed was dictated by "the top brass of Philips" as the "Compact Cassette was a great success, [and they] don't think CD should be much larger"[16]. The standardised CD had a diameter of 12cm[17] enough to hold 74 minutes of audio. This decision had a considerable impact on the "album" as an artistic work. Although the popular myth that the head of Sony wanted the CD to be able to hold Beethoven's 9th Symphony lingers, Immink supports the argument for a practical rather than artistic consideration for this decision. The result of the collaboration was the Red Book CD-DA standard published in 1980. Philips' and Sony's engineering collaboration agreement ended in 1981 with each company retiring to prepare its own CD-DA products. Both agreed "that if either was unable to design a commercial product, the other would donate its design" (Pohlmann 1992 p.11). The Red-Book standard represents an important coming together of various actor groups to strengthen one design rather than a fractious number of similar but ultimately competing novelties. The Red Book

Figure 4: Sony CDP-101 the first commercially available CD player in Japan.

standard, already supported by two key actors within the sound carrier manufacturing space, was used to enrol further actors.

Philips, with the cooperation of Sony, licensed its hardware and shared information about its manufacturing process to more than thirty manufacturers effectively creating several strategic alliances in a successful bid to reduce competing formats. Only the laser assembly needed to be

[16] A Compact Cassette has a diagonal length of 11.5 cm and the Philips' prototype met this.
[17] Immink, the only engineer involved in the process who has written on the subject, specifically says we should not believe such stories despite how compelling this one seems to be.

consistent across the various manufacturers allowing them to differentiate their hardware offerings as they wished (McGahan 1991). Success of the initial licensing agreements for the CD-DA standard led one observer at the time to refer to the format as "blessed" compared to other format war veterans (Penchansky 1982). The standardisation and subsequent licensing of the CD-DA hardware stabilised the CD-DA as the dominant digital optical sound-carrier format amongst manufacturers however, for the CD-DA configuration to challenge and break through to the existing socio-technical regime the CD-DA software also had to come into alignment.

5.2.3. Engaging and enrolling external regime actors to bring new content to the format

The software had to be produced and this required the involvement of the music industry. The technology companies had existing relationships with some of the major labels. Sony was affiliated with CBS Records[18] whereas Philips owned 50% of Polygram. Hans Gout[19], sought to strengthen this network and approached EMI and Warner to help secure the Philips' disc as the industry standard. Toshiba who had a close relationship with EMI publicly announced its reluctance to pay Philips royalties for use of the CD-DA format, although this was not enough to threaten the legitimacy of the nascent format amongst other actors (Jones 1982).

In 1981 Philips introduced a Compact Disc Introduction Team (CDIT) to co-ordinate the introduction of both software and hardware to the USA. In Japan, the first players were introduced in the autumn of 1982. Sony's CDP-101 (Figure 12) was launched alongside approximately 50 software titles[20] and was officially launched to consumers in the Netherlands and the UK on the 1st March 1983 with 1000 titles made available by the end of the year.

Despite some hesitance within the industry to adopt the CD-DA, with both Philips and Sony partnering with labels through pre-existing relationships they could enrol additional key actors from within the music industry. There was also wider opposition to entirely digital systems within the recording industry but Sony utilised artists such as Stevie Wonder and Herbie Hancock to endorse their digital products legitimising the use of digital to capture and playback sound.

[18] Sony Corporation of America would later buy CBS in 1987 for $2 billion changing its name to Sony Music Entertainment in 1991.
[19] Director of marketing for Polygram
[20] The first title is officially recognised as Billy Joel's 52nd Street pressed at the Sony CBS plant which opened in April 1982 in the Shizuoka Prefecture, Japan. The first production CD pressed at Polygram's plant in Hanover was Abba's The Visitors in August 1982 although the plant had first produced test pressings in 1980. In America the CDIT chose to wait until 1984 to open a plant pressing Bruce Springsteen's "Born in the USA".

Philips and Sony created a considerable social network with an expansive resource base. The CD-DA as an innovative new sound-carrier was very stable within its niche, the threat from other competing innovations was neutralised through enrolment and licensing to other manufacturers and it had considerable momentum behind it from a support network of enrolled actors across a range of multi-regime actors. However, upon its launch no one knew how the CD-DA would fare in the existing market.

5.2.4. Actor manipulation of existing markets

Popular consensus states that the CD replaced the vinyl album. However, the reality of music sales at the start of the 1980s is less clear. Vinyl record sales had already started to decline before the introduction of the CD-DA having reached a peak in 1981 with 1,140 million units (see Table 3). By the time the CD-DA was introduced to the market, vinyl records were already being threatened by Compact Cassettes as the incumbent sound-carrier. Both vinyl and Compact Cassettes sold 800 million units each in 1984 essentially creating two subaltern regimes. These two subaltern regimes differed from each other in the user practices they created, and the CD-DA drew from both the established cultures, user preferences and behaviours whilst differing enough to hinder adoption initially amongst retailers and consumers.

Table 4: Estimated world sales. Units in millions (Hung and Morencos 1990); Aggregate column added.

	LP	MC	CD-DA	Aggregate Sales
1973	*617*	*185*		*802*
1974	*655*	*209*		*869*
1975	*674*	*236*		*910*
1976	*743*	*289*		*1032*
1977	*898*	*374*		*1272*
1978	*942*	*428*		*1370*
1979	*896*	*470*		*1366*
1980	*878*	*474*		*1352*
1981	*1,140*	*510*		*1,650*
1982	*900*	*570*		*1470*
1983	*850*	*660*	*6*	*1516*
1984	*800*	*800*	*20*	*1620*
1985	*730*	*950*	*61*	*1741*
1986	*690*	*970*	*140*	*1800*
1987	*590*	*1,150*	*260*	*2,000*
1988	*510*	*1,390*	*409*	*2,309*
1989	*450*	*1,540*	*600*	*2,590*
1990	*339*	*1,447*	*777*	*2,563*

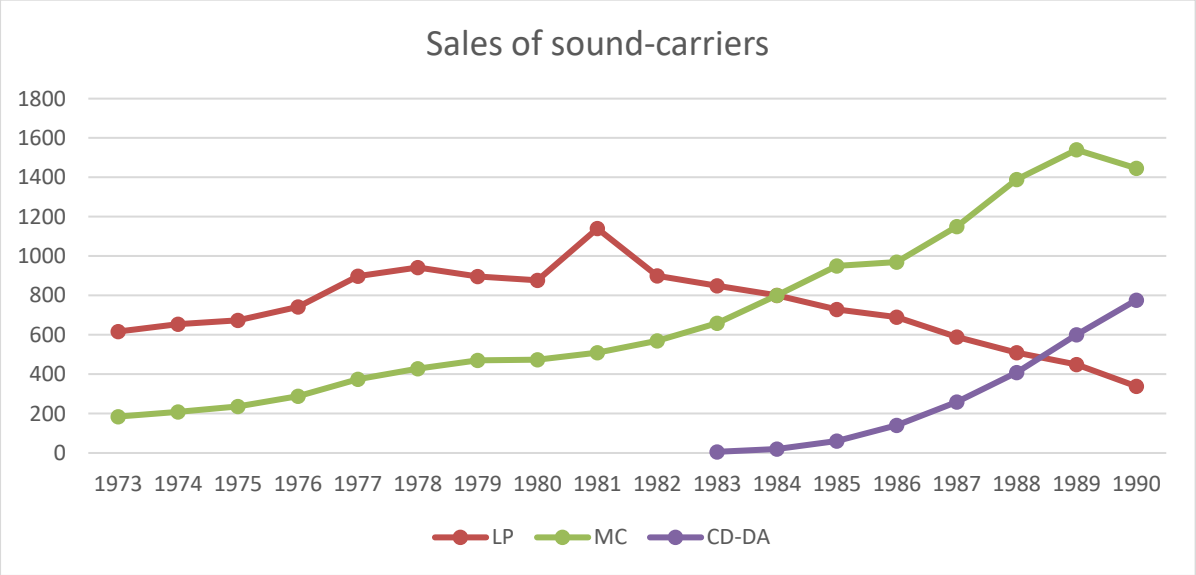


Figure 12: Long Player, Micro Cassette, CompactDisc Digital Audio sales between 1973 and 1990

Retailers, who were an integral group of actors within the socio-technical regime, as they linked production with consumption, resisted the new technology. Locked into vinyl and cassette they disliked having to stock an additional sound-carrier of the same album as they were concerned about

theft and were worried about sunk investments in having to refit store displays. Retailers slowly adapted to the additional stock but CD long boxes (Figure 13) were introduced to ease the transition so that retailers did not have to replace existing systems immediately.

Figure 5: CD long boxes were transitional aids, 12 inches tall by 6 inches wide they fitted into existing storage and display solutions.

Outside of early adopters, consumers were initially hesitant as CD-DA players were expensive. Once consumers had purchased the new players they were also locked in. Sony introduced the Sony D-50 portable Discman which increased interest in the CD-DA as a response to a perceived consumer hesitance which further reduced prices and the consumer's adoption risk.

The majors, perhaps inspired by the CD-DA's premium price and increased margins over vinyl and the fact that it encouraged consumers to replace their existing vinyl collections, changed some of their existing distribution contracts with retailers offering financial incentives to stock CD-DA which saw fewer vinyl albums being stocked.

Unusually for such a significant socio-technical regime re-alignment few, if any, socio-technical landscape pressures appear involved in the break-through of the niche. Instead, actors within the regime manipulated other actors enrolled within their extended social networks to create windows of opportunity allowing for the rapid adoption of the CD-DA. In turn, this modified consumer-behaviour and consumer preferences resulting in consumers who became locked into the new sound-carrier. This lock-in was exaggerated by the decreasing availability of newly released vinyl records which led to further adoption of the CD-DA.

As Table 3 shows, the uptake of CD-DA sales was rapid. Earlier growth may have been greater still were it not for the limitations of CD-DA production capacity resulting in labels concentrating on present hits and front-line catalogue titles. Sales of software accelerated as more pressing plants came online allowing more back-catalogue artists to be released (Sutherland 1986). In its ninth year more, CD-DAs were sold in a 12-month period than vinyl albums had sold at its peak and unit sales continued to rise year on year until 2000. The CD-DA outsold Compact Cassettes in 1993 as Compact Cassette sales entered a decline after which the CD-DA can be said to have become the dominant sound-carrier

within the socio-technical regime. What is also notable is the huge but steady increase in aggregate sales across the sound carriers. This will have had considerable material impacts a topic returned to in Chapter 6.

The adoption of the CD-DA novelty within the incumbent regime was considerable. The creators of the sound carrier presented it as technologically superior, but it was the record industry that manipulated actors within the incumbent regime by shorting supplies, changing contracts and pushing the new product through adverts at the expense of existing sound carriers. Consumers who had effectively been coerced into adopting the new technology became enamoured with the convenience and technological superiority, as promoted by the manufacturers, of the CD-DA and once locked in continued to purchase new CD-DAs to replace their existing collections. The CD-DA was touted as a technology of the future, available today and as such once consumers were familiar with digital technology it presented windows of opportunity within other regimes.

5.2.5. The impact of the CD-DA on other technologies

Before becoming the dominant sound-carrier by numbers the influence of the CD-DA was already appreciable on the socio-technical landscape. Further collaborative efforts between Sony and Philips saw the first extension of the CD-DA which was specified through the Yellow Book. The CD-ROM[21] was built atop of the CD-DA specifications which bequeathed many encoding techniques and structures. Whereas CD-DAs held only audio, CD-ROMs were more general purpose digital storage mediums.

Compact discs' bandwidth was limited to around 1.5 mbit/s. On CD-DA this was used only for audio, but CD-ROMs brought with it the promise of video. In addition to the niche in which CD-ROMs sat, several other industries were also concerned with the development of audio and video compression. These convergent niches, influenced by expectations from several socio-technical regimes, came together developing compression standards that broke through to other existing socio-technical regimes fundamentally changing the way consumers engaged with media.

5.3. External pressures – Socio-technical landscape influence and niche developments

Through the 1980s, several industries were faced with similar technological dilemmas. In particular, the compression of video and audio was becoming pivotal for three disparate industries who shared a common rationale in trying to reduce digitised delivery from 200 Mbit/s bitrate to a value of around

[21] Compact Disc Read-Only Memory

1.5 Mbit/s (Mitchell *et al.* 1997). The computer industry is discussed here in detail because of its importance in creating landscape pressures that directly affected the music industry, broadcast radio is discussed in detail subsequently in section 5.3.2 because its niche development is of great significance and telecommunications is discussed in more abstract terms throughout as its narrative is only of tangential interest.

5.3.1 The computer industry fits and stretches

The computer industry, a rapidly expanding socio-technical regime consisted of two distinct user practices in the early half of the 1980s. Users typically interacted with one of two types of computer. Home computers, which connected to a television set or work station style business computers with dedicated high-resolution displays. As a niche development, computers were largely adopted in a fit and stretch pattern wherein the capabilities of computers were restricted by the technologies they were replacing. As Rosenberg (1986 p.24) noted:

> "when drastically new technologies make their appearance, thinking about their eventual impact is severely handicapped by the tendency to think about them in terms of the old technology. It is difficult even to visualize the complete displacement of an old, long-dominant technology, let alone comprehend a new technology as an entire system. Thus, time and again, new technologies have been thought of as mere supplements to offset certain inherent limitations of the old."

However, new opportunities for computers were continually recognised and as such an innovation cascade was also occurring whereby computer capabilities fit and then stretched into other areas of productivity in business and home contexts.

The home computers of the 1980s became more focussed on gaming whereas the workstation style computers began to find their ways into people's homes as productivity tools. This meant that work station style computers and home computers began to merge into much more capable multi-tasking devices. The end of the 1980s saw PC manufacturers and software developers pushing development of Multimedia PCs[22].

Multimedia PCs were influenced by the landscape pressures caused by CD-DA. These developments in the PC regime were one of the key exogenous landscape pressures that created windows of

[22] Multimedia PCs were computers that had the ability to "manipulate text, graphics, sound, pictures and even full motion video" by combining multimedia tools with the robust storage found on CD-ROMs (Quindlen 1990 p.94).

opportunity for MP3 as a novel music sound-carrier to destabilise the music industry's CD-DA regime some years later. Although the increased prevalence of multimedia PCs would eventually be an important factor especially in universities, it was the need for multimedia content in the first instance that saw the need for CD-ROMs.

The computer industry utilised CD-ROMs as storage mediums but video and audio required compression to fit more than a few seconds of playback. Similarly, other consumer electronics industries wanted to position digital video as a more interactive and more capable way of playing computer games utilising discs for digital video storage. The telecommunications industry had already taken steps towards developing codecs such as h.261 for teleconferencing as a means of improving its existing products and reducing resource demands[23]. Of the innovations being developed across different regimes, the European broadcast radio project provides a comprehensive example of niche innovation development on commercial audio compression.

5.3.2. EUREKA! Digital Audio Broadcasting (DAB)

O'Neill posits that although the digitalisation of radio is often presented as an inevitable development of broadcasting systems in technical literature it was the digitalisation audio and video elsewhere that influenced the European radio regime to follow suit (2009; Layer 2001). The DAB project began in 1981 when the Institut für Rundfunktechnik (IRT) collaborated with the main German broadcasters to explore data compression techniques. The project gained support from the German government who commissioned a study on digital radio which concluded that although development was possible it would require considerable research and an international collaborative effort (Sterne 2012). By 1986, there had been a significant enrolment of actors with nineteen organisations from Britain, France, Germany and the Netherlands agreeing to collaborate. Funding was received in 1987 as Eureka-147 (EU-147) (Sterne 2012). DAB was intended to eventually be a technological substitution for AM and FM radio when at the appropriate time landscape pressures largely engineered through policy[24] would allow niche-innovation to substitute the existing radio socio-technical regime.

EUREKA-147 saw CCETT, IRT and Philips co-develop the MUSICAM[25] system which was rooted in perceptual coding which represented a cluster of conceptual breakthroughs in audio compression that

[23] Cable television companies were also exploring the potential of digital video for satellite uplinks and downlinks as well as for delivery to the home and also tentative discussion about how best to start implementing HDTV either through broadcasting digital or increasing the bandwidth of existing analogue systems (Mitchell et al. 1997).
[24] Such as FM signal switch off
[25] Masking pattern adapted Universal Subband Integrated Coding and Multiplexing

were based on work that had begun in the 1930s. In simple terms, sound could be filtered to remove the components of the signal that the human ear could not detect allowing for compression through the removal of the redundant data (Dehery *et al.* 1991)[26].

5.3.3 The seeds of systemic change - MPEG and creating standards (1988-1994)

Parallel to MUSICAM's development, other industries were focussing on compression technologies for video and audio attempting to compress the two to around 1.5 Mbit/s. The potential for convergence between the three otherwise disparate industries was recognised by Leonardo Chiariglione who was instrumental in setting up the Moving Pictures Expert Group. MPEG formed as an ad hoc meeting at a Joint Photographic Experts Group meeting in 1988 and was established to standardise compression of video and audio. The work done by MPEG was outside the music industry's influence or interest. That it is relevant at all to the music industry relies on a quirk of circumstance beyond both MPEG's and the music industry's control. Within its convergent development however, Chiariglione set about creating a protected space for research and innovation.

Eureka-147 was already a considerable social network with an expansive range of actors and significant resource base. The MPEG committee expanded that even further with the enrolment of many different actors many of whom had their own innovations, developed separately in the hope that their novelty was the one that MPEG would promote as the dominant design[27]. The MPEG standard was anticipatory and had no clearly defined use; it was expected that it would be applicable in a range of situations. MPEG initially articulated its vision for the technology as "intended for application to digital storage media providing a total continuous transfer rate of about 1.5 Mbit/sec for both audio and video bitstreams" such as using the compact disc for interactive video (ISO 1993)[28].

[26] A thorough recounting of the emergence of perceptual coding and the technologies that contributed to it can be found in Sterne (2012 pp.92–127).
[27] Contributions to the standards came from a variety of agencies working in the fields of telecommunications, broadcasting, computers, consumer electronics and VLSI[27] manufacture based on the prospects of future applications of the compression standard.
[28] The net bit rate of a CD of "2 x 706 kbits = 1.41 Mbit/s was split into a bit rate of 1.15 Mbit/s for an encoded video signal and 0.256 Mbit/s for a encoded stereo sound signal" (Musmann 1990 p.511)

Table 5: Performances to be tested (Musmann 1990 p.512)

Performance	*Weighting Factor (w)*
1. Sound quality of forward audio playback	*121*
2. Sound quality of fast forward audio playback	*067*
3. Random access	*118*
4. Ability to encode in real time	*055*
5. Data capacity for ancillary information	*093*
6. High quality stereo	*086*
7. Intermediate quality audio	*096*
8. Robustness to bit errors	*089*
9. Encoder complexity	*059*
10. Decoder complexity	*117*
11. Short decoding delay	*072*

*s = s1*w1 + s2*w2 +... + s11* w11*

The scoring S of each performance is between 0 and 10, where 10 is the best score.

S is the total score for a coding algorithm

Sonic factors were set against technical factors weighting them against one another in a complex scale. This evolved into a set of competing values and compromises (*Table 4*) conflating the sonic and the technical into a false equivalence. As Sterne notes "[a]n MPEG audio file is at once about sound quality, compatibility, manipulation, storage, data intensity, and distribution […] MPEG's weighted list of criteria has its biases in kind and in weight" (2012 pp.144–145). The difficulty in such a scale is that the scale itself is already a compromise. Those who contributed to it and argued for the weightings were also aware of the strengths and weaknesses of their compression technology although it was intended to level out any such self-interest.

Table 6: Coding concepts and development groups of ISO WG11 audio group (modified from Musmann 1990 p.512)

Initials	***ASPEC***	***ATAC***	***MUSICAM***	***SB/ADPCM***
Coding Concepts	*Transform coding with overlapping blocks*	*Transform coding with non-overlapping blocks*	*Subband-coding with more than 8 bands*	*Subband-coding with 8 or less bands*
Members of Development Group	*AT&T: USA*	*Fujitsu: J*	*IRT: FRG*	*BTRL: GB*
	D.Thomson-B: FRG	*NEC: J*	*Philips: NL*	*NTT: J*
	Fraunhofer-G: FRG	*Sony: J*	*CCETT: F*	
	France Telecom: F	*JVC: J*	*Matsushita[29]: J*	

USA: United States of America, FRG: Federal Republic of Germany, F: France, J: Japan, NL, Netherlands, GB: Great Britain

The MPEG niche inherited the most promising novelties from fourteen other niches, a considerable enrolment of actors and resources. Weighting the results according to the scale in *Table 4* two of the codecs emerged above the others, MUSICAM and ASPEC. Despite the weighting scale, the test results were interpreted differently by different actors resulting in internal conflicts with factions falling in line with industrial interests.

Conflicts and tensions were mediated by layering the standard as layer 1, 2 and 3. Layer 1 contained a basic mapping of the digital audio input into 32 subbands. Layer 2 descended directly from the MUSICAM codec but was ultimately modified and layer 3 was a modified version of the ASPEC codec. Layer 2 required less computational power as it was not as complex as layer 3 and was less susceptible to transmission errors. However, it was not as capable as layer 3 at compressing the data resulting in larger files sizes. The MPEG conflict spilt outside of the MPEG meetings, with chip vendors anxious to move forward with their products reluctant to do so until MPEG was fully standardised. Other video compression technologies had become available[30] focussing attention on MPEG audio. It was posited that the additional expense of Level 3 put it beyond reach of most users and critics both within MPEG and without were concerned it would diminish MPEG's acceptance as the de facto industry standard (Krohn 1991). This conflict was later mediated by the market however, with manufacturers choosing to support the more cost-effective layers 1 & 2 in the short term which proved problematic for supporters of layer 3.

The layers therefore were a way of allowing compromise into the "standard" resulting in a group of compatible codecs merging. As part of the compromise and as a way of making layer 2 and 3

[29] Matsushita Electric Industrial Co., Ltd. changed its name on January 10th, 2008 to the Panasonic Corporation.
[30] Such as Intel's DVI

compatible layer 3 was built atop of layer 2[31]. The filter bank of layer 3, originally a 512 band MDCT became more complicated because of the compromise and introduced a technical flaw that was not part of the original proposal. However, without this compromise the ASPEC proposal may not have been included as part of the MPEG-1 standard at all. The technical compromise allowed for a political compromise within MPEG and the wider industrial sectors that contributed to it. This resulted in a standard with greater flexibility, despite applications of such a standard still being thought of in the producer-distributor-consumer model. In developing such a standard for digital storage media, MPEG was ultimately considering extensions of the existing systems: digital radios, HDTV, boxes in people's homes, portable devices for watching and not just listening, CDs for video. These were add-ons to the existing producer-consumer socio-technical system of the post second world war consumer electronics and media industries: "if there was a dream of universality, it was the old universality of the multinational conglomerate" (Sterne 2012 p.138).

The MPEG-1 standard was published in 1993. MPEG-1 layer 2 (MP2) saw use in DAB systems as the project rolled out across Europe. In America, it was used in satellite radio. MP2 was also used to provide the audio on compact discs, a development in Philips' interests as it was instrumental in developing both the CD and technologies in MP2. Further, MP2 would be used in satellite systems in the broadcast industry where bandwidth was at a premium. MPEG-2 which had started development even before MPEG-1 was published adopted the audio layers from the MPEG-1 standard. As part of MPEG-2 the layers saw further adoption on products such as DVDs which were released from 1995[32] onwards. The result being that even today, hundreds of millions of systems use MPEG-1(/2) layer 2 audio.

MPEG's enrolment process of actors with convergent novelties created a powerful niche momentum in which all involved parties had a vested interested in seeing a standard emerge. The MPEG process was in many ways an ideal incubator for innovation ably enacting the many social processes that the multi-level perspective prescribes to niche innovation. Even when the groups disagreed on one standard for audio, MPEG as a group reached a compromise through the adjustment of expectations whilst overcoming organisational issues to produce a technical design that was widely applicable thus stabilising the niche around a central dominant design composed of a three-layered standard. The socio-technical regimes which contributed actors to the MPEG niche did so because of landscape

[31] Originally ASPEC and MUSICAM handled signal processing in different ways: ASPEC used a 512 band MDCT (modified discrete cosine transform) to filter the audio where as MUSICAM used a pseudo-QMF bank (aka a poly-phase bank) to filter the audio (Spanias et al. 2006). One of the internal contentions with in the MPEG audio group was that the MDCT required too much processing power.

[32] DVDs had a staggered worldwide release. They were released in Japan in 1995, North America in 1997 and Europe in 1998.

pressures caused by a general socio-technical transition of analogue to digital. In developing a standard these novelties were linked together in MPEG's niche. Through its testing processes and much political wrangling, the MPEG standard's process tied these novelties together, selecting three of them and modifying them as "layers" as the dominant designs. Outwardly, the audio standard was meant to be singular but the "layers" allowed for compromise and for a unified standard to be moved forward for publication. The compromise within the protected space of the MPEG niche allowed for the standard to become more precise. The impact of such actor behaviour was to create a format that could more readily be utilised by other actors as many of the risks of adoption of niche technology were mitigated, such as a competing format proving more popular.

5.3.4 Competition and lockout

The standard split into its layers as to how it was adopted and broke through to the disparate socio-technical regimes. MP2 took advantage of windows of opportunity in various socio-technical regimes as engineered by the manufacturers and involved actors. For DAB, this was engineered through policy, for example. Therefore, it was the adoption specifically of MP2 that adjusted the socio-technical regimes and not of the MPEG standard more generally with respect to audio. Within the MPEG niche enrolled actors were no more or less powerful than each other by design. However, outside that protected space, competition returned and larger actors with greater resources were better able to position their MPEG-1 layers for adoption than those who lacked such resources.

The initial success of Layer 2 proved to be particularly problematic for backers of ASPEC. Developed by AT&T of North America and Fraunhofer-Gesellschaft, a German research organisation, the ASPEC codec, modified for MPEG and renamed MPEG-1 Layer 3 proved difficult to market as it was out competed by its sister codec Layer 2. The chips in new consumer devices were capable only of decoding layer 2 which locked out adoption of layer 3 resulting in layer 3 being locked out of entire media systems.

Within just a few years however MP3, as MPEG-1 Layer 3 would be rebranded and would fundamentally threaten the distribution model of the music industry. However, it was layer 2 that was the first codec to initially find traction in online communities as a way of sharing music.

5.4 Summary

The development of the CD-DA began its life within the protected space of Philip's labs as an attempt to further develop the Laserdisc technology into an audio only digital format. Similarly, Sony also began work on digital discs as an extension of their DAT technology. When both technologies were demonstrated senior management realised that due to the potential overlap of the two technologies

and perhaps fuelled by deficiencies encountered by their own engineers' progress a process of collaboration between the two groups could significantly improve innovation. This enrolment of additional actors within the same regime was not an uncommon practice and is a means through which actors expand their resources significantly to stabilise innovation. In agreeing to standardise their new technology early on both actors were responding to external pressures that were affecting performance of their products in other markets such as Sony's loss of market share in the home video cassette market. The recognition of past failures and market struggles by senior management meant that certain features of the CD-DA technology were dictated to the engineers as part of the standards setting process whereas others were set by technological constraints and cross-party agreements.

Once the CD-DA standard had been set the enrolment of actors both within and without of the regime became of paramount importance. Within the regime other technology companies were approached in a bid to halt their own innovation in this area and to have them instead license and development their own products around the CD-DA red-book standard. Outside of the regime, Philips and Sony sought to encourage record labels to publish their music on the new format, this was helped by their existing relationships with the record labels but also relied on the enrolment of important artists to endorse and legitimise the sound carrier to expand the social network of the CD-DA technology.

This attempt at legitimisation won over early adopters of the technology but to further enrol consumers both the technology companies and the record labels had to manipulate the markets through the enrolment of retailers making them complicit in the manipulation of various sales practices such as decreasing the availability of vinyl records. This led to consumers becoming locked into the new CD-DA format. The control and manipulation exerted by a host of different actors across interrelated but complicit regimes created many windows of opportunity for the CD-DA to become an integral part of the consumers' music consumption and as such was the reason for its break-through and rise through to the year 2000 as the most popular sound carrier.

Further to the multi-regime interactions that created the windows of opportunity for the CD-DA to break-through in the 1980s the technology of the CD-DA itself also provided new forms of innovation that appealed to actors external to the music industry. The computer industry was interested in the CD-DA as a general-purpose storage medium. As such several disparate actor groups took an interest in the development of the compression innovations that were the focus of the CD-ROM technology. MPEG was set up to bring these disparate actors together into a multi-regime niche in which to provide a protected space to innovate a set of video and audio compression standards with a view to avoiding market conflict. MPEG itself grew out of the nascent multimedia PC regime’s JPEG committee which had been developed to innovate similar compression technologies for still images. In doing so,

Chiariglione created a mediated space for key actors from various regimes that had hitherto been developing overlapping technologies. Within in this niche structure was given to these future developments in the hope that through political wrangling the key stakeholders could agree on standardisation that would be of benefit to all actors that had been enrolled from the various regimes and not just those within the personal computing regime. The resulting standards were adopted across a range of regimes because of the very specific multi-regime interaction although notably not the music industry at the time.

The following chapter takes the audio compression technologies at its starting point and shows how a multitude of new actors emerged who introduced further novelties which were to increase the appeal of the compressed audio carriers and enrol additional actors within the niches developing them to the point where they threatened the stability of the incumbent regime.

6 The emergence of dematerialised sound-carriers

6.1 Introduction

The views and perceptions of the MPEG-1 standard were initially confined to predictable usage and technological substitution within the three-existing socio-technical regimes of consumer electronics, multimedia PCs and telecommunications. This chapter focuses on the ways in which the audio layers of the MPEG standard were adopted by actors for use outside of these regimes but continuing to use technology within them. The chapter focuses first on how the Layer 2 technology was first used by consumers as a means to distribute music online (6.2), the record industry's first forays into online distribution (6.3), early forms of online radio (6.3), how the record labels began to respond to online distribution (6.5), how innovation and unlawful activity created further windows of opportunity for the new dematerialised sound-carriers (6.6), how new innovations formed around these sound-carriers further stabilising them (6.7), further novelties continued to emerge (6.8), section 6.9 introduces the idea of Disruptive Entrepreneurs who emerge as important new actors, physical hardware begins to be created which allows dematerialised sound-carriers to become portable (6.10). The chapter closes with a discussion on the transition and development of the dematerialised sound carriers and the actors that influence the transitions (6.11).

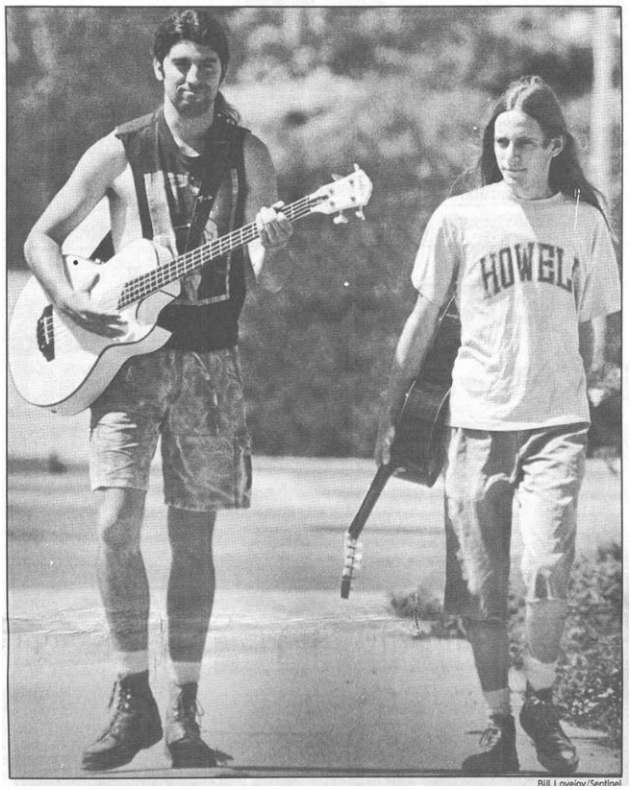


Figure 6: Ugly Mugs promotional photo with Jeff Patterson co-founder of IUMA on the right

As the MPEG standard, with Layer 2 in particular, fit with established concepts and categories of the socio-technical regimes it also began, slowly at first, to be stretched by entrepreneurial individuals who articulated their own technical and use principles for the layer 2 technology developing a niche around the new compressed audio novelty (Geels 2005b). This section details this niche development, with the actors and subsequent novelties that were developed or co-opted into the niche that led to MP3 emerging as the dominant design and significant adjustments within the incumbent socio-technical regime in response.

6.2 Compression comes to the internet via FTP and Newsgroups

Xing Technology was keen to investigate and leverage the developing JPEG[33] and MPEG compression technologies. The company released its XingSound[34], an encoder/playback software developer's kit for MPEG audio at the end of 1992 at a cost of $249[35]. The software was intended to "enable OEMs, developers and end-users to incorporate […] sound […] into cost-effective PC-based business, education, and training tools" (Xing Technology Corporation 1993). In addition to Xing Technology's predicted market XingSound was adopted by those interested in sharing their music across computer networks the large file sizes of uncompressed audio made such an undertaking impractical.

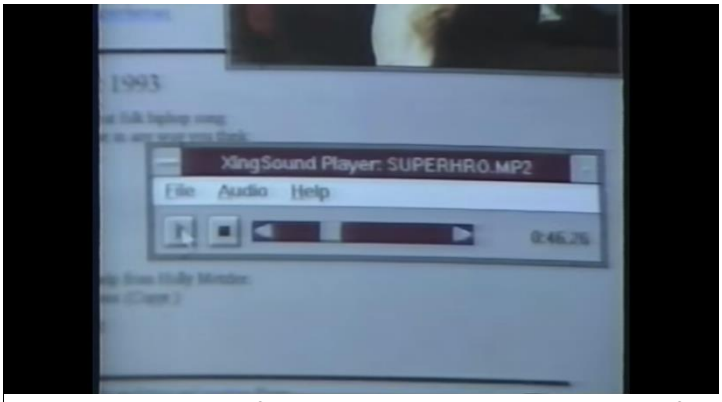


Figure 7: Video still of XingSound Player playing an MP2 file

Rob Lord and Jeff Patterson used XingSound to compress songs by Patterson's band the Ugly Mugs (Figure 14). Having uploaded the MP2 files to alt.binaries.multimedia[36] along with *Xing Sound MPEG Audio Player*[37] (Figure 15) Lord and Patterson were encouraged by emails from around the world asking for more. Lord and Patterson realised the potential for digital music distribution. They launched the Internet Underground Music Archive in November 1993. Initially IUMA[38] hosted files on an FTP server hosted by University of California Santa Cruz, unaware of the World Wide Web[39] (Patterson and Melcher 1998).

[33] Xing Technology's VT-Compress was one of the first software utilities for JPEG compression retailing for $179.

[34] The software was the first software based encoder capable of compressing audio (typically a PCM/.wav file) using MPEG Layer-2 compression.

[35] Media Vision Inc. released a similar kit in January 1993, it was intended for the same market but was not based on the MPEG compression standard. The price of Xing Technology's offering had dropped to $149.95 by November 1993.

[36] Usenet is a distributed discussion system that has no central server. It was created in 1979 and is separate from the World Wide Web but is part of the internet.

[37] The retail version of the software included the audio player which could be freely distributed (Damore 1993 p.19). The free to distribute player offered a lower quality playback (mono) than the purchased software (stereo) but allowed for compressed files to be disseminated.

[38] Pronounced "ay-you-ma"

[39] This is the popular account of IUMA's origin. However, some of the original posts made by "Robert Daniel Lord" are still accessible through various archives which show Lord posting samples of Vivaldi, Incognito and Primus in "MP2" whilst soliciting other bands to get in touch for more info with no mention of Ugly Mugs. He also notes in one of his posts that "Sounds.sdsu turned the offer down due to lack of space. The people at the

Although IUMA only took up a small amount of server space, use of the service accounted for 70-80% of the bandwidth. Once the founders realised the web's potential for increased accessibility amongst its user base they developed IUMA into a website; the new site contained information about the bands as well as song samples, full downloads, text and graphics. Still, utilising MP2 compression even a three-minute song took around 30 minutes to download[40]. These technical limitations were problematic although they did not deter users from downloading free music. The bands first found on IUMA were 'underground', or as the presenter of New Media News put it "bands that don't stand a chance of getting signed".

By late 1994 IUMA hosted 700 artists and was accessed 300,000 times a day. As IUMA grew in terms of popularity they began to offer additional services including the purchase of physical media and merchandise. Although the numbers were insignificant compared to album sales through conventional retailers it suggests an add-on pattern was beginning to occur but one that conformed to the existing practices of the dominant socio-technical regime. Digital music distribution was being used as a way of solving a problem: how does a band with little commercial appeal gain the attention of potential fans? The enrolment of actors within the niche of compressed audio that IUMA was creating was stabilised not by the enrolment of more powerful actors with greater access to resources but by the enrolment of many small actors who provided content for the archive in exchange for a web presence and by visitors to the site who were able to obtain and discover music for free. The activity that IUMA was attempting to substitute was something on the periphery of the music industry, despite their much loftier vision of being a genuine alternative to the existing distribution model. What IUMA achieved in its early form was the digitalised equivalent of swapping demo tapes of unsigned artists. In this sense, IUMA created an add-on to the internet. It was an additional form of entertainment that enabled users to discover new bands. It solved a problem with the existing cassette tape technology in that people from all over the world could download the music digitally with no need for the complexity or cost of physical distribution.

The early success of IUMA in digital music distribution of unsigned artists looking for exposure became more targeted at the incumbent socio-technical regime as IUMA grew. IUMA began to adjust their vision and scope. This represents one of three social processes considered crucial for niche development as it provides direction to "internal innovation activities" (Geels and Kemp 2012 p.51).

OTIS project are interested though." suggesting that they attempted to enrol multiple actors as hosts for the IUMA project before finding a willing participant (Lord 1993).

[40] Some users with older modems experienced download times of hours.

To achieve these rearticulated visions, IUMA needed to enrol more powerful actors with social and resource bases into the compressed audio niche.

6.3 Major labels Head First into digital distribution?

In June 1994, *Aerosmith* released *Head First* online in what is considered the first full length, official digital release of a major label artist track[41]. "We did it because it can be done and is cool and is fun," said Luke Wood[42] (Strauss 1994). The track was available as a compressed WAV[43] file. Robert von Goeben who created the online services division[44] at Geffen and Jim Griffin[45] approached Compuserve asking the ISP to consider waiving the $10 an hour usage fee so that fans could download the 4.3mb file and *Aerosmith* agreed to waive royalties for the song. “If our fans are out there driving down that information superhighway, then we want to be playing at the truck stop” said Steve Tyler, *Aerosmith*’s lead singer (Gillen 1994b p.19). Although the release was successful in a promotional sense, Universal, Geffen’s parent company, were wary of the premise and it was many years before Geffen became involved in digital distribution again. Others too were critical of the event. Tim Nye, operator of SonicNet[46] felt that Geffen was deliberately trying to make the process of downloading music difficult: "What Geffen is trying to do, quite clearly, is convince the public that the technology isn't there to make this a viable way of distributing music” (Strauss 1994). It was noted that the time it took to download the track, anywhere from thirty minutes to several hours depending on the capability of the modem, was too long compared to other compressed songs available through SonicNet and sites such as IUMA. The Geffen employees noted that this was because they wanted to offer a higher quality listening experience although Wood acknowledged the issue “people are starting to understand the problems of this technology because of the difficulties in downloading ‘*Head First*.’ I think we're trying to embrace this technology instead of turn people away” (Strauss 1994). Wood also suggested that they wanted to do it “to show there's these other issues involved, like how do you collect copyright fees?”(Strauss 1994).

Head First was downloaded somewhere between 8,000-10,000 times. The questions it raised, the technological issues it encountered, the controversies it courted and the music industry apathy it met

[41] Although *Headfirst* is often mistaken to be the first ever digitally downloaded song.
[42] Director of Marketing for Geffen Records
[43] Waveform Audio File Format – Typically uncompressed raw audio format developed by IBM and Microsoft and released in 1991. Uncompressed CD quality WAV files are 10.09mb a minute in size indicating that the *Aerosmith* track was compressed.
[44] The first such department in the music industry and tasked with building websites for Geffen artists such as Nirvana
[45] Geffen’s chief technology officer
[46] SonicNet began as an alternative-music discussion forum but grew into a website where “independent record labels, already signed and on-the-cusp bands, downtown clubs, cutting-edge magazines and all-around indie distributors [...] staked out a new territory in the region known as cyberspace” (Gillen 1994a).

would define attempts to distribute music digitally in a lawful and legitimate manner until the end of the millennium. However, these initial attempts of novel technologies to lawfully breakthrough the incumbent socio-technical regime are ultimately futile and adjustments as a response to these technological niches are insignificant in comparison to those happening within unlawful niches analysed in the subsequent section. Although the pathways are presented here as distinct, this is to aid the narrative and to simplify the processes and elements being analysed. These influence each other and are analysed further in section 5.4.5.4 detailing the successful breakthrough to the incumbent regime.

6.4 And everything I had to know, I heard it on my radio

"On a 14.4 modem, it takes about five times as long as the real length to download a program[47]" Rob Glaser noted in an interview in Billboard "so a 30-minute radio show could take you more than two hours" (Gillen 1995 p.3). Glaser, a former Microsoft Multimedia and Consumer Systems VP, headed up the Seattle based start-up Progressive Networks, founded in 1994. Glaser put together the idea for Progressive Networks' RealPlayer towards the end of 1993 around the same time that IUMA was uploading their first songs. RealPlayer differed significantly from IUMA and other newsbin file-sharing groups in that audio was not downloaded but streamed. Glaser and the small team at Progressive developed a streaming protocol that allowed for audio content to be played on demand. Glaser and his team had deliberately selected a combination of codecs that could keep file sizes to a minimum but there was the inevitable trade off in quality. Polyphonic content sounded poor and the .ra streaming formats[48] intended usage was initially talk-radio broadcasts.

As the next generation of faster modems[49] proliferated, Progressive increased the quality of their streaming content although Glaser was quick to note where he felt the usefulness of his product was for the music industry:

> "We'd love to work with the record industry, but we want to make sure they understand we're not saying that this generation of technology is going to open up the world of direct delivery of albums – it won't. But if they have an interview with an artist, fantastic. If they want to offer samples of music or a song to preview, that's great too." (Gillen 1995 p.3)

[47] In American-English program equates to the British-English programme and should not be confused with the British-English program as in software program.
[48] Which streamed at 8-bit resolution and a sampling rate of 8 kilohertz (the same as a Walkie-Talkie) compared to CD's 16bit & 48Khz
[49] 28.8kbps modems were released in 1994

As audio on demand technology, RealPlayer provided a solution to the problems experienced by users of downloaded music, but such a solution came with a compromise. Streamed music was for the latter part of the 1990s low quality. Streaming audio fitted broadly with a usage pattern of existing radio although initially it could not be streamed live[50]. It lacked the quality of an FM broadcast but was comparable to AM radio. As a new technology, it spread and stretched beyond its initial functionality. Although the idea of sampling music was not unique RealPlayer with its on-demand functionality meant that the process became far more linear to the browsing experience. Record labels started utilising Progressive's software to provide short clips of songs for fans to listen to. The music industry was less welcoming to full length songs being made available for consumers however.

6.5 The music industry responds

Head First's distribution succeeded in focussing media attention on a hitherto largely underground activity. IUMA, no longer just a way to trade songs online and reach a wider audience, hoped that music fans and artists could in future "side step the record selling establishment by hooking up via computer" which saw the first tentative steps towards compressed audio being framed culturally as a way of freeing music from the incumbent regime (CNN 1994). The early work of IUMA, far from being able to break through to the incumbent socio-technical regime was never-the-less putting pressure on the socio-technical landscape which saw other innovators in other niches respond with alternative novelties. More directly, IUMA's presence was partly responsible for the *Head First* release. Jim Griffin, whose own label was reticent about repeating the *Head First* promotion became a mentor to Lord and Patterson. Additionally, other majors were interested in what was happening with IUMA and Warner Bros. Records hired IUMA to create their first website. The role IUMA played, exposing unsigned artists to new fans, stretched. A&R executives, such as Steve Rennie[51], acknowledged that he used the service to discover potential new signings as it was "a good place to see what fans are talking about. That way you're not just surmising what they're talking about. They're telling you directly. It's a good place to get a reaction to the buzz bands we're chasing" (Lieb 1995 p.10).

IUMA and Progressive were always on the lawful side of sharing music online but their initial success created tensions about the assumed threat of digital distribution and was enough for the Recording Industry Association of America (RIAA) to push for changes to existing laws. In September 1993 President Clinton established an advisory council tasked with investigating how to "prevent piracy and to protect the integrity of intellectual property" (Information Infrastructure Task Force, 1993 in Segal 1996 p.121). The advisory council produced a white paper, sections of which were incorporated into

[50] Streamworks by Xing Technology could stream radio live over the internet and was doing so from September 1995 onwards.
[51] A senior VP of Epic Records

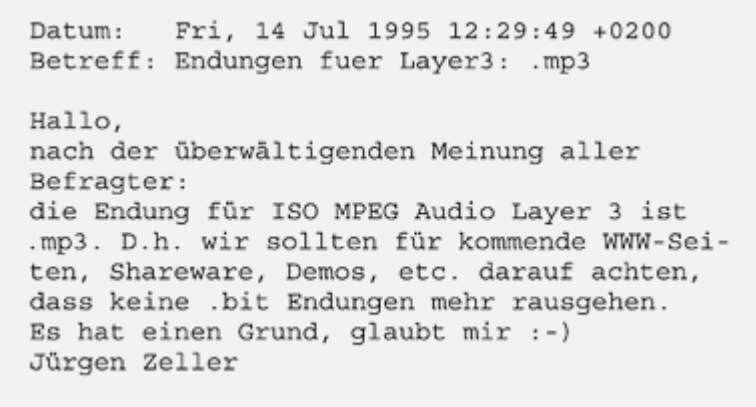
the Digital Performance Right in Sound Recordings Act that Clinton signed into law on November 1st 1995[52] pre-empting the large-scale copyright infringement that was to come.

6.6 MP3 comes online

The developers of MPEG-1 Layer 3 had been left in a difficult position after the release of the MPEG standard. Layer 2 was backed by Philips and Panasonic and early adoption of layer 2 had effectively closed the windows of opportunity for layer 3. The lower audio quality of layer 2 was an acceptable compromise for the lower hardware demands. Once layer 2 had become embedded, even though it had yet to fully break through to the various socio-technical regimes its trajectory became locked in. As such manufacturers were unwilling to consider alternatives once they were invested as there was an element of path dependency and control in the implementation of bringing novelties to market. Introducing a similar but slightly better codec would have introduced confusion and destabilised the dominant design affecting their windows of opportunity. Layer 3 was not part of the patent pool for DAB radio and without these constraints Fraunhofer were free to secure patents for their contribution and autonomy in marketing layer 3 (Denegri-Knott and Tadajewski 2010).

The engineers and developers of layer 3 sought other markets. For the most part, these forays into other markets were modest, insignificant, unsuccessful or typically some combination of the three. However, when Fraunhofer introduced a software version of their codec for use on computers things started to change and rapidly so; it is this that is the primary focus of this section with additional focus on the development of the internet and the unlawful activities of users that provided the compressed audio niche with a powerful new novelty, one that brought with it many new actors and Disruptive Entrepreneurs which further stabilised the niche for compressed audio by surpassing and suppressing layer 2.

[52] The Act modified the existing Copyright Act adding clause 106 that the copyright owner has the exclusive right to perform the work publicly by means of digital audio transmission. A digital audio transmission was defined in section 101 as a digital format “that embodies the transmission of a sound recording” providing legislative protection for music copyright holders on the internet for the first time with great clarity.



```
Datum:   Fri, 14 Jul 1995 12:29:49 +0200
Betreff: Endungen fuer Layer3: .mp3

Hallo,
nach der überwältigenden Meinung aller
Befragter:
die Endung für ISO MPEG Audio Layer 3 ist
.mp3. D.h. wir sollten für kommende WWW-Sei-
ten, Shareware, Demos, etc. darauf achten,
dass keine .bit Endungen mehr rausgehen.
Es hat einen Grund, glaubt mir :-)
Jürgen Zeller
```

Figure 8: The original email sent confirming that layer 3 was being renamed .mp3

6.5.1. Fraunhofer takes Layer 3 to market

Fraunhofer licensed the Layer 3 technology to Telos Systems for use in a product that broadcast conversations over ISDN, to Deutsche Telekom for a music on demand service over ISDN, and also to a British company called Cerberus Sound and Vision whose music on demand service was more successful than the German one (Sterne 2012). When Cerberus launched in 1995 it was similar to IUMA, consisting of a catalogue of unsigned artists[53]. Importantly, the Fraunhofer institute realised that it could not continue marketing "MPEG-1 Audio Layer 3" as a product and voted internally on a new name, MP3 won although they continued to use the Layer 3 moniker on products that were already in development. Fraunhofer had developed two proofs of concept command-line programs[54] L3Enc and L3Dec and released them in July 1994 for DM 350[55] along with two shareware versions limited to producing 20 second clips at 112kbit/s.

Karlheinz Brandenburg of Fraunhofer recalled in 2007 how the full version of L3Enc "was bought by a student in Australia using a stolen credit card number from Taiwan […] who [then] did some reverse engineering […] and started distributing it as […] freeware (tagged 'thank you Fraunhofer')" (Guisanni, 2007 in Denegri-Knott and Tadajewski 2010 p.397)[56]. For the first time, users could both encode and decode MP3 files on their PCs in a manner similar to MP2. Adoption of the new sound-carrier novelty was relatively swift by those users who already formed part of the social network of the niche as it

[53] Cerberus had two notable aims in using MPEG-1 Layer 3 rather than continuing to use physical sound-carriers in an attempt to rectify problems it had identified in the existing physical distribution model. It wanted to limit the financial exposure of the record industry to unsold product and it wanted to reduce piracy by tying customer's payment information to the music they are listening to through the Cerberus Jukebox software.

[54] Command-line programs have no user interface. Users type commands as a set of instructions. Like XingMusic before it, L3Enc and L3Dec were the first software versions of codecs that had previously required specialist hardware.

[55] Approximately £160. The full version of L3Enc was capable of encoding a PCM (.wav) file into a MP3 file at a number of bit rates up to 320kbit/s.

[56] This claim is difficult to substantiate despite being printed in peer reviewed journals. There is also evidence to suggest that the registration codes for the L3Enc were also circulated online allowing users to download L3Enc directly from Fraunhofer's own servers and register the software as if they had purchased it (ShereKhan/MegaByte/MindRape of DAC 1996).

offered higher quality sound files at smaller file sizes than MP2 which meant files could be downloaded faster.

6.5.2. Landscape pressures: Multimedia PCs full of Trojans

As discussed in section 5.2.5, CD-ROM drives were a key component of the promise of multimedia PCs allowing for access to large amounts of storage for applications such as interactive encyclopaedias by the mid-1990s. The potential for music playback via CD-ROM drives was realised early on, Trantor Systems released a utility that could control the playback of CD-DAs on CD-ROM drives in 1991 (Grunin 1991). This meant that each computer that had a CD-ROM drive[57] could be utilised to copy the audio from a CD-DA to the computer. 'Ripping' a CD-DA allowed users to shift sound-carriers turning their physical media into a dematerialised one. The multimedia PC had brought with it an innovation cascade in which many new technological opportunities were presenting themselves.

6.5.3. New user practices emerge

In 1995 the process of ripping audio from albums was still an arduous one. Users would have to rip the audio file into a lossless format using software such as the command line based "CDDA" which allowed users to rip directly to the PCM (.wav) format. The ripping and encoding stages could be lengthy and it was not unusual for the ripping and encoding of an entire album to take a day. For most people, the activity served no practical purpose, but some entrepreneurial individuals had seized up on it as a way of disseminating music through computer networks such as IUMA who performed this task on behalf of unsigned musicians. When Fraunhofer released L3Enc and L3Dec it allowed users to perform these same practices to produce MP3 instead of MP2. Fraunhofer released WinPlay3 as a freeware application on September 9th, 1995 which allowed for real-time playback of MP3 without first requiring decoding for the first time.

Despite the apparent hassle of compressing audio to MP3 many individuals self-organised themselves into groups with the express intent of releasing MP3s of copyrighted music through FTP sites[58]. These groups released single tracks at a time by splitting them into RAR files of 1.44MB in size along with a file ID and hosting them either on FTP sites or Bulletin Board Systems. They also posted Fraunhofer's

[57] Of a certain kind, not all early CD-ROM drives were capable of CD-DA playback

[58] The individuals who made up the groups had names such as NetFrack, vATo, N0fX and Mindrape. Some of the earliest groups were called Digital Audio Crew (DAC), Rabid Neurosis (RNS) and Compress 'Da Audio (CDA) started to release tracks in the summer of 1996 with the first known 'scene' rip thought to be Metallica's *Until It Sleeps.* Although this was the first scene release, other copyrighted material was doubtless being traded on a very small scale and in a less organised manner almost as soon as the various compression technologies became available.

WinPlay3 MP3 playback software, so that those who downloaded the files could listen to them, popularising the player in the process. What started as a very small-scale adoption of the MP3 novelty grew and by the end of 1996 the number of releases and groups flourished. Improvements in processor speed and storage space on computers saw MP3 groups sharing entire albums in 1997. In doing so, more users became enrolled supporting the nascent novelty. However, despite the apparent anonymity of what the various groups were doing, the copyright infringement did not go unnoticed by the music industry who sought to destabilise the new practice.

6.5.4. The incumbent regime responds to early niche developments

The RIAA first noticed internet sites offering archives of MP3s for download recognising that they could "theoretically, represent lost sales" (Jeffrey 1997b). Having sent cease and desist letters the RIAA were moved to file suits in federal courts against three "Internet music archive sites" that encouraged users to upload MP3s in exchange for access to other MP3s[59]. The RIAA were specifically concerned that the $2 billion worldwide piracy costs each year would soar because of file-sharing online and saw the technological capabilities of MP3 as being a major driving factor. There was also concern amongst labels that the MP3 archives would damage their tentative forays into online music marketing (7.4). Rosen, the head of the RIAA noted "[t]he idea is to crack down on the illegal market, but also to create an opportunity and incentive for a legitimate market" in reference to record labels charging for their copyrighted material online (Rosen in Jeffrey 1997b p.83).

The compressed audio niche was largely unscathed by the litigious actions of the incumbent socio-technical regime. Instead, it benefitted from the influx of new participants who were quick to learn new user practices for downloading music freely as knowledge of the process spread quickly through like-minded internet communities.

The transition of MP3 from a hardware codec to a software codec launched MP3 as a novelty into a niche in which existing elements such as the emerging culture for sharing files linked with user patterns for discovering music through online communities and a culture of sharing and dissemination. MP3 was a technologically superior novelty to MP2 and served to address the technological limitations resulting in the enrolment of considerable numbers of new users who spread the practice to other users in turn. The linking of the various elements meant that MP3 quickly became the dominant novelty within the compressed audio niche as software-based solutions did not suffer from the same lock-in mechanisms present in hardware-based playback. Users utilised the new sound-carrier as a method to share copyrighted material through several new distribution channels echoing

[59] "Fresh Kutz", the largest of the archive sites hosted some 500 recordings

a practice that had been begun with MP2. The music industry responded by pursuing the largest visible actors that they deemed to be guilty of copyright infringement in a bid to shut-down the nascent new distribution channels but managed only to raise the profile of such activities which added to the user base. For the RIAA and the record labels this public admonition was the first of many responses that sought to control the use of MP3 technology.

Additionally, in 1996[60], the World Intellectual Property Organisation (WIPO) conference focused on the need to understand what copyright meant in a digital world and its subsequent WIPO Copyright Treaty. Webcasters were of considerable concern as they paid no performance royalty payments to rights holders and file-sharing as an activity increased during the consultation and writing period. As such the treaty was an early policy-based response to what the industry and law makers predicted would be a future concern and was an attempt to position measures of control. The resulting implementation of the WIPO Copyright Treaty in America was the DMCA (Digital Millennium Copyright Act).

The DMCA is notable for three reasons that affected the music industry and the development of online music distribution particularly in America but with consequences felt in digital music distribution around the world. It exempted ISPs from direct and indirect liability for user's copyright infringement[61]. However, as groups such as the RIAA wanted ISPs to be held strictly liable for the acts of their users, certain concessions were made that included the ability for the rights holder to request that infringing material be removed from the service. The DMCA also criminalised the act of circumventing access control even if copyright infringement never occurs. It also mandated that internet broadcasters and record labels create a licensing system for webcasters wishing to play music that was under copyright on the internet that came into force in 1999. The music industry has used the DMCA as a powerful tool in how it has controlled its content but also how it has attempted to control technological developments to grapple with the MP3 sound-carrier.

6.7 Linking together elements to further stabilise MP3

Although music on computers was little more than a gimmick in the early 1990s, by the mid-1990s several technologies had emerged maturing the experience. Two of those novelties developed as part of the multimedia PCs' innovation cascade seemed initially to be a way of reconciling the loss of the physical media experience by using the multimedia PC's capabilities to enhance listening in a way that countered that loss of physicality. Developers achieved this through several ways which found favour

[60] Although it was based on Green and white Papers dating back to 1993
[61] Exemptions that the EU would also adopt in 2000.

with users, but focus is paid here in particular to the Compact Disc Database (CDDB) and ID3 as they were latterly co-opted to make MP3 easier to organise and playback.

6.6.1. The Compact Disc Database

The CDDB was a response to the problem of a CD-DA's audio tracks not containing track metadata[62]. It originated as a supplemental database delivered as part of the xmcd player used for playing CD-DA discs on CD-ROM drives (Swartz 2002). CD-DAs were identified by calculating track durations and disc length to create a discid which could be queried from the online database. Meta-information was provided by a large community of users who submitted data for free[63]. The advent of the CDDB eased users into listening to music on their computers by displaying information in the playback window. The software became immensely more useful when utilised by CD-DA ripping software which automatically stored the meta-data along with the ripped file and could be accessed by certain software.

6.6.2. ID3 – Embedding metadata into MP3 files

The original MP3 standard had no native way of storing metadata save for simple parameters about whether the file was copyrighted, private or original. This was problematic for users of MP3 as unlike physical formats, MP3s lacked artwork to reference song and album titles. The absence of metadata was overcome initially by software that that could store it externally but as MP3s began to be shared online it became clear that the metadata of MP3 needed to be embedded internally. As MP3 was already standardised and software and hardware already existed that could decode MP3 any solution for embedding metadata within MP3 would have to be invisible to decoders. Eric Kemp, a software programmer, developed software known as Studio3 which was able to tag the end of an MP3 with 128 bytes of metadata information[64] (Seibel 2005). Kemp released Studio3 and ID3v1 (the tag) in 1996 where upon it was adopted by several MP3 ripping programs. Most ripping programs were capable of querying the CDDB and automatically populating the tag fields of the ID3. ID3v1 was superseded in 1998 by ID3v2[65], a much more flexible format that did not suffer from the length and genre code limitations of ID3v1.

[62] Information such as Artist, Track Title, Album Title etc.
[63] When the CDDB was later sold to a third party this became a particularly contentious issue and a number of alternative databases emerged that operated under OpenContent licenses so that they could not benefit financially from end-user's efforts in the same way.
[64] Enough for 30 character spaces each for the track name, artist name and album name, a comment field, a four-byte year code and a one-byte genre code
[65] Developed by Martin Nilsson

Both the CDDB and ID3 were crucial elements in the development of MP3. In providing MP3 with metadata they allowed for them to be sorted and controlled. As MP3 collections grew, the metadata allowed for large collections to be navigable and useable. Metadata also allowed for files to be distributed without the loss of their identity[66]. The metadata also meant that users had greater control over the music they were listening to in terms of the order it could be played[67] much of which came down to newly developed audio listening software.

6.8 New novelties emerge

The software player WinPlay3 was only available for Windows based PCs. A programmer named Tomislav Uzelac created a similar decoder and player for Linux[68] based PCs in 1996. AMP (Audio Mpeg Player), created with the help of other contributors, was the first player to become popular and formed the basis for several other players. AMP as well as the new players are the first examples of novelties that began to emerge specifically because of MP3 and were created by individuals who felt that MP3 "freed" music online. The entrepreneurial behaviour that these actors display was often fuelled by a desire to disrupt the existing distribution models of the incumbent socio-technical regime and as such they are termed Disruptive Entrepreneurs here. Several Disruptive Entrepreneurs are responsible for creating new novelties within the compressed audio niche, often specifically associated with MP3 and seemingly motivated by the mantra of freeing music from the music industry. They were often fuelled by little more than the desire to just be disruptive or fix something they consider inconvenient with no real concern for the consequences of their actions. A fuller discussion of Disruptive Entrepreneurs as drivers of niche innovation occurs in section 6.5.1.

Whilst many of the players were essentially iterations of the same novelty, fulfilling the same user requirements on incompatible systems some differed, emphasising different user practices, each serving to bring more users into the compressed audio niche. Two players, WinAmp and Sonique were also responsible for the enrolment of powerful actors who were attracted not only to the software's user base but to the MP3 technology itself and saw the players as the most direct way of engaging with MP3 and wider community of MP3 users and music fans. These actors brought with them funding for the new novelties and by extension helped stabilise the niche.

[66] Although the groups releasing MP3s would eventually settle on naming conventions for MP3 files their early releases were often truncated.
[67] Something that had previously required expensive CD multi-changers
[68] Linux is the catch-all name given to a number of Linux based distributions which are free open-source operating systems. The first Linux release was in 1991.

Figure 9 Winamp 0.92's interface

6.7.1. *Winamp – it really whips the llama's ass*[69]

WinAMP was an MP3 decoder, ported[70] for Windows from Uzelac's AMP. Released in April 1997 and developed[71] by Justin Frankel[72], a college drop-out from Arizona who was known for his laid-back attitude. Underwhelmed by the capabilities of existing MP3 players, Frankel set about developing his own. The software was originally freeware, but Frankel's parents and friends encouraged him to charge for it which led to him copying a popular model in the software industry releasing it under a shareware license and requesting donations of $10.

Frankel set up Nullsoft with Tom Pepper[73] who hosted the website and Rob Lord who had moved on from IUMA. Nullsoft positioned Winamp as *the* MP3 player and as the popularity of MP3s grew so did Winamp but given the ease of use of Winamp it too was responsible for helping to disseminate MP3 use. Winamp made use of ID3 metadata displaying information about the music being played as well as allow users to build playlists[74]. In a review for Billboard Atwood noted that Winamp had "evolved as one of the choice options for legitimate and illegitimate distribution" and that the "music industry should be afraid – *very* afraid" (1997a p.23 their emphasis).

When Frankel wanted to listen to a Los Angeles based radio station whilst in Arizona he programmed software that could capture sound from a friend's radio in LA, encode it to MP3 and stream it to him[75]. Shoutcast[76], as it became known, also proved to be a hugely popular Nullsoft product further perpetuating Frankel as an internet innovator and Nullsoft as smart and tech savvy. The company pushed their association with MP3 which was fast obtaining pariah status within the incumbent socio-technical regime. By culturing this association Nullsoft portrayed themselves as underdogs of the Web,

[69] This was the intro sample MP3 which included a whipping sound and llama bleating.
[70] Porting software is a process whereby the original software is adapted to work in an environment other than the one for which it was originally designed.
[71] He had originally ported AMP to DOS. DOSAmp originally had more features than the first version of WinAMP (as it was stylised at the time) as the first WinAMP release version 0.20a was really a test to show that the AMP library could be compiled and run on Windows.
[72] Dmitry Boldyrev was also involved to some extent in developing WinAMP although there are a number of strange accusations that make it difficult to ascertain his level of involvement.
[73] Pepper would eventually go on to be VP of Operations of Beats Music before its acquisition by Apple whereupon he became a Senior Manager of Operations at Apple.
[74] This was not features unique to Winamp, but it was one of the first to start introducing them.
[75] Similar technology already existed for streaming radio, but Frankel's system incorporated MP3 for its compression.
[76] It underwent further development by Frankel, Pepper and a third programmer Stephen Loomis to develop it into the full Shoutcast system.

which allowed them to build a community of like-minded individuals who proselytised for them. The Nullsoft site was generating advertising revenues of $8000 a month, and Winamp alone had some 15,000,000 users; in June 1999 as part of a larger acquisition process[77] AOL purchased Nullsoft for between $80-$100 million dollars in stock. Although the community were originally concerned that Nullsoft had sold-out by selling to one of the largest technology companies in the world at that time, Frankel reassured them that the AOL deal was hands off allowing Nullsoft autonomous operation. Frankel continued to release new products whilst working for AOL some of which would be the cause of embarrassment for AOL as discussed in section 5.4.8.3. AOL was not alone in this MP3 based acquisition though, Lycos and Yahoo too had ideas to purchase a ready-made community of music fans.

6.7.2. Sonique – Aliens Made My MP3 Player

The story of Sonique is a similar one to that of Winamp. Two friends, Lyman and McCann had been early adopters of MP3 after McCann stumbled across one online around 1995 "I thought it was so cool" said Lyman "[it] sounded great and the file size was tiny. I instantly became a pirate" (Hellweg 1999 p.152). They began collaborating on an MP3 player. They created Vibe which they claimed hardly worked; despite this it was being downloaded around 1,000 times a week and they sold it to ST Microelectronics for $6,000. Realising the potential MP3 held they built on their initial success with a new player.

Sonique had features that no other player had such as the ability to pitch bend MP3s. When an early version leaked in May 1998 the response online was dramatic. Such was the online hype that Lyman and McCann were invited to present at the first MP3 summit, sponsored by MP3.com. After their presentation, a Goodnoise representative rushed to offer $1 million dollars but they rebuffed. They formed Mediascience with their contact at ST Microelectronics, and hired friends. They released the first official version of Sonique (version 0.55; Figure 17) on September 25th, 1998. Within eight months Sonique had been downloaded four million times. Lycos, who had found favour with the MP3 community by offering the first MP3 search engine, offered to buy Mediascience and following negotiations purchased Mediascience for 1.1 million shares of Lycos' stock[78] (CMJ 1999).

[77] At the same time AOL announced the acquisition of Nullsoft it also announced it was purchasing spinner.com, a large internet radio website.
[78] Worth around $38.8 million at the time.

Figure 18: The alien inspired Sonique interface

6.7.3. Acquisitions strengthen resource base

In 1999, Lycos was the most visited web destination with a global presence in some 40 countries. Lycos' purchase of Mediascience was both in response to AOL's purchase of Nullsoft and Yahoo's purchase of the media site Broadcast.com. Portal sites like AOL, Yahoo and Lycos relied on visitor numbers to prove their worth in an emerging market in which investment was flooding in but the model for profitability was yet unclear.

AOL's purchases were aggressive moves into the developing online music market and Bob Pittman, President of AOL hoped that by "combining these leading Internet music brands with the audience reach of our brands [we] will lift music online to the next level of popularity" (AOL 1999). The acquisitions by AOL and Lycos represent the adoption of the new novelty by mainstream technology companies. Although at the time of the acquisitions the legality of the MP3 sound-carrier and the activities of its community of supporters were still being defined, its adoption by moneyed technologists represented a serious investment on AOL's and Lycos' behalf.

Although in the short term, the acquisitions were destabilising as existing users were distrustful of the new owners resulting in a degree of alienation, the hands-off approach and the ability for the users to adopt other competing software within the niche meant that any disruption quickly settled. For the compressed audio niche generally, AOL's and Lycos' investment of resources was considerable, and it

brought with it an influx of new users as the new acquisitions were rolled out across their portal platforms exposing MP3 to new users who adopted niche practices along the way.

6.9 Further actor enrolment

Disruptive entrepreneurs like Kemp and Frankel engaged with MP3 in a bid to improve their user experience with the sound carrier and compressed audio playback. Other Disruptive Entrepreneurs emerged whose *modus operandi* differed significantly but arguably had a far greater effect on both the niche and the socio-technical regime. Two are discussed here in particular. Michael Robertson and Shawn Fanning took different approaches to each other and to those Disruptive Entrepreneurs who came before. Robertson began as an opportunist rather than a technologist or programmer and played the role of MP3 evangelist championing it and encouraging others to use it whilst cultivating an "us versus them" mentality by framing music culturally as something that should be free of the music industry. Fanning, a programmer who was looking for a project to flex his skills beyond his university courses looked to his housemate's frustrations with existing portals for accessing MP3s, which included Robertson's MP3.com, as a source of inspiration. Both Robertson and Fanning's enrolment in the niche stabilised it initially although the litigation brought against both went beyond a direct threat to their respective novelties to threatening the wider stability of the niche and the acceptability of the established user practices found within it. Both actors, and the subsequent actors and resources they enrolled represent the "tipping point" for MP3 and the compressed sound-carrier niche in which the incumbent socio-technical regime began to reconfigure itself as a response to niche activity.

6.8.1. MP3.com

MP3.com was launched by Robertson in October 1997. Robertson seeing an increase in search traffic for MP3 hoped to find a way to commercialise it. He purchased the domain MP3.com for $1000[79] and *MP3 Shopping Mall* for $2500, a Netherlands based site which did not host illegal files but listed software programs[80]. Without registering with search engines or advertising, the site received 10,000 visits on day one. Lacking musical content Robertson concentrated on aggregating MP3 related news. Spending his days researching and interviewing for articles on MP3.com Robertson found that artists "take the shaft" in the music industry. He saw a potential opportunity with MP3.com as a way for artists to circumvent the existing industry structure by distributing their music online. Not knowing

[79] It was purchased from Martin Paul who did not understand the significance of MP3 and had purchased the name as it was his Internic handle because MP, MP1 and MP2 were already taken.
[80] Robertson offered the former owner $500 to continue running the site as webmaster.

any real musicians MP3.com initially linked to musicians who uploaded their own MP3s. Proving problematic MP3.com morphed into a service that hosted music producing web pages for artists.

In a traditional record industry deal, artists forfeit ownership of their master recordings and agree long term, multi album deals (Passman 2011); MP3.com offered artists the ability to terminate at will in return for the licensing rights to tracks that they could host online. This gave MP3.com music content. Artists received a web presence courtesy of MP3.com which included their own website and the ability to ship and package physical media in exchange for at least one full length MP3 that could be downloaded freely by visitors to MP3.com[81].

MP3.com hosted the first MP3 summit on July 2nd, 1998 where it announced the launch of its online label. It was well attended, and participants included several technologists including Scott Jamar of a2bmusic, Xing CEO Hassan Miah, founder of Goodnoise Gene Hoffman, Geffen Records' Jim Griffen, and Dr. Karlheinz Brandenburg of Fraunhofer. The summit was also attended by several programmers, many of them still teenagers who were establishing new software programs around the MP3 technology, several which were championed by MP3.com such as Winamp and Sonique (5.4.7). The convention raised the profile of MP3 in two ways, first it allowed otherwise disparate groups to meet and network and second it brought a great deal of media attention specifically to the sound-carrier and MP3.com. Doug Reece[82] ran a front page article in Billboard following the conference in which he praised the conference and detailed MP3 including listing sites where MP3 files were available for example (Reece 1998b).

At the time of the conference MP3.com was recording 65,000 unique visitors a day, many were coming for the linked music, but many were visiting to read Robertson's articles. Robertson criticised copy-protected sound-carriers such as Liquid Audio and a2b (see section 5.5.1). In an article questioning whether "Can music be secure?" he directly linked users to a "crack" that was available for the Liquid Audio and a2b software systems that allowed users to bypass the Liquid Audio or a2b encryption. Liquid Audio responded with a cease and desist letter to MP3.com. In response Robertson removed the link, although the name remained so that users still could find it, Robertson also published the letter on the site creating further animosity between the MP3 community and secure digital music sound-carriers which Robertson saw, and positioned in his writing, as attempting to perpetuate the existing distribution model in the digital era. Robertson believed that users did not want "locks and

[81] The resulting online record label was similar to the way IUMA operated before it.
[82] Doug Reece would later go on to work for MP3.com

restrictions [but] more value. If they believe they are getting more value and it is easy enough to pay, then consumers will pay" (Robertson 1998).

MP3.com began attracting interest from some major label artists which saw MP3.com, Alanis Morissette and her management creating a strategic alliance. MP3.com hoped Morissette's involvement would help legitimise the site's model and user practices given the massive success of her debut album *Jagged Little Pill*. The intention was for Morissette to give MP3.com one MP3 and in return MP3.com would sponsor her *Supposed Former Infatuation Junkie* Tour but Maverick (her label) and Warner Bros. (her distributor) became involved. Warner Bros. were reluctant to be involved with anything that was supportive of the MP3 community. New negotiations opened as Maverick were still in favour of the tour and MP3 deal. As part of the final deal MP3.com gave shares of stock to Morissette and her team[83]. At the time of the deal the shares were valued at $0.33 but MP3.com debuted at $20 per share, closing on its first day at $63, having peaked at over $100. For their substantial payment, MP3.com received one streamed live song from Morissette and one from tour support Tori Amos and promotional photographs. The songs were hosted on non MP3.com sites in a non-MP3 format that could not be downloaded.

MP3.com's IPO meant the company was briefly valued at $6.9 billion (EMI at the time was valued at $6.4 billion). MP3.com was generating revenue through banner ads, selling consumer data and sharing micropayments with artists generating revenue of only $1.2 million the previous year and $665,785 in the quarter to March 31st 1999[84] (Krigel 1999). As such MP3.com's IPO was illustrative of the stock market hype surrounding "dot-com" companies but also of the potential of the MP3 community at the time but which over valued them considerably in the expectation of substantial future profits.

MP3.com used the IPO investment to launch two commercial applications in addition to existing services in January 2000. Instant Listening and Beam-It, supposedly gave users free online storage for 25 CD-DAs[85] through mymp3.com. After verifying that they owned the CD-DA by placing it in the CD-ROM drive or by purchasing it from one of MP3.com's online affiliates, users could log in from any computer gaining streaming access to their albums. Other companies, such as Myplay and Launch.com, had considered launching similar services but unlike Myplay and Launch.com, MP3.com

[83] The exact figures were never disclosed with some reporting the number as high as $658,654 although it seems likely the actual amount was just under $400,000; additionally, the terms of divestment were also not known but Morissette sold her stock through the latter half of 2000. Morissette sold her stock through a number of sales, eventually making about $3.4 million after MP3.com's stock had crashed considerably. The original stock offering by MP3.com was worth around $120,000 before the IPO and $25 million at the end of the first day. It was probably one of the most lucrative music deals ever (Garrity and Fitzpatrick 2000).
[84] With operating losses of $219,768 and $1.5 million respectively.
[85] This limit could be increased through a subscription fee

launched the service without first consulting with the RIAA. MP3.com's executives believed they were covered by fair-use which they felt allowed for space-shifting, whereby a user could copy a CD-DA to another format for personal use if there was no financial gain[86]. "If someone has a CD, they can make copies for their use because it's their personal property. The consumer has the license, not MP3.com" Robertson said and so MP3.com did not seek licensing permissions (quoted in Paoletta 2000 p.7). The RIAA filed suit against MP3.com within weeks. The service continued to operate despite the April 28th 2000 ruling that found that MP3.com had illegally amassed a database of more than 45,000 CD-DAs (Fitzpatrick 2000b). In the short term, MP3.com removed major label artists from its database but within ten days of the ruling MP3.com announced that it had struck a deal with BMG to allow on-demand streaming of their catalogue and within a few months announced similar deals with the other majors worth approximately $20 million apiece (Garrity 2000b). UMG however, refused taking the suit to trial for damages for $450 million, with the Judge ruling that MP3.com should pay $25,000 for each of the UMG discs the service hosted for a total for $250 million. MP3.com agreed to settle for $53.4 million, the most it could pay without going bankrupt (Garrity 2000b).

Upon relaunching the streaming service with the majors' reluctant support, MP3.com was purchased by Vivendi Universal[87]. Affected by the dot-com bubble more widely and more specifically by the uncertainty caused by the lawsuits against them, MP3.com's stock price had dropped to $3.01 per share. Vivendi Universal offered $5 per share purchasing MP3.com for $372 million in May 2001 (Holland 2001). At the time of the purchase Napster (5.4.8.2) had already been shut-down in its original form but copycat technologies loomed large. "Vivendi Universal [got] the technical infrastructure to stream music online to large numbers of users a capability that analysts [said] Universal Music Group (UMG) did not have on the same scale of MP3.com. What's more, Vivendi Universal gain[ed] control of the MP3.com locker service, which ha[d] licenses from all five major record label companies" (Garrity 2001a p.108). MP3.com was split in two, with the site becoming an online music reference guide[88], and the technology utilised as part of Vivendi Universal's joint venture with Sony known as Pressplay (5.5.3.2).

MP3.com started by an opportunist turned evangelist turned technologist, introduced millions to MP3. It contained the tools, the knowledge, the links to software and the community to allow those new to MP3 to quickly enrol in the niche's social networks and user practices. It ruffled the established

[86] American law has never expressly forbidden of supported space shifting although case-law much of which emerged because of the various MP3 suits does seem to support it so long as there is no commercial gain for the user.
[87] A French media group owner of Canal+ and UMG
[88] MP3.com was eventually acquired by CNET

music industry by presenting itself as an alternative to it, setting up as a record label and alternative form of distribution for artists using MP3 as both the medium and the message. Despite falling foul of copyright infringement laws, it managed to progress further than those who had attempted to license the music lawfully such as Liquid Audio (5.5.1) and developed technology that saw it become an attractive proposition for the majors once realignment of the socio-technical regime in response to niche activity pressure became inevitable. MP3.com was an integral element in stabilising MP3 as the dominant sound-carrier and in turn an integral part of the eventual technological break-through to the incumbent socio-technological regime.

6.8.2. The RIAA Verses Napster

Fanning invented Napster in his first year at North-eastern University where he was majoring in computer science. Looking for a challenge beyond his course he was inspired by his roommate's complaints about his online MP3 experiences "It was rooted out of frustration not only with MP3.com, Lycos and Scour.net, but also (the desire) to create a music community" said Fanning (BBC News 2001). As errors could occur during the download process resulting in download failure, users could waste 30-40 minutes waiting for an MP3 to not download. These were the problems with existing novelties that Fanning sought to address. He discussed the idea in a chatroom under his username, Napster[89]. Though most chatters were uncertain about Fanning's ideas, Sean Parker saw its potential. A sometime online acquaintance of Fanning's, he managed to secure $50,000 in investment whilst Fanning continued to work on the program at his Uncle's offices using a borrowed PC. Fanning set up business with his Uncle and Parker. Fanning and Parker met for the first time in real life and moved to California, launching Napster in May 1999.

Napster functioned by turning a user's PC into a peer client. It catalogued the metadata of user's MP3 files, storing them on a centralised database on Napster's servers. When another user searched for songs or artists it would list users who had that MP3 available it established a connection between the peer clients[90] and transferred the track. By October 1999 the program was sharing 4m songs between its users.

The RIAA filed suit against Napster in U.S. District Court[91] on December 6th, 1999 charging Napster with contributory and vicarious infringement of copyright and related state laws. Despite Napster combining legal technologies, search engine creation, addressing functionality (outside of DNS) and

[89] A reference to his shaved curly hair.
[90] Napster is generally considered to be the first peer-to-peer file-sharing system.
[91] In the Northern District of California

file transfer, the RIAA alleged that Napster operated "as a haven for music piracy on an unprecedented scale" (Holland 1999b). Despite the litigation, Napster attracted a $15 million investment from venture capitalists Hummer Winblad[92], who regarded Napster as a "killer application", on May 19th, 2000 despite not generating any revenue.

Napster was allowed to continue to operate despite the litigation so instead of being able to quickly shut it down, the RIAA raised the profile of Napster. Web measurement company Media Matrix said that usage of Napster's service grew from 1.1 million in February 2000 to 6.7[93] million unique users in August, an increase of 509% (Gillen 2000b p.117). Napster created a different problem for the music industry than MP3 archive websites. File-sharing before Napster was well established but it still required a degree of determination by the user, Napster, with its clean interface, database and access to millions of tracks rather than the archives of several hundred meant that downloading music was now easier, faster and more reliable than it had been before (Sterne 2012). In taking Napster to court, the RIAA had highlighted this to a whole host of new users with Napster estimating that their user base grew by between 5% and 25% daily[94].

Metallica filed a separate lawsuit along with E/M Ventures and Creeping Death Music for $10 million for copyright infringement and racketeering against Napster as well as the University of Southern California, Indiana University and Yale University as they had "knowingly sanctioned and encouraged [their] students to pirate" (Fitzpatrick 2000a). Metallica were alarmed to find that over 100 of their tracks were being shared on Napster[95].

On June 12th, 2000, the RIAA and the National Music Publishers' Association filed a motion that sought to remove all tracks owned by their member companies from Napster's directory. The suit was a preliminary injunction whilst the courts decided the outcome of the ongoing copyright infringement case filed in December 1999. The RIAA had commissioned Jay[96] (2000) to conduct a study into Napster usage and CD sales.

[92] Hummer Winblad had also invested heavily in Liquid Audio and some analysts at the time felt that the Napster investment was a way of recouping its losses as Liquid Audio was completely overshadowed by MP3, others however saw it as another example of "dot-com" fever.
[93] Napster claimed more than 32 million downloads of its software during the same period, but Media Matrix recorded those who have used the software at least once during a given month.
[94] This type of action would later be named the Streisand effect, whereby an attempt to hide remove or censor information publicises it. Barbra Streisand attempted to have a photograph of her Malibu property removed from a publicly available collection of photographs, suing for $50,000,000. Prior to the lawsuit the photograph had been downloaded six times. 420,000 people downloaded the image within a month of the lawsuit being made public.
[95] Including five different versions of a then as yet unavailable track from the Mission Impossible 2 soundtrack.
[96] Researcher for the Field Research Corporation

> "The company surveyed 3,218[97] college students […] in the survey, 500 said they were Napster users, one third of whom had downloaded more than 75 songs in the past four months. The study said 22% of the users downloaded the software because it meant they didn't have to purchase CDs, and 40% said that they believe Napster has 'some' or 'a great' deal of impact on music purchases" (Fitzpatrick 2000d p.125).

In addition, the RIAA and NMPA had commissioned Michael Fine[98] (2000 pp.1–2), for a report which detailed the album sales within college markets. He concluded that the data indicated:

> "that national retail music sales [had] grown significantly and consistently on a quarter-to-quarter basis during which music file-sharing [had] been widespread. However, sales at stores near colleges and universities declined significantly in the same period. Moreover, when analysing stores near a subset of colleges and universities where 'Napster' use [had] been recently banned and stores near a subset of colleges and universities designated as the more 'wired', the data [showed] a steep decline in sales compared to other colleges and universities".

Napster countered both reports with their own expert report from Peter Fader[99]. He found that Napster stimulated CD sales based on six other studies, that Jay's interpretation was misleading in order to favour the plaintiffs and that her data actually supported Napster "when properly interpreted" (Fader 2000 p.2), and that Fine's report failed to accurately capture changes in music sales overtime and so was unable to say anything about Napster usage on those sales. Despite Fader's concerns the judge did not think Jay's report was inappropriate and therefore did not negate the entire study especially as Napster itself had said it targeted college students and was therefore suitable for injunction purposes (Patel 2000).

Napster defended itself against the RIAA suit by claiming it was exempt from copyright infringement charges under the DMCA because it was an ISP[100], that it was allowing users to space shift in the same way the Rio (5.4.9.1) did and that Napster was suitable of substantial non-infringing uses[101]. The Judge ruled in favour of the RIAA and NMPA finding that not only were Napster users violating copyright but that Napster representatives were complicit in this infringing behaviour. Knowing that Napster had been able to block users from sharing Metallica and Dr. Dre tracks from the service Patel said Napster

[97] Of these, 2,555 were actually internet users willing to participate in the survey.
[98] CEO of Soundscan
[99] Associate Professor of Marketing at the Wharton School of the University of Pennsylvania
[100] Internet Service Providers were not accountable for their users infringing copyright under the DMCA
[101] The Betamax defence.

had to ensure that no copyrighted material be shared in the future. In discussing her ruling Patel had been convinced that Napster was stopping the majors establishing their own online marketplaces.

Napster appealed the preliminary injunction immediately and although the three judge panel of the Court of Appeal confirmed Judge Patel's decision, they granted Napster's request as the case "raised substantial questions of first impression" (Anon 2000b p.2). The Court of Appeals found that Napster was not given adequate time to detail how its technology worked, or how it had non-infringing uses. Further, there was concern that the studies submitted by Napster were not considered despite them contradicting the claims made by the studies submitted by the RIAA and NMPA.

Prior to the injunction ruling, Napster's CEO Hank Barry (of Hummer Winblad) met with the highest ranking representatives of the majors[102] along with Napster investor John Hummer to discuss a potential settlement although publicly the labels refused to acknowledge any such proposals (Fitzpatrick 2000c). The majors were interested in Napster with the potential to migrate it into a commercially viable system, but talks were tense. A week later, Hummer allegedly claimed he had received another offer intimating it was from AOL he hoped the labels could match for $2 billion[103].

The Court of Appeal announced its findings in October, finding in favour of the original injunction with only one concession that the labels had to prove that a file offered by Napster violated their copyright. Despite the distancing of Hummer and Napster from the majors and the ongoing litigation the Bertelsmann CEO Thomas Middelhoff continued talks with Napster. Bertelsmann announced its "strategic alliance" between its BMG label and Napster in October loaning Napster $50 million in exchange for equity in the newly developed legitimate service as well as access to the "rights in the file-sharing technology, the Napster brand and the Napster's customer data" (Anon 2000a p.101).

The legitimate version of Napster was scheduled for release in June 2001 and was intended to have three tiers including a free tier of low quality free to trade files. The service never launched as Patel's ruling on February 12th, 2001 ruled that it could be held liable for copyright infringement. On March 5th Patel issued an injunction giving Napster three days to remove illegally traded tracks. Napster and Bertelsmann attempted to strike a deal with the other majors offering $1 billion in payments over five years (Anon 2001). The majors fully rejected this offer.

[102] Including the founder of UMG, the Bertelsmann CEO, Sony CEO and Sony's U.S. Chief

[103]It is unclear what motive Hummer may have had for this but some have suggested that the labels simply wanted to obtain Napster to control the file-sharing aspect of it, controlling and restricting the technology as much as possible and so Hummer sought to simply stall negotiations (Menn 2003).

With the new filtering system in place, users began to migrate to other similar peer-to-peer services. The number of users dropped dramatically as did the number of files they were sharing. The service shut down on July 3rd, 2001 claiming it needed to retool is filtering technology.

The record labels suspended their lawsuits in January 2002 (except EMI)[104] but Napster filed for bankruptcy on June 3rd unable to obtain the licenses it needed to launch a legitimate model. BMG had continued to sue itself whilst Napster worked on a legitimate model[105]. Publicly the RIAA and majors claimed there was no legal means for online music sharing but privately the big five were strategically purchasing companies who were doing that to hold file-sharing under their exclusive control (5.5.3).

Napster was an important novelty in the stabilisation of MP3 and the niche. Before it, MP3 technology, though increasingly popular, could still be a frustrating and often difficult user experience. Napster removed the temperamental nature of early download options. It created a catalogue of millions of songs through a huge user base with a reliable means of obtaining songs[106]. Napster was the program that took file-sharing into the mainstream where it penetrated consumption culture on the internet in a way that could not be reversed.

The Napster court case determined how existing copyright laws would accommodate new technologies. More generally, the case sought to address whether or not copyright as it existed at the end of the 21st century was sufficient in protecting works from infringement or if rights holders needed additional technology to protect their work (Blackowicz 2001). Even at the time it was clear neither was sufficient individually. Napster brought about an entirely new distribution model, yet it was one that the music industry wanted shut down or at least tied up in litigation. Napster was crucial in eroding and altering the market and user preferences of the incumbent socio-technical regime. As Phil Leigh[107], noted "Napster has demonstrated beyond a shadow of a doubt that the public wants music over the Net, and if the [music] industry doesn't provide some kind of legitimate alternative to the consumer, then the consumer is going to go to the illegitimate option" (quoted in Garrity 2000a p.98).

The internal momentum of the niche was considerable because of Napster and MP3.com. Both services had been sued and their technological components purchased at heavy discount by those

[104] In one final show of strength Napster had managed to convince Judge Patel that the major labels were potentially guilty of collusion given that they had created two joint ventures to distribute music over the internet themselves but had refused to license music to Napster and BMG/Bertelsmann.
[105] The Napster name would eventually re-launch as a legitimate service different to either the original Napster or the proposed Napster v2. It was retained essentially for brand recognition.
[106] For the most part, the system was not faultless, and several other problems existed such as fake songs being uploaded, viruses being spread, peers going offline during the download and not coming back leading to incomplete downloads etc.
[107] An analyst covering the digital music industry at the time

who had instigated the court action. The incumbent socio-technical regime's response was to take ownership and control of the dominant actors in the niche as part of their reconfiguration response. Despite shutting down the threat piracy continued as Napster imitators appeared pressuring the majors to utilise their newly purchased technologies to create a new market with their own content for the first time. These new marketplaces, though based on MP3.com's and Napster's popular technology were poorly received by those users enrolled in the compressed audio niche and so music piracy continued through services based on the Napster model.

6.8.3. Decentralised imitators – Gnutella and FastTrack

The demise of Napster was a drawn-out affair, but Napster's closure had always felt imminent which resulted in unrelated programmers developing new novelties like Napster's peer-to-peer technology but without the centralised database which was considered its fatal flaw in legal terms. The technologies built on Napster's legacy even whilst Napster was still operating allowing many Napster users to switch between software platforms to continue "trading" MP3s. The refinement of peer-to-peer technology through various means as detailed below, allowed user practices within the niche to remain consistent despite attempts by the incumbent socio-technical regime actors to eliminate such behaviours. The social network and practices of users within the niche continued to shape any attempts by the socio-technical regime to engage directly with these actors and by extension influenced emerging digital markets (5.5.3).

Gnutella was a peer-to-peer client software program designed to operate in a decentralised manner by Frankel and Pepper of Nullsoft shortly after their acquisition by AOL[108]. This caused AOL some embarrassment[109] and software was quickly removed, despite this, other programmers reverse engineered Gnutella and other versions of the software emerged propagated by the open-source community.

The migration from Napster revealed some flaws in the original Gnutella's protocol as it was unable to scale to meet the demands of influx of users. It treated every user as both a peer and a client and so modifications were made to treat some users as ultrapeers so that some users only connected to them instead. The Gnutella network was designed to be difficult to shut down as the nodes exist on a

[108] Gnutella was released on March 14th 2000 and its name was a portmanteau of GNU (a recursive acronym of GNU's not Unix) and Nutella of which the developers claimed to eat a lot of during development.

[109] Peer-to-peer technology was considered subversive and at the time AOL had just finalised a merger with Time Warner, who in the 1990s were the largest media company in the world. Additionally, the new conglomerate hoped to acquire either EMI or BMG. As such, having Nullsoft release software which actively promoted copyright infringement was particularly awkward. However, it helped Nullsoft retain their underdog status with Winamp's and Shoutcast's users.

great many computers that form the network. Additionally, the number of clones that utilised the network protocol meant that shutting down the clone client would only shrink the network, not close it fully. LimeWire, which became the best known of the Gnutella clients operated until October 26th, 2010 when an injunction against the developer was issued although unofficial versions still operate today[110].

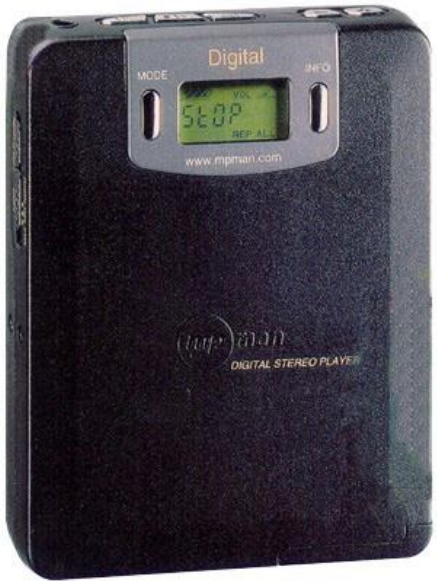


Figure 10: Saehan's mpman with 6 song capacity (Achat Meuble n.d.)

FastTrack was Gnutella's main rival. In a manner similar to Gnutella, it too avoided a centralised database utilising supernodes[111] that positioned the protocol somewhere between a central server and a decentralised one. The FastTrack system could not be fully shutdown. The system also allowed for downloads from multiple sources using the UUHash hashing algorithm[112]. FastTrack licensed its system to several clients with KaZaA emerging as the most popular, benefitting as LimeWire had done from Napster migration. Shortly after KaZaA's launch both the RIAA and the MPAA filed suit in the USA against FastTrack and its founder whilst the Dutch music publishing body BUMA-STERMA sued in Amsterdam. The Dutch court found that KaZaA could not demonstrate its ability to control copyright infringement and had to cease operations or face a heavy daily fine (Garrity 2001b). KaZaA's owners responded by selling KaZaA to the Australian owned Sharman Networks for a reported $500,000 in January 2002. Subsequently the Dutch appeals court overturned the earlier judgement stating that due to the decentralised nature of the network it was the users who were guilty of infringement and not KaZaA. Similarly, the US Supreme Court overturned an initial summary judgement brought by the RIAA and MPAA as the software was capable of non-infringing uses and because the respondents "had no actual knowledge of infringement owing to the software's decentralized architecture" (Anon 2005). Ultimately though,

[110] The Limewire shutdown only effected versions of the client that had "back door" functionality built into it, so earlier versions of the software continued to function. Additionally, other developers forked the software and continued to develop it under the "pirate edition" banner making the court injunction seem a futile attempt to stop the copyright infringement alleged to be occurring on the Gnutella network.

[111] Supernodes were FastTrack's version of ultrapeers although it is perhaps more accurate to say ultrapeers were based on the supernodes idea.

[112] UUHash was employed as it allowed large files to be hashed in a short period of time. However, it hashed only a fraction of the file creating a vulnerability that could lead to corruption of the downloaded data.

KaZaA settled agreeing to pay damages of $100 million and to convert KaZaA into a legal service although this service was short lived[113].

6.10 Physical novelties – MP3 based hardware is developed

The increasingly widespread use of MP3 on computers, caused in part by Disruptive Entrepreneurs, spurred interest from other outside actors. Unlike the Disruptive Entrepreneurs, who for the most part were young programmers able to produce innovative software with little initial investment, the actors who developed portable MP3 players required significantly more capital for their ventures. As such, those companies who were initially able to bring portable MP3 players to market were smaller technology companies as they were more agile than the more established consumer electronic behemoths. Unlike typical technology transitions however, there was a degree of creative destruction as the early innovators ultimately lost out as they were unable to adapt to changing user expectations brought about by subsequent refinement of the technology.

6.10.1 The first portable MP3 players

In early 1997 Micronas a Swiss/German semiconductor company demonstrated the first[114] MP3 decoder chip, the MAS3507D, which was also capable of decoding MP2 files[115]. Major manufacturers were uninterested in the radically innovation but a small Korean company unused to producing consumer electronics saw potential and opportunity. The first commercially produced portable MP3 player featuring the MAS3507D was launched in February 1998 by Korea's Saehan Information Systems and was coproduced with Digitalcast[116]. It attracted enough attention at CeBit to be put into commercial production and was subsequently sold as the MPMan for $350 and later $250 (Figure 19: Saehan's mpman with 6 song capacity (Achat Meuble n.d.). Sold exclusively online it sold 15,000 units in Korea and 35,000 units to primarily Europe, the US and Japan in its first year. Licensed to Eiger Labs it launched in North America in the summer of 1998 as the Eigerman F10 and F20. The player was flash based and could hold 6 (32mb) and 12 songs (64mb) respectively. The mpman/Eigerman is largely

[113] Unauthorised versions of KaZaA are still in use and thousands of users still exchange files using the decentralised networks today although use is fractions of a percent of what it was at the height of KaZaA's popularity.

[114] Two MP3 players predate this. Fraunhofer introduced a proof of concept model in 1994 capable of holding 1 minute of audio based around a chip design co-developed with Intermetall (later Micronas) but flash memory was in its infancy and it could not hold anything more. Fraunhofer did not even patent the idea. The other player was designed by Audio Highway; the Listen Up Player won an Innovation Award at CES in 1997. However, only 25 units were rumoured to have been produced and little is known about the actual player. As it is here, it really is just a foot note in the section of portable MP3 player history.

[115] The Micronas chip was Digital Signal Processor (DSP) which was an Application Specific Integrated Circuit.

[116] Another Korean Company.

forgotten in most accounts of portable MP3 players but for the first year of portable MP3 player sales it held about 30%[117] of the market-share but soon tailed off to a single digit[118].

The American company Diamond Multimedia[119], introduced the Rio PMP300 in September 1998 with an October release date. Diamond had acquired MP3 player production technology from Digitalcast and like the MPMan was based on the MAS3507D chipset. It offered a larger display than the mpman/Eigerman and had an expansion slot allowing its 32mb to be expanded to 64mb via a SmartMedia slot for an additional $100 over its list price of $200. The Rio could play both MP2 and MP3 files and shipped with a CD of 170 MP3 files from www.goodnoise.com and MusicMatch Jukebox software that allowed users to rip their CD-DAs to MP3. Ken Comstock[120], recognised the risk of launching an innovative new product but also recognised the potential market for a portable MP3 player: "the Rio represents a new arena in the market for us, which is consumer devices, and a solution for one of the big problems that has held back music from expanding more in the PC space: a lack of portability" (Reece 1998c p.102).

Portable MP3 players emerged as a knock-on effect of the increasing scale of the compressed audio niche; a technological response to the cultural demand for personal music portability that had begun in earnest with the introduction of the Sony Walkman in 1979, a demand that could not be fulfilled by multimedia PCs that kept MP3s locked in a largely non-portable environment[121]. The first portable MP3 players even shared physical characteristics with such products. Although playback functionality necessitated the need for play, stop, rewind and forward buttons, the shape, colour and appearance of the players appear based on CD and Cassette products available at the time. Saehan even went so far as to include the suffix "–man" in the name showing its portable MP3 player was part of a lineage of portable music sound-carriers. Whereas most of the novelties that had come about because of MP3 were software-based innovations, portable MP3 players were perhaps the first hardware innovations to be realised. Despite this, as Comstock noted, the portable MP3 player was intended to play an important role in supporting MP3 in introducing a means of portability. As such portable MP3 players

[117] Another German company, Pontis who had started working on their prototype player in 1995, also showed their player at CeBit. Initially selling their player through their website they began mass production in 1999. Although the Pontis player and subsequent models were well received the company lacked the resources to remain competitive in the portable MP3 player market as it became more populated with players that could do more and cost less withdrawing from the market in early 2003.

[118] The patents SIS held were sold to iRiver, who in turn sold them to SigmaTel in 2006 when they got into financial difficulties with their own MP3 players.

[119] Founded in the early 1980s and specialising in several multimedia technologies including graphics cards, motherboards and modems.

[120] Diamond's General Manager

[121] It could be argued that laptop computers allowed for some degree of portability, but they were not personal players in the sense of the Walkman and Discman style physical sound-carrier players.

became important elements in the stabilisation of MP3 as the dominant sound carrier within the compressed audio niche as well as increasing the internal momentum of the niche more generally in breaking through to the incumbent socio-technical regime.

6.10.2 The RIAA attempt to stop the Rio

The RIAA having become increasingly vocal over the number of MP3s available through internet archive sites (5.4.1) announced that the new hardware units were also problematic. As Cary Sherman[122] stated "[we're] examining the legality of these devices very carefully" (Reece 1998c p.102). Tim Wort[123] claimed that the Rio was a playback device and as such did not fall foul of the 1992 Digital Audio Home Recording Act (AHRA): "it doesn't record; it plays back MP3 files that have been recorded somewhere else. The ripping and encoding of the song is the recording, but our device is a PC peripheral that can't do any recording on its own" (Reece 1998c p.102). The RIAA filed for preliminary and permanent injunctions against Diamond ahead of release in retail claiming it was in violation of AHRA[124]. "Our concern with these devices … is not the technology, but how it's used, and we sincerely doubt there would be a market for these MP3 portable recording devices but for the thousands and thousands of illegal copies of songs on the internet" Rosen said (Reece 1998e). She also noted that the RIAA felt the Rio was illegal under the AHRA because it lacked a Serial Copyright Management System and as such the Rio was likely to increase the number of files online. Sherman's concerns about such devices were such that they would be damaging to any development of a digital distribution infrastructure as they supported the illegal market that was already developing. The RIAA also had support from the U.K.s Music Publishers Association whose Chief Executive, Sarah Faulder, took a similar stance "[w]hatever Diamond's claims, this device clearly enables Net surfers to copy and pass on copyright material without reference or payment to the authors or copyright holders[125]" (Reece 1998f p.109).

The RIAA was granted a temporary restraining order on October 16th, 1998 causing Diamond to delay shipment. On October 26th Judge Collins denied the request for a preliminary injunction stating that the RIAA was unlikely to prevail. She found that the Rio probably would be categorised as a Digital Audio Recording device under AHRA but that the innovation the Rio made was only that it allowed the movement of files from the computer to the Rio. However, MusicMatch ,software capable of ripping

[122] Senior executive VP/General counsel for the RIAA
[123] Diamond's VP of corporate marketing
[124] The RIAA targeted Diamond's Rio because of availability through large US retailers such as Best Buy and Electronics Boutique and the Rio's lower price over the mpman/Eigerman according to the RIAA president/CEO Hilary Rosen.
[125] The software, MusicMatch, that it shipped with could space-shift and users could then share files online if they so wished, but the device itself was an extremely inefficient way of sharing music so Faulder's claim suggests a misunderstanding of the problem.

CDs, was independently available, and not made by Diamond and as such was not part of the device. Collins found no basis for the assertion that the Rio facilitated downstream copying despite that being a claim central to the RIAA's objection to the Rio.

It is not clear if there was genuine technological confusion about the capabilities of the Rio within the RIAA *et al.* or if the legal action against Diamond was simply part of the RIAA's apparent greater anti-MP3 stance in which it operated as a litigious cartel (see section 6.5.2). As a direct result of the RIAA's action, Diamond countersued claiming the RIAA had requested they withhold the Rio from market along with other companies developing similar products until the music industry had decided on which delivery system to endorse. Ron Moore[126] , claimed that this amounted to collusion and "the reason the Sherman [Anti-trust] Act was enacted" (Reece 1998a p.8). Diamond also claimed that the RIAA's pursuit of it in court even after it incorporated the SCMS was evidence that the "RIAA's real goal [was] stopping the legitimate MP3 market" amongst other claims (Reece 1998a p.8). Bob Kohn[127], also claimed during the initial case that the RIAA's action against Diamond had "everything to do with the protection of the major record companies from legitimate competition" (Nelson 1998). Other unspecified "industry insiders" were quoted in Billboard as saying the RIAA "made its point […] by issuing the legal challenge. Other manufacturers were readying MP3 players for the marketplace at the time, and all but Diamond Multimedia held back. Those manufacturers like Diamond, have since joined the SDMI initiatives" (Holland 1999a p.100). The RIAA in its own prepared statement claimed that they filed "this lawsuit because unchecked piracy on the Internet threatens the development of a legitimate marketplace for online music, a marketplace consumers want" (Holland 1999a p.100).

The RIAA's and the Alliance of Artists and Recording Companies (AARC)[128] appeal against the ruling was the first to bring resolution. On June 15th 1999, the Ninth Circuit Court of Appeals ruled 3-0 that the Rio was not a digital audio recording device as defined by AHRA and that "in fact, the Rio's operation is entirely consistent with the Act's main purpose […] The Rio merely makes copies in order to render portable, or "space-shift," those files that already reside on a user's hard drive." (Anon 1999 p.1079).

The ruling was significant as it was the first time that a court had endorsed a consumer's ability to "space-shift" by making a digital copy of a digital recording from a physical sound-carrier that they had

[126] Diamond's general counsel
[127] Co-founder of goodnoise.com
[128] Who were an almost entirely ignored third-party by the press but were the body who collected and administered the royalty payments collected under AHRA

lawfully acquired; a privilege the RIAA had long denied existed[129]. It also allowed for the space-shifting of authorised MP3s although did not extend to copyrighted works that were being shared online unlawfully through MP3 archive sites. This was the first time the legitimacy of MP3 and the burgeoning legal market (see section 5.5.2) had been tested and to the RIAA's "disappointment" it had been legitimised by the courts stabilising the niche still further. For Diamond the suit resulted in significant sales[130] and RioPort[131] began expanding the range (Traiman 1999).

6.10.3 The Secure Digital Music Initiative (SDMI)

The Rio case forced the RIAA to reassess MP3. The speed at which they lost against Diamond, effectively opening the market for other competitors was rapid. Despite ongoing appeals, the RIAA began enrolling technology companies in proposals for a secure system which eventually emerged as the SDMI. It was formerly announced December 15th, 1998 at Sony's New York headquarters attended by major label CEOs. It was intended to be "a framework to work with the technology community to create a voluntary digital music security specification […] The open specification will protect copyrighted music in all existing and emerging digital formats and through all delivery channels" (RIAA 1998).

The SDMI was a response to the pressure of unlawfully shared MP3s and in technology seen as enabling infringing behaviour. Rosen was keen to stress that the SDMI was "not about the recording industry imposing a standard on technology companies" although compliant technology would earn a compliancy 'seal' (RIAA 1998). Companies like Diamond who had started providing digital music portals such as "RioPort" through which consumers could purchase content were forced to strategically align themselves with the RIAA in the hope of fostering amicable relationships to access content. The implicit threat, was that non-compliant technologies could be deprived licenses for the major label content (Krigel 1998). This led some critics such as Steve Grady[132] to claim, "the announcement was not at all about security or about piracy--it's about control […] by implementing security, they maintain control."

[129] Computers were exempt from AHRA because even though hard drives could hold digital sound-files, the act was applied specifically to "material objects". As such digital sound-carriers such as DAT and audio CD-Rs were required to pay the royalty but hard drive manufacturers did not. Portable media players such as the Rio were also exempt because of the ruling.
[130] The Rio had sold more than 200,000 units
[131] RioPort was spun out from Diamond Multimedia in 1999 to manage the MP3 players and was also the name of their MP3 marketplace.
[132] Vice President and General manager of Goodnoise

Other commentators tried to understand the labels' position and understand their incentives for such an initiative:

> "It means that labels can now start exploring this space more openly and with less repercussion. Now it's a reactionary thing because they can throw up a smoke screen and say, 'If we don't do this, we'll get killed by piracy.' But the further truth is it allows them to enter this new business in the name of a formalized initiative without the kind of backlash Capitol got from retail when it did its Duran Duran promotion (see section 5.5.1)" (un-named source quoted in Reece 1999 p.62).

When SDMI was announced it was claimed to have been in development for a year. Diamond reported being asked to hold back releasing the Rio, but it is unclear what, if anything, had been developed. This led some critics to refer to SDMI as vapourware[133] (Reece and Jeffrey 1998; Litman 1999). The involvement of competing compressed audio sound-carriers, such as Liquid Audio and a2b (5.5.1), would initially have been in the hope that they could position their technology as the one adopted. As Gene Hoffman[134], noted "with Liquid Audio and a2b and Madison[135] and all these other people competing, it's going to be very hard to anoint one of them over another, especially because of antitrust issues facing the RIAA. And if they don't anoint [one system], then you end up with a very fractious business" (quoted in Reece and Jeffrey 1998 p.83).

Leonardo Chiariglione, convenor of MPEG, was appointed as Executive Director of the SDMI. His role was essentially to create a compressed sound-carrier that could be used on the music industry's terms[136]. Stage one of SDMI was intended to employ digital watermarking to identify ownership; the second stage would stop SDMI players from playing SDMI tagged music from playing on an unauthorised device. Although the SDMI was successful in producing watermarking technology the watermarking technology itself was not successful[137]. Unable to get through stage one and with

[133] Vapourware - A condescending phrase used to describe software that has yet to be developed but whose announcement serves a strategic purpose

[134] President/CEO of MP3 record label GoodNoise

[135] Madison was a venture between the majors and IBM that was tested in San Diego due to the cities fast broadband structure. The Madison Project was intended to allow users to securely download using IBM's crytoplope technology and then manufacture it at home. The trial never moved beyond the test stage as beta testers were unimpressed with the involved nature of manufacturing and the high prices which were higher than CD-DA albums at retail. The work done eventually contributed to the SDMI.

[136] This probably would have taken the form of something like AAC, MPEG's Advanced Audio Codec and placed inside a wrapper technology similar to a2b and Liquid Audio's technology.

[137] The SDMI published an Open Letter to the Digital Community demonstrating four digital watermarking techniques and called on hackers and cryptographers to remove the watermark from samples they provided. A team led by Ed Felten removed all four watermarks successfully. When Felten, an academic, tried to publish his work (he chose not to take the prize money so was not bound to the confidentiality agreements) the SDMI, RIAA and Verance Corporation attempted litigation under the DMCA.

internal conflict between the technology companies and the majors over who should bear the cost of implantation the project stalled[138]. Chiariglione stood down in 2001 saying that SDMI was waiting for "progress in technology".

6.10.4 Technological outcomes of the RIAA's SDMI interference

Despite the lack of success of SDMI the pressure it had on socio-technical niche developments was considerable. In the short term, the SDMI's influence on the nascent portable MP3 market was to corral manufacturers into reluctant compliance with the idea of the SDMI in the hope of a future payoff of access to major label content. As SDMI had no technology of its own manufacturers created an ineffective hotchpotch of copyright protection[139].

Several other semiconductor manufacturers (such as Texas Instruments and Zoran Corp) had entered the market established by Micronas. Initially the chips produced were fixed function Digital Signal Processors (DSP). These chips were limited relying on PC software to implement DRM. The RIAA lawsuit against Diamond made for a tumultuous time for those producing MP3 players and the SDMI floated the very real proposition of alternative formats with complex DRM that required considerable processing power. Existing fixed-function chips were incapable of supporting such increased functionality and there was an awareness amongst producers of MP3 players that "in general terms, we will definitely want our next player to play more than MP3" (Creative's Lowe quoted in EE Times 1999).

In addition to the uncertainty created by SDMI, Cirrus Logic said their customers were "asking us to look into Real Audio's G2, AAC and AT&T's a2b" (Maurin quoted in EE Times 1999). The semiconductor manufacturers began adapting general purpose microprocessors such as the ARM720T which Cirrus announced it had adapted for "emerging Internet compression audio standards" and that could "evolve" and "adapt" "thanks to its programmable ARM processor core" (Cirrus Logic 1999). This meant that the chip could be modified quickly to support new compression standards as they emerged. The EP7209[140] was the first in a line of chips to later take the name "Maverick" and was referred to by those in the tech industry as the "Granddaddy of all MP3 chips" (Hachman 2000). It offered other advantages over existing fixed-function DSPs such as decreased power consumption,

[138] It was likely to be accepted poorly by consumers anyway due to the limitations it intended to impose

[139] Some would not allow users to copy MP3s which had been downloaded from the player to another computer, others simply put up vacuous warning messages if copied MP3s were detected It was rare for MP3 files to be marked as copies even if they were and it was rare for copies to be marked as such even if they were.

[140] Cirrus's chip, the EP7209, was initially designed for handheld computer platforms such as the Psion and Windows CE devices and the chip was "retasked" to decode music in light of market demands (EE Times 1999)

the ability to manipulate the bass, treble and volume and included capabilities for graphic equalizers as well as support for its own LCD[141].

The result of the RIAA's lawsuit and implementation of the SDMI plunged the MP3 chip market into "chaos" (Hachman 2000). The interim confusion, before the SDMI circulated draft specifications in June 1999 in which it was made apparent that MP3 players would need the ability to play more than just MP3, led chip manufacturers to evolve beyond fixed-function chips so that products continued to be attractive to portable MP3 player manufacturers, the majority of who were keen to be seen as SDMI compliant. Even though the SDMI was essentially a flop, its influence pushed semi-conductor manufacturers towards microprocessors that were capable of multiple operations. The SDMI was the primary socio-technical regime influence for this, though the rise of other audio compression formats within the niche was also influential, demonstrating the level of control the RIAA could wield on the nascent portable MP3 market.

More and more consumer electronics manufacturers introduced portable MP3 players. Creative introduced a line of flash-based players under the Nomad brand and Samsung introduced a line of Yepp models. As Gene Hoffman[142], noted at the Consumer Electronics Show in January 2000 "I was actually kind of blown away by just the total raw volume of them. I knew that there were a lot of hardware companies behind it, but the fact that literally everyone who had the hardware expertise had made one really surprised – and excited-me" (quoted in Gillen 2000a p.24). Largely reiterative[143] of the Rio models some began to include additional features such as basic video playback on Samsung's "Motion Yepp". Sony, whose own portable music products the Walkman and Discman were so successful they had become proprietary eponyms also released portable audio players.

Sony's players which included the Memory Stick Walkman and VAIO Music Clip released in the latter half of 1999 and the Network Walkman which debuted at CES used Sony's proprietary ATRAC3 audio compression along with OpenMG, Sony's SDMI compliant DRM. Despite Sony's products being technologically desirable the addition of the DRM features were some of the first to market and proved undesirable with consumers. Although supporting MP3s, the players did not do so natively

[141] Other manufacturers achieved this by using a number of fixed function chips working together with software running atop of the architecture to enable features. Texas Instruments continued with this approach for some time as their C54x chips proved popular, but their architecture was considerably less adaptable than the newer approach adopter by Cirrus and later by PortalPlayer who introduced the Tango chip which would prove instrumental in the development of the most successful MP3 player range of them all – the iPod.

[142] President/CEO of emusic.com

[143] The first hard drive based MP3 player was put into development in May 1998 by Compaq, although the final device was marketed by HanGo Electronics (later Remote Solutions) known as the PJB-100 (Personal Juke Box 100). It had a 4.8GB hard drive capable of holding 1200 songs and much like the Mpman despite being first it is largely forgotten.

requiring MP3s to be converted Sony's PC software. The Memory Stick Walkman had initially been intended to support both formats natively as "the last thing they want to do is cede that market to a peripherals manufacturer (Diamond)" (Miles 1999). Several commentators suggested that lack of MP3 support came as a compromise with Sony Entertainment (Benz 2001; Doctorow 2004). As such, direct MP3 support was dropped as a resolution to an internal conflict where one side of the organisation supported MP3 to match competitors whereas the other side saw it as a threat to its content and wanted to minimise its support. As such Sony was outmanoeuvred initially by smaller, agile companies that did not require the same lead times in bringing products to market but also later by competitors because although they were keen to commit to the SDMI in the discussion stages they did not implement DRM on the devices in such a methodical manner as they did not have content divisions to protect. This left Sony "in the dust, because they do not support the MP3 format […] unique in this sense because they've got two sides of this business that might well have [had] conflicting objectives" (Benz 2001 p.14).

Although some like Mark Knox[144], felt that the market was maturing ("the timeline between the infant stages to mature market has gone from decades to seconds" (Gillen 2000c p.72)) the lack of availability of larger flash memory modules restricted development of MP3 players' storage capacity. Building on the model released by HanGo, Creative debuted the Nomad Jukebox[145] at CES 2000 which they released in August 2000[146]. The first Compact Flash Type II based player was released in early 2001; i2go's e-Go (Figure 20) could accommodate IBM's new microdrives[147]. Initially the drives were available in 170mb and 340mb sizes but in June a 1GB model was released meaning that the i2go could hold up to 2GB of data. However, the 1GB drives were priced at $1,000

Figure 11: i2go's e-go MP3 player could adapt to increased storage capacities as they were developed.

[144] Senior manager of marketing, digital products group, at Samsung
[145] The Nomad Jukebox was positioned as a portable player that was too big to be truly portable and was intended rather to be a transportable desktop-based MP3 player initially.
[146] The Nomad Jukebox was built around a 6.0GB laptop hard drive and was capable of storing around 150 CDs worth of music, far outstripping the flash-based players which struggled to hold much more than a single album at 128kbps.
[147] 1inch hard drives that were designed specifically to fit into CF slots.

each so it is unlikely many consumers could take advantage of this increased capacity[148].

By the end of 2000, portable MP3 player sales were estimated to have totalled 1.18 million units that year and were predicted to increase to 1.8 million units in 2001 (Traiman 2001 p.62). More than 50 companies were selling portable players within the USA alone, and many Asian companies sold players via the internet. Many of these players were reliant on the Micronas chipset MAS3507D or its successor MAS3509F. In 1999, Micronas had a 90% market-share which had remained strong through 2000. Micronas, as the dominant MP3 chipset manufacturer promised that the MAS3509F would be fully compliant with the SDMI given that a large portion of its customer base had promised to be SDMI compliant, but they were reliant on external technologies to be able to accommodate any eventual solution. Although the players with the larger market-shares were utilising "big-box" stores as distribution there was no clear dominant player in this "matured market". This situation changed considerably between 2001 and 2003 and with it the niche.

6.10.5 iPod, therefore I am – Refinement of existing novelties

According to the official Apple timeline, development of project Dulcimer began in June 2001[149]. The January before, Apple had released its iTunes software[150]. In late October 2001, Apple unexpectedly announced that they were releasing an MP3 player that could fit "1000 songs in your pocket". The player was hard drive based which Steve Jobs reasoned in economic terms as hard drive players could hold 1000 songs which equated to $0.30 per song "and that's where we [Apple] want[ed] to be" (Jobs 2001)[151]. Jobs felt the iPod was a "quantum leap" because it had three major breakthroughs over existing portable MP3 players. It was "ultra-portable" taking advantage of a 1.8-inch hard drive that had been engineered by Toshiba, found by Jon Rubinstein one of the engineers tasked with creating the iPod on a routine tour of Toshiba[152]. Using Apple's proprietary Fire Wire technology, it could transfer an album in 10 seconds compared to USB's 5-minute transfer[153]. The iPod also used a

[148] Despite i2go's innovative storage solutions the company were out of business by 2002.
[149] Although when introducing the iPod for the first time Steve Jobs stated that the project began at the start of the year 2001 (Jobs 2001) and elsewhere it is said that Jobs asked Rubinstein to look into a portable music player in late 2000.
[150] Which was based on the SoundJam MP music software for Mac computers Apple had purchased in 2000. SoundJam MP was developed to allow Diamond's Rio players to work with Mac computers by Jeff Robbin and Bill Kincaid. Robbin is still lead developer of iTunes.
[151] Flash players, which stored around 15 songs equated to a cost of around $10 per song, an MP3 CD player could hold around 150 songs and equated to around $1 a song according to Apple's infographic used during their special launch event.
[152] He would later recall though that in 2000 when the project was first touted "the technology really wasn't there yet to make a great player" and so the project had initially stalled for a few months and then whilst at Toshiba in Japan the engineers there showed him a 1.8 inch hard drive that he knew had potential (Aaron 2005 p.14).
[153] 1000 songs would take 10 minutes but 5 hours to transfer with USB.

rechargeable lithium-polymer battery capable of 10 hours of continuous play back[154]. The iPod was the size of a deck of cards and was similar in size to most existing flash players and the iPod was also "easy to use". The iPod introduced a unique scroll wheel allowing for fast access to long lists of artists and albums[155]. Job's felt the third break-through with the iPod was that it automatically synced with iTunes so that the iTunes library updated the iPod when connected without user involvement. These "break-throughs", as Jobs repeatedly referred to them, were the Apple design team's response to criticisms (see Kaplan 2001) and issues they identified with existing players. Jobs noted that MP3 players "before ha[d] not been easy" and there was "nothing like this before". Jobs did not

> "think there's another company that could do this. To bring the hardware design, the industrial design, the application software design, Fire-wire, everything under one roof together to be able to create a product like this" (Jobs 2001).

Hyperbole aside, there is more than a grain of truth in Jobs' claims; MP3 players had lacked one or more attributes found in the iPod. However, these innovations were not Apple's alone, and it was disingenuous, although not unusual of Jobs to imply that they were.

Tony Fadell, a former Phillips employee also wanted to produce a small hard drive based MP3 player (Apple 2006). Fadell turned to Apple[156] who according to their own timeline were considering an MP3 player when they hired him. Unconvinced that Apple were willing to fund the full development of a custom player, Fadell looked for existing systems on which to base the iPod. The heart of the MP3 player is its firmware and the semiconductor chip on which it was embedded.

PortalPlayer was always intended to be an MP3 chipset and firmware for MP3 players[157] much like the Micronas chipsets[158]. The chip was based on one designed by the U.K. based ARM[159] which PortalPlayer's engineers heavily modified. The chip was very like Cirrus' Maverick series of chips

[154] The physically larger Nomad Jukebox managed 4 hours.
[155] Creative would later take Apple to court as they had patented the means of using metadata to sort songs, by Artist, title etc and then using an interface to view and play them, with the Creative Nomad Jukebox. The case would eventually be settled out of court but the patent itself was considered ridiculous by many at the time as it was so general and had the potential to stifle innovation (Yong 2005)
[156] His first attempt at RealNetworks had failed as the company could not rationalise introducing a consumer electronic into their existing content delivery system (Markoff 2004).
[157] Firmware is a form of miniature operating system that is embedded on the hardware and is capable of things such as audio decoding, power management and database tasks.
[158] One of PortalPlayer's founders Gordon Campbell, a venture capitalist, suggested a similar chip for National Semiconductor in 1999 targeting the nascent MP3 player market (consisting primarily at that time of Diamond's Rio and some other Korean imports like Samsung's Yepp models). National Semiconductor as a company were not interested but others within the company could see the potential leaving their jobs to form PortalPlayer with Campbell. Other capital came from MP3.com and Techfund Capital.
[159] A company founded in 1990 by Apple and two others

(5.4.9.4) but unlike the Maverick chips the PortalPlayer chip could control hard drives, not just flash memory. The similarities between PortalPlayer and the "Maverick" chips are indicative of the multiple similar innovations that occurred to fulfil perceived market demands of the nascent technologies at the time being developed to fill the same predicted requirements[160]. Working with the team at PortalPlayer, Apple's engineers improved upon and essentially finished PortalPlayer improving the firmware to where they felt it needed to be – improved battery life, better playlist handling, adding equalizers etc. The iPod's graphics interface was also licensed from a small Cupertino start-up called Pixo a company who specialised in interface design for mobile phone companies[161].

The iPod innovation is one that pulls together several other inter and intra-sectoral novelties from the PC sector along with related technology sectors such as those developing batteries and displays as well as bringing together and refining existing novelties from within niche. It relied on novelties that had enrolled a series of well-resourced actors and brought them together using its own considerable resources. Apple's engineers and designers innovated by way of a form of harmonious meta-coordination wherein these separate technologies were brought together and engineered to function as a singular refined innovation. Whilst it is certainly true that other companies were doing similar things with their own portable MP3 players, the iPod is the most representative of this process.

Despite the iPod's claimed advantages over other MP3 players its own market-share was severely limited by its lack of Windows support[162] with critics suggesting the iPod was too little too late (Kary 2001). Other critics were more optimistic however, calling the iPod "the world's coolest – and dare we [PC Magazine] say best MP3 player" noting that the iPod was a good reason to buy an Apple computer (Dreier 2001; easyboy 2001).

[160] Apple contracted PortalPlayer as their chip and firmware supplier because PortalPlayer reportedly sounded better and had greater flexibility than the nine others considered.
[161] The very first iPods credited Pixo on their about page although this was removed from later models. The exact contribution and how much of the iPod's operating system was reliant on Pixo has never been divulged although it seems clear that Apple used an outside source to speed up development to some extent.
[162] Mac had only a 2-3% share of the PC market at that time.

By Christmas 2001 the iPod had sold 125,000 units in its 3-month introductory period[163]. Third party developers such as Xplay and EphPod started trying to implement software that would allow the iPod to work with Windows based PCs producing functional demos by January 2002[164]. Apple introduced a larger capacity model in March 2002 and on July 17th, 2002, Apple made four announcements: a 20GB model was to be introduced, the Scroll Wheel was to be made touch sensitive, the prices of the models was being reduced[165] but most importantly in terms of adoption of the iPod, Apple announced that the iPod would now work with Windows based PCs. PC versions of the iPod came bundled with MusicMatch Jukebox 7.1[166] software instead of iTunes to manage the transfer of songs between computer and iPod. The second-generation iPod was well received by the press and users alike. Maximum PC called it a "kick ass product" whilst highlighting that the iPod was the MP3 player to beat. Indeed, subsequent players released by rival companies started to become more iPod-esque. iPod had shown that there was a demand for greater storage, so competitors produced similar products in a smaller form factor. However, with their newer designs, competitors also started introducing more premium materials such as brushed metals and rounded control panels (Figure 21).

Figure 12: Toshiba's Mobilphile MP3 player with swappable hard drives and iPod-esque styling

Table 6 details sales figures for iPods. In October 2003 Apple announced that iTunes[167] was to be made available to Windows users for the first time opening the iPod software and hardware experience to the other 97% of the home computer market. Apple ran a tongue in cheek campaign declaring that "Hell Froze Over" given its long-standing reluctance to release software for non-mac computers. The Windows version of iTunes was downloaded one million times within three and a half days. Allegedly Jobs had been reticent in releasing the iTunes

[163] Outselling most competitors although it benefitted from both being a new product and holiday shopping period, in the two quarters following sales dropped to half this leading some premature commentators to announce the failure of the iPod as a product.
[164] This reflects the similar processes the team behind SoundJam MP went through trying to bring Diamond's Rio to the Mac.
[165] The 5GB dropped to $299, the 10GB to $399 and the 20GB to $499
[166] This was an improved version of the MusicMatch software that shipped with the original Rio and the same that shipped with other more current Windows based MP3 players and was at the time the best-selling music software for PCs (Apple 2002).
[167] Along with the iTunes Music Store

software for PCs. Rubinstein recalled that “finally, Phil Schiller and I said, 'we're going to do it.' And Steve said, 'Fuck you guys, do whatever you want. You're responsible”. Apple introduced the iPod mini, which contained a 4GB Microdrive[168] manufactured by Hitachi and Seagate taking advantage of AAC audio compression Apple could claim that the player held 1000 songs like the original iPod despite the smaller capacity.

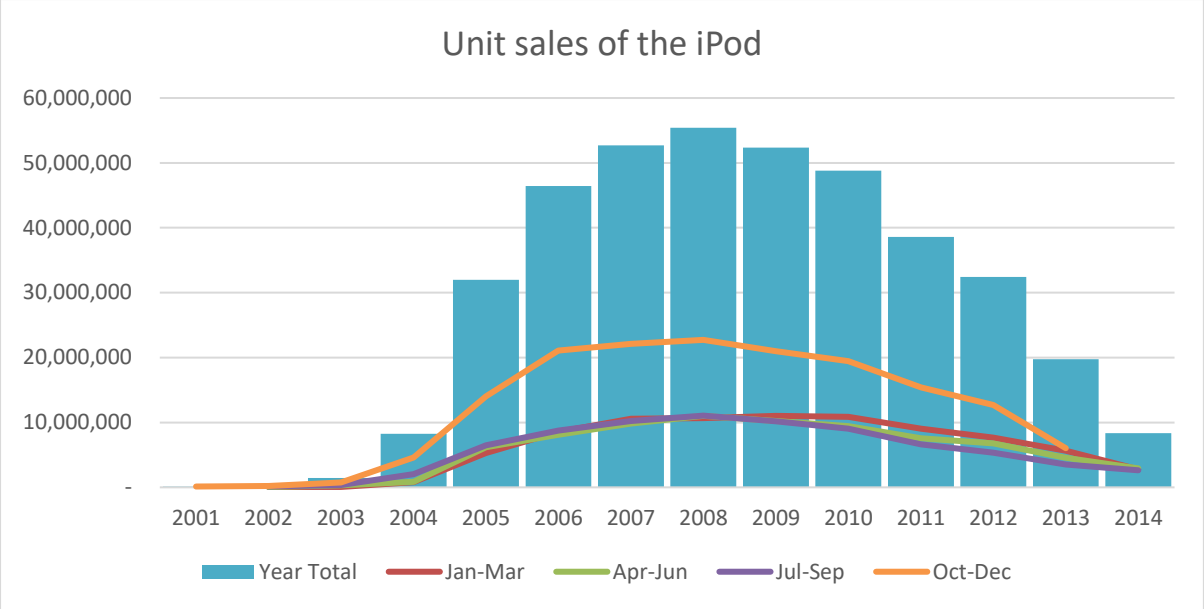
Table 7: Sales of the iPod range from launch until Q4 2014 when Apple stopped reporting unit sales.

Year	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Year Total
2001				*125,000*	*125,000*
2002	*57,000*	*54,000*	*140,000*	*219,000*	*470,000*
2003	*78,000*	*304,000*	*336,000*	*733,000*	*1,451,000*
2004	*807,000*	*860,000*	*2,016,000*	*4,580,000*	*8,263,000*
2005	*5,311,000*	*6,155,000*	*6,451,000*	*14,043,000*	*31,960,000*
2006	*8,526,000*	*8,111,000*	*8,729,000*	*21,066,000*	*46,432,000*
2007	*10,549,000*	*9,815,000*	*10,200,000*	*22,121,000*	*52,685,000*
2008	*10,644,000*	*11,011,000*	*11,052,000*	*22,727,000*	*55,434,000*
2009	*11,013,000*	*10,215,000*	*10,177,000*	*20,970,000*	*52,375,000*
2010	*10,885,000*	*9,410,000*	*9,050,000*	*19,446,000*	*48,791,000*
2011	*9,020,000*	*7,540,000*	*6,622,000*	*15,397,000*	*38,579,000*
2012	*7,673,000*	*6,751,000*	*5,344,000*	*12,679,000*	*32,447,000*
2013	*5,633,000*	*4,569,000*	*3,498,000*	*6,049,000*	*19,749,000*
2014	*2,761,000*	*2,926,000*	*2,641,000*	*Unreported**	*8,328,000+*
Total iPods sold between 2001 and 2014:					*397,089,000+*

Apple’s fiscal year begins in October. From Q1 2015 it stopped reporting iPod sales as a separate entity instead combining it with “other” sales.

iPod for windows iTunes Store iTunes for windows iPod Touch

[168] IBM and Hitachi had merged their Hard-drive divisions since



Apple continued to make incremental changes to the main iPod line as well as introducing new models within the iPod family. In January 2007 Apple unveiled its iPhone (sold from June), billed as "a revolutionary mobile phone, a widescreen iPod® with touch controls, and a breakthrough Internet communications device". Heavily influenced in design by the existing iPod range as well as the trend for convergent hand held consumer electronics more broadly, especially the developing "smart phone" market (Apple 2007). Although phones that played music had existed for some time none had been tied to a content service like iTunes. The iPod touch which had the same form-factor as the iPhone was introduced in September 2007. With its Wi-Fi connection, the iPod Touch was the first iPod that could operate as a standalone device and not as a PC companion piece.

Sales in 2009 started to decline and sales of the iPod have continued in a downward trend since that period. In September 2014 Apple announced that it would no longer be manufacturing the iPod classic, the longest unchanged product it still sold. Sales of the device had dropped significantly as changes in the way users were consuming music had shifted away from a need or desire to carry substantial collections in their pockets in the large numbers that helped drive early sales (5.5.4.3). Tim Cook[169], stated that they were not longer able to obtain all the parts required to continue manufacturing the device.

6.11 Summary

There were several important actors identified during the historical narrative that adopted, adapted, interacted with or used dematerialised sound carriers. The specific use and transition was not predicted by any of the regimes that had helped to develop the MPEG audio layers. Indeed, it was

[169] Cook became Apple's chief executive after Steve Jobs death from pancreatic cancer in October 2011.

various Disruptive Entrepreneurs that recognised the potential in the innovation that began experimenting with MP2 and eventually MP3 and trialling them in different use scenarios online that began to popularise the sound-carrier as an alternative means of music consumption.

The specific role of unlawful activity also cannot be understated. This type of activity is difficult to control, as the RIAA found but as a mechanism for innovation is surfaced several times within the niche. From the original purchase of the Fraunhofer software with a stolen credit and subsequent unlawful distribution of the software with the cracked licensing key to the sharing of copyright MP3 files on hidden servers to the eventual use of services like Napster and LimeWire that users could unlawfully obtain so many of the tools needed and the content they wanted removed one of the main issues to the adoption of any new technology: cost. Further, software such as WinAmp and Sonique was simple to use which gave a further lower barrier to entry for already technology savvy internet users whilst websites such as MP3.com provided clear instructions for those who were unsure how to obtain music but may have heard about the sound carrier.

As such, MP3 was a technology that was difficult for any one actor to control the transition and adoption of. The unlawful spread of both the software and copyrighted content saw the RIAA make several attempts to halt its spread, with their Cartel of Condemnation behaviour, which raised MP3's profile in the popular consciousness as well as the profile, if not of the individual Disruptive Entrepreneurs but of their software, which made obtaining content easier for those who were interested in doing so. The introduction of the physical MP3 players was also seen a legitimising factor which obfuscated the legal issues surrounding MP3 further as hardware devices were defined as legal by the courts. However, the content online was overwhelmingly unlawful and for the clear majority of users it was not clear how to obtain music legally online.

This chapter discussed the actors that emerged around the compressed sound-carriers such as the MPEG standard and the additional novelties they brought to the niche. The next chapter focuses on the attempts made to produce legal alternatives to the unlawful online distribution channels for dematerialisation sound-carriers that had emerged as the most successful implementation of the compressed audio novelties.

7 The road to iTunes and the legitimisation of dematerialised sound-carriers

7.1 Introduction

Chapter seven focuses on attempts by actors to engage with the music industry in a bid to legitimately license content to sell dematerialised sound-carriers to consumers rather than the unlawful distribution channels that had helped promote the compressed sound carrier novelties as discussed in the previous chapter. A number of actors attempted this from the mid-1990s onwards but there was a strong reluctance reflecting the Cartel of Condemnation and Litigation that did not want to be seen to be legitimising the nascent technology that hampers earlier efforts by companies such as Liquid Audio and a2b (7.1), to companies who work with smaller labels (7.2), major label attempts to launch their own market places (7.3), the marketplaces that begin to emerge as a result of congressional interference with the record labels marketplace attempts (7.4), the eventual emergence of streaming services as alternatives to download only market places (7.5) and finishes with a summary discussion on the development of online market places for dematerialised sound carriers (7.7).

There were several attempts within the niche to create marketplaces for dematerialised music. In many ways, the earliest marketplace was IUMA, but other actors soon appeared that sought to monetise access to music either as MP3 files or in proprietary compressed audio formats. Such market places relied heavily on content and their success or failure came down to how well they could enrol content providers into their networks, a problem that those who eschewed licensing copyrighted works did not encounter in the same manner.

7.2 "Copy-Protected" Novelties - Liquid Audio and a2b

Gerry Kearby was perhaps the first to realise the potential for a fully digitised commercial distribution system. Although RealNetworks had a 90% market share in 1995, Kearby was unimpressed with their sound quality and with his background[170] in custom audio equipment he "looked at RealAudio, and thought [he] could try come on the market as a better-than-RealAudio competitor" though he felt that made no sense as "the first law of marketing is that it is better to be first than it is to be better. The second law of marketing is if you can't be first in the market, find another market to be first in." Sensing that a digital music economy was inevitable Kearby founded Liquid Audio along with Robert Flynn and Phil Wiser as the next logical step to the online physical distribution models that had already started to appear. He secured venture Capital from Hummer Winblad[171] of $2 million dollars and convinced

[170] Kearby's background saw him work for the Grateful Dead, Jefferson Starship and George Lucas
[171] The same venture capitalists who would later invest in Napster.

Dolby Laboratories to license their AC-3 encoding technology which Liquid Audio used inside a container Liquid Audio file. Liquid Audio appropriated Dolby's superior sound reputation and emphasised their own format quality as well as copyright protection they felt was absent from competitors[172]. Liquid Audio's copyright protection was achieved through watermarking and digital signatures and was intended to stop unauthorised playback of streamed music through encrypted signatures. Copyright infringement within the niche was not yet happening on a scale noticed by the RIAA but Liquid Audio hoped that such a pre-emptive stance would show Liquid Audio were sympathetic to the practices of the incumbent socio-technical regime.

The company debuted their technology and began securing licensing details with significant but smaller music companies including IUMA. In September 1997, Capitol announced they were to use the system, the first major label to be actively involved with a compressed audio promotion since *Head First.* Duran Duran's *Electric Barbarella* was sold for $0.99 through Capitol's hollywoodandvine.com (Figure 22). Robin Bechtel[173], said at the time "selling the single via Liquid Audio is a promotional effort to increase awareness […] We are committed to using the Net to promote a wide variety of music, and making our partnership with Liquid Audio a long-term success for us, our artists and their fans" (Liquid Audio 1997). The release was significant for several reasons. It allowed Liquid Audio to demonstrate its platform could work for majors and not just independents. It brought the Liquid Audio platform to a new group of users and it successfully demonstrated that the Liquid MusicServer could allow for proper payment tracking and accounts ensuring correct mechanical and publishing royalties could be allocated as in physical distribution models.

The reaction from traditional retail was predictable if unexpected especially as Liquid Audio and Capitol involved several traditional retailers such as Tower Records (Holland 1999c). Offended that the single was available online before it was available in store several retailers reacted by pulling Duran inventory from their stores, others refused to promote the album and single. Capitol Records withdrew the download. In response, Liquid Audio opened lines of dialogue with traditional retailers as Liquid Audio wished to "complement them with an online presence…not put them out of business". As a result of the reaction subsequent licensed digital releases attempted a tie-in with traditional retail that would encourage consumers to purchase full length albums through physical stores. The successful enrolment of new actors and users in the novelty of digital music commerce was reliant therefore on traditional retailers acting as gatekeepers. The majors were unwilling to damage existing

[172] There was concern that RealNetworks' system let users "record to their hard drives".
[173] Senior director, new media, of Capitol Records

relationships for the sake of an untested and unprofitable new practice. It was not just Liquid Audio that learnt from this experience but emerging competitors.

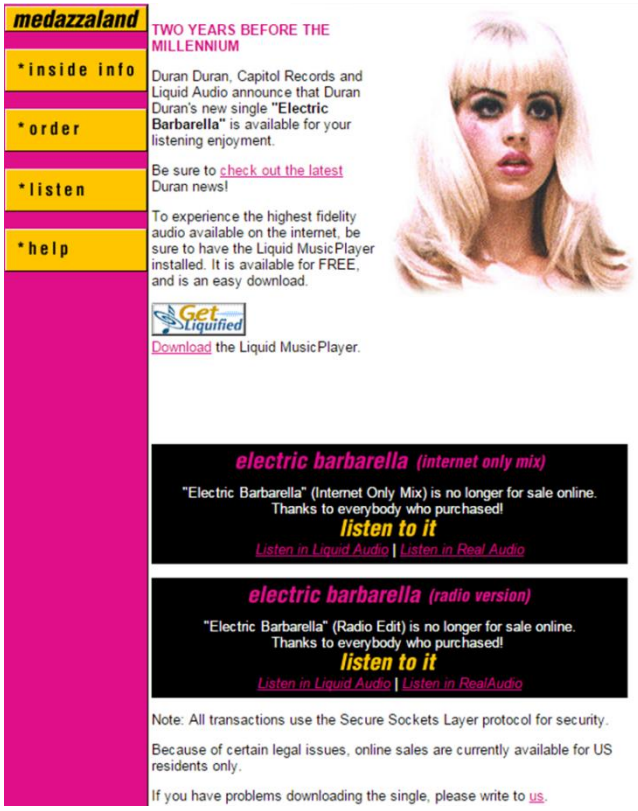


Figure 13: The hollywoodandvine.com landing page for the Duran single promotion

AT&T revealed in November 1997 that it had been working on a technology similar to that of Liquid Audio for the past two years. In a widely publicised trial, AT&T demonstrated its a2b format by releasing a live version of an album track 'Reverend Girl' by the Verve Pipe for free. The a2b trial provided details for consumers to purchase the album through traditional distribution channels. For Kevin Conroy[174] the purpose of the trial was to develop partnerships both online and offline for promotion of artists rather than in introducing a new technology. However, for Larry Miller[175] it was an opportunity to demonstrate an "integrated platform solution for the record industry to be able to securely ship music to consumers that is the best quality bit-for-bit available in the world…in such a way that copyright holders feel absolutely secure it will not hurt them but actually help them" (quoted in Jeffrey 1997a p.5).

a2b was the first major competitor to Liquid Audio in the end-to-end market and the trial had several symbolic victories over Liquid Audio. By releasing a track in the online/offline manner a2b pipped Liquid Audio to promoting a major label artist in a way that was well received by the industry, avoiding furore from traditional retailers. Although a2b was short lived[176] the sound-carrier within the a2b format was significant in terms of compression technology. AAC (Advanced Audio-Coding) was capable of better compression rates without loss of sound quality compared to the Dolby Digital compression found in the Liquid Audio format.

[174] Senior VP of BMG Entertainment North America
[175] COO of a2b
[176] Its engineers all left for different projects within the space of a few months

AAC had been declared an international standard by MPEG in April 1997 and was co-developed by several companies including AT&T, Bell Laboratories, Dolby Laboratories, Sony Corporation, Nokia and Fraunhofer. Shortly afterwards Liquid Audio announced that they would adopt the AAC standard within the Liquid Audio file as it was "widely recognized as the most technically advanced audio compression algorithm … available."

Adoption of Liquid Audio was very slow and sales poor. Playback always required the Liquid MusicPlayer™ and the catalogue contained little to no major label content and sporadic independent content. The promise that consumers would be able to burn their purchases to CD-R was slow to be realised due to incompatibilities with most CD-ROM burners[177] available. The increasing availability of free music through MP3s being shared through FTP sites (5.4.1) and rival MP3 stores, detailed in the succeeding section, satiated consumers' appetites for music without tying them to a closed and restricted system.

7.3 MP3 stores and content acquisition

The first MP3 music store Nordic Entertainment Worldwide, launched with 400 songs[178] available for 25-65 cents in March 1997 whilst Liquid Audio was still testing its technology. Nordic targeted consumers that had the ability to burn their own CDs as well as customers who wanted otherwise inaccessible content as they "planned to offer titles that would not sell in a physical medium" (quoted in Atwood 1997b p.95). Nordic, unlike other digital distributors[179], had an explicit environmental statement:

> "I don't know how many trees were cut down, or how many tons of plastic were melted to distribute Alanis Morissette's debut album, or Madonna's last multi-million seller. I do know that it was too many. Soon, with the advent of this technology, it will no longer be necessary to cut down a tree or manufacture synthetic materials to distribute music. Every song purchased now, through Nordic will not hurt the already overburdened and limited planetary resources."

Despite this awareness, focus from commentators fell on the rights of labels to distribute music digitally rather on the potential to reduce environmental harm, the novelty of approach or the apparent potential for piracy as Nordic offered no form of DRM. N2K Entertainment which intended

[177] CD-ROM drives capable of burning CD-Rs were becoming more widespread with a price point below $400 at the very end of 1996.
[178] Many of the songs featured established artists including Ike and Tina Turner's River Deep – Mountain High as well as Jimi Hendrix tracks that had yet to be released on CD.
[179] No evidence has been found which suggests other distributors were considering the environmental benefits of non-physical releases.

to sell Liquid Audio files via their e_mod site stated that they were not yet ready to charge. J.J. Rosen[180] said "we are concerned about treating the artists and publishers properly. We don't feel comfortable beginning to sell this way until all the issues are resolved, including the ability to track and account for artist royalties, mechanicals on the publishing side, and the security aspect of the transaction" (quoted in Atwood 1997b p.95).

A second store, GoodNoise, began trading in July 1998 distributing MP3s for 99 cents for individual songs or $8.99 for nine to 13 songs (Reece 1998a). Robert H. Kohn[181], laid out the company's long term aims which proved prescient "[o]ur vision is of a world which sees the inevitable shift from physical distribution to online delivery of files direct to consumers". The story of GoodNoise, which after several acquisitions would become EMusic.com indicates the problems they and other similar services had in acquiring content to sell through their platforms. Tracks on GoodNoise lacked DRM as Gene Hoffman[182] would discourage adoption. GoodNoise also formed a strategic alliance with Diamond whereby a CD of GoodNoise released MP3s was distributed with each Rio sold and in October 1998 GoodNoise announced that it had purchased Nordic Entertainment Worldwide[183] because of Nordic's access to catalogue music (Reece 1998d p.8). GoodNoise also acquired Creative Fulfilment Inc. (which owned the EMusic brand), IUMA (which they operated as a subsidiary), cductive.com and Tunes.com. The latter was to expand the reach of the website by placing links to purchases on articles published on the Tunes.com website. They also penned a deal with Rykodisc who were feeling pressure to begin digital distribution as Lars Murray[184] stated "we got to a point where we thought it was probably wiser to engage the MP3 listener and try to bring them into the fold and protect artist rights" and that the Rio was a major catalyst "once you are able to take an MP3 file away from the computer setting, it becomes a much more attractive proposition to the consumer, and it creates more demand; and if the only way you are fulfilling that demand is to have people pirate your stuff, that's not good" (quoted in Applefeld Olson 1999 p.111). From its launch to December 31st, 1999 EMusic.com had sold over 350,000 songs to over 14,000 customers and by April 2000, had sold a further 650,000 and had expanded its catalogue to 90,000 songs. On July 24th, 2000 EMusic.com launched a subscription based service recognising that "paying for single downloads … can be awkward" (Hoffman quoted in Rohde and Ferranti 2000 p.25) although they considered the subscription offering experimental so continued to offer their catalogue for sale. The many acquisitions made by EMusic.com represent a consolidation

[180] Senior VP/GM of N2K
[181] Chairman of Goodnoise.com
[182] GoodNoise's president/CEO
[183] It was also strongly rumoured that GoodNoise had attempted to purchase MP3.com for $10 million in January 1998 when the site was only just a few months old and before GoodNoise had even launched but Robertson had turned them down (Reece 1998d).
[184] The director of new media at Rykodisc

of actors who were attempting to provide legitimate music downloads online. Rykodisc, the largest of the record labels that agreed to license their tracks was still a small independent label and as such none of the major labels in the music industry were willing to license music to these legitimate online market places. The enrolment of actors from the incumbent regime was minimal as many retained the opinion that any online marketplace legitimised a novel technology that they saw as unlawful. This reluctance would slowly erode as the result of attempts by the major labels to squash online file sharing which saw them acquiring assets that allowed them to launch their own marketplaces.

7.4 Major label marketplaces

After the majors' first forays into music downloads they withdrew from offering full length tracks of their artists online. Instead, they had utilised systems such as Liquid Audio, a2b and RealAudio to allow users to stream short clips; where full length tracks were made available, they had been in the Liquid Audio or a2b formats that claimed copyright protection and control. MP3 had emerged as a controversial sound carrier offering neither of these assurances and was associated from the beginning with music pirates despite legitimate music sharing communities (6.8.2) and marketplaces (7.2) using MP3. Major label engagement with MP3 had been almost entirely negative. However, over the course of 1998 as MP3 became less obscure, a number of those involved with the majors started to re-evaluate MP3's use as a legitimate sound carrier as such the major labels' actions towards the new technology can be split into two parts.

7.4.1 Tentative dalliances – pre-Napster

The treatment of The Beastie Boys during this period is representative of the ambivalence towards MP3 within the incumbent regime. The Beastie Boys were some of the most active artists online with an established web identity and a considerable online fan base. When they had their webmaster post a copy of their single Intergalactic during its week of release as well as live versions of some album material in exchange for fan's email addresses the band were admonished by their major label contact, "we were this big band endorsing this thing the industry was trying to be united against" said Mike-D. Heller[185] noted "we need to be progressive, we want to be part of it, but at the same time, we want to be protected". Insisting that the files be put back online Mike-D commented in defiance of Capitol that "it boggles my mind that labels are freaked and afraid instead of really getting involved with what's going on as opposed to co-opting and becoming the source of it". Conroy of BMG, said at the time that having a major band like the Beastie Boys endorse MP3 files was "disappointing. It makes cleaning up the Net that much more difficult" (Shapiro 1998).

[185] An executive vice president at Capitol

When Tom Petty's management arranged with MP3.com to post "Free Girl Now" online in February 1999 it was downloaded 156,992 times despite being removed after two days because as Jim Wagner[186], was quoted as saying "we think it sets a bad precedent" (Nelson 1999). Petty's subsequent album release, Echo, unexpectedly entered the top ten lending credence to MP3 as a successful promotional tool. As a result, it paved the way for the negotiations that led to MP3.com's deal with Alanis Morrissette and her management team (5.4.8.1).

Despite Petty's success and endorsement by high profile artists, most label executives were reluctant to engage with MP3 continuing to frame it as insecure and controversial, and a tool for pirates rather than promotion. Rumours online abounded that the RIAA centralised and organised a Cartel of Condemnation against MP3 and anyone who attempted to utilise it in a positive way. Even if the RIAA as a body was not centrally organising such activity people in charge of the major labels within the incumbent regime were certainly not accepting of the new sound carrier beyond a few "marketing experiments". It was not until the successful lawsuits against MP3.com and Napster, when the incumbent actors asserted control over niche activity, that the majors began to publicly develop digital music marketplaces.

7.4.2 Launching their own marketplaces

The high-profile court cases against Napster and MP3.com had revealed without doubt that the internet had become a viable system for 'space shifting' dematerialised sound-carriers. The major labels refusal to engage with the "secure" and legal sound-carriers such as Liquid Audio and a2b early on meant that huge catalogues of music were unavailable through lawful protected channels. Post-Napster, with imitators rampant and other attempts to placate consumer demand such as SDMI a failure the majors attempted to create their own marketplaces through which consumers could lawfully obtain music online.

Two major label music services were developed: MusicNet, a joint venture announced April 2001 between AOL Time Warner, Bertelsmann (BMG) and the EMI Group backed by RealNetworks' technology, and a rival service set up by Sony and Vivendi Universal called PressPlay. MusicNet, which had a user interface that bore a strong resemblance to Napster allowed users to download and stream files in the RealAudio 8 codec[187] where as PressPlay utilised technology purchased as part of the MP3.com lawsuit. Both MusicNet and PressPlay were heavily criticised for the levels of control implemented. The DRM for both services was extreme although MusicNet which launched first was considered the most draconian, in part because PressPlay had time to respond and adapt to the

[186] Warner Bros senior vice president of sales, advertising and marketing

[187] It was based on Sony's Atrac3 which was algorithmically similar to MP3 in the way it compressed audio. Eventually the service also offered the Windows Media Audio (WMA) sound carrier also.

criticisms against MusicNet before launch. The number of files that could be downloaded or streamed were also restricted (see Table 7). MusicNet files expired after 30 days where as PressPlay files remained accessible only if the user retained their subscription. Both MusicNet and PressPlay operated as full-service subscription models accessed through affiliates.

Table 8: Subscription structure for the PressPlay service (BBC 2001)

	Basic Plan	Silver Plan	Gold Plan	Platinum Plan
Number of Streams / month	*300*	*500*	*750*	*1000*
Downloads/ month	*30*	*50*	*75*	*100*
CD burns allowed	*0*	*10*	*15*	*20*
Price/month	*$9.95*	*$14.95*	*$19.95*	*$24.95*

In the press, which spanned internet discussion forums to high profile opinion pieces in Time Magazine and the Wall Street Journal saw both services frequently conflated, confused and panned. Taylor wrote in a Time Magazine op-ed piece titled "Hitting All the Wrong Notes" questioning why anyone would be willing to put up with such restrictive services: "you would think you were downloading homeland-security documents, not N'Sync" (2002). The unlawful P2P services had no such restrictions allowing users to burn music and transfer them to their MP3 players if they so wished. Taylor also voiced his frustration, as many did, with the "incomplete selection" of music available.

There had been an ongoing tension between the two groups of majors over licensing their content to each other's ventures or from independent labels. Other technology companies such as Liquid Audio, RioPort, Listen.com and Napster[188] were also attempting to position rival services in the marketplace but complained they were having difficulty obtaining content licenses (Garrity 2001c). This had led to a bill to promote the digital music marketplace but also anti-trust investigations into the majors which had been instigated even before the services had managed to launch. Following an investigation by the European Commission, the DOJ requested information to look for evidence of collusion amongst the majors (Garrity and Holland 2001). The antitrust investigation hinged on the aggressive manner with which the majors launched the services when they had all but refused to license their catalogues to similar services effectively launching without competition.

The DOJ's concerns were based on the seemingly deliberate attempts by the majors to retain control of their copyrighted works by refusing to license their copyrighted material to anyone but themselves and by litigating against competing services or by purchasing competitors as they had done with MP3.com. Further, the DOJ considered the MusicNet and PressPlay systems of such "poor quality"

[188] The legitimate version of the service

and of a “restrictive nature” with heavy handed DRM that that they were substandard to the unlawful services they were meant to compete with (ASSISTANT ATTORNEY GENERAL R. HEWITT PATE 2003). The insinuation was that the major labels were not only attempting to retain copyright but also stifle growth of the online music market by making it some unattractive to consumers. The DOJ investigation took place over two years before ending, finding no evidence for its initial claims.

The result of the antitrust investigation was that both MusicNet and PressPlay became less restrictive but more importantly the majors also began licensing their catalogues to each other and other services although these deals still took time to materialise (Wilde-Mathews 2002). MusicNet, PressPlay and other services such as EMusic went through further acquisitions but despite middling subscriber numbers (MusicNet have 500,000 subscribers) were all running at considerable losses.

The majors’ implementation of online music services had very limited success; they were poorly received by consumers, critics and legislators. Compared to the P2P networks they were intended to rival, the legitimate services offered by the majors did little to reconfigure user behaviour in a way that would see them switch from MP3 despite using systems that were technologically similar. PressPlay and MusicNet lacked the momentum of MP3 in part because MP3 had started to be supported by hardware devices outside of the computer. Portable players (5.4.9) and the burning of CDs were supporting technologies that eased the user in the transition of dematerialised sound-carriers. The subscription services, whereby music was little more than rented, removed this physicality almost entirely and presented an unease amongst the music community where they were aware that they were paying for something they would never own.

7.5 Windows of opportunity

The result of the majors’ failed attempt to launch their own DRM-hobbled marketplaces had significant influence on the socio-technical niche. The niche itself had been legitimised through the purchase of Emusic.com and although too late for companies like Liquid Audio whose sales had collapsed, the involvement of the European Commission, the DOJ and legislators in investigating anti-trust issues surrounding the major-labels’ marketplaces had brought forward windows of opportunity for the socio-technical niche to challenge the incumbent's distribution model with access to much of its content for the first time.

7.5.1 Legal pressure results in content parity

Under pressure from the DOJ the major labels began licensing their copyrighted material. Rhapsody, a service launched by Listen.com utilising technology they had acquired from Tuneto.com called Aladdin was launched on December 3rd, 2001. Rhapsody was one of the services that benefited from the DOJ intervention (Graves 2001). Although the initial catalogue offering on Rhapsody consisted of independent record labels because of the congressional concerns of the majors’ digital distribution

efforts (7.3.2) along with their existing relationship with the majors which included financial backing, within a month Listen.com could secure major label content for Rhapsody.

Listen.com was the first company not owned by a major to achieve content parity with MusicNet and Pressplay when it announced deals with BMG, Sony and EMI adding Warner Music in February 2002 and Universal in July 2002 (Graves and Mullens 2002). Listen.com CEO Sean Ryan said "what we're seeing in general is [the majors] viewing [licensing] as a way to make money, as a way to kick-start their business again – not in huge numbers but enough to make a difference to them" (quoted in Garrity 2002 p.54). Fred Ehrlich[189], said of the deal "it is a priority for us to make our music available to fans in as many legal outlets as possible, and legitimate services such as Rhapsody are very important in that effort" (quoted in Garrity 2002 p.54). Rhapsody 2.0 launched at the end of October 2002 brought the ability for users to purchase individual song files for $0.99 along with CD-burning capabilities[190] (Graves 2002). As of November 13th, 2002, EMI extended their existing licenses with several distributors which allowed the transfer of purchased songs to portable devices, the first major label to do so.

7.5.2 A la carte starts to breakthrough

As RealNetworks announced that it was to acquire Listen.com, Apple announced a significant update to iTunes. The software would now feature an integrated music store. The iTunes Music Store was initially only available to Mac users, as PC based iPod users still used the MusicMatch software. Apple benefitted from the licensing agreements Listen.com had established along with the majors' new-found willingness to license their catalogues and had access to all five majors from launch. Unusually, compared to nearly all other services that came before, they did not first build up a catalogue of independent labels[191]. Songs could be purchased for $0.99 replicating the a la carte model that had started to appear on other services for major label content and had first emerged with Nordic and GoodNoise. In the first week Apple sold 1 million songs through iTunes. 45% of all songs had been bought as part of an album and 90% of sales had been one click sales which meant users had stored their credit card details on the service (Garrity and Morris 2003).

[189] Sony's president of new technology and business development

[190] Prior to this, some content could be burnt in the same way as the PressPlay service and was limited to 10 tracks per month.

[191] The independents came later; on June 5th at Apple's Cupertino headquarters representatives of between 80 to 100 independent labels were given a two-and-a-half-hour presentation on iTunes. The labels were impressed and although unlike Emusic.com and Liquid Audio there was no upfront payment for licensing their content the iTunes system and its initial sales figures were liked enough for many independents to sign up.

The major's saw the iTunes Music Store as an experiment as it was only available to a small market of Mac users[192]. Compared to other services' restrictive DRM[193], Apple's iTunes Music Store was rather more liberal. iTunes had no restrictions on the number of times a user could burn a purchased song to a CD for example. It also allowed a user to authorise up to three computers that could access and download the same songs. The songs were sold in the AAC lossy compression format coupled with a DRM restriction known as FairPlay[194].

FairPlay was based on a purpose-built DRM solution developed by VeriDisc in 2000 and acquired by Apple. Whenever a song was purchased from the iTunes Music Store a random user key was generated and stored on Apple's servers and in the iTunes database. The key was required to receive and decrypt the master key and was necessary to decrypt the audio content. These keys were also transferred to the iPod which had its own encrypted key repository (Maximum PC 2004). As a result, only the iPod and no other portable MP3 player could play iTunes' downloaded content.

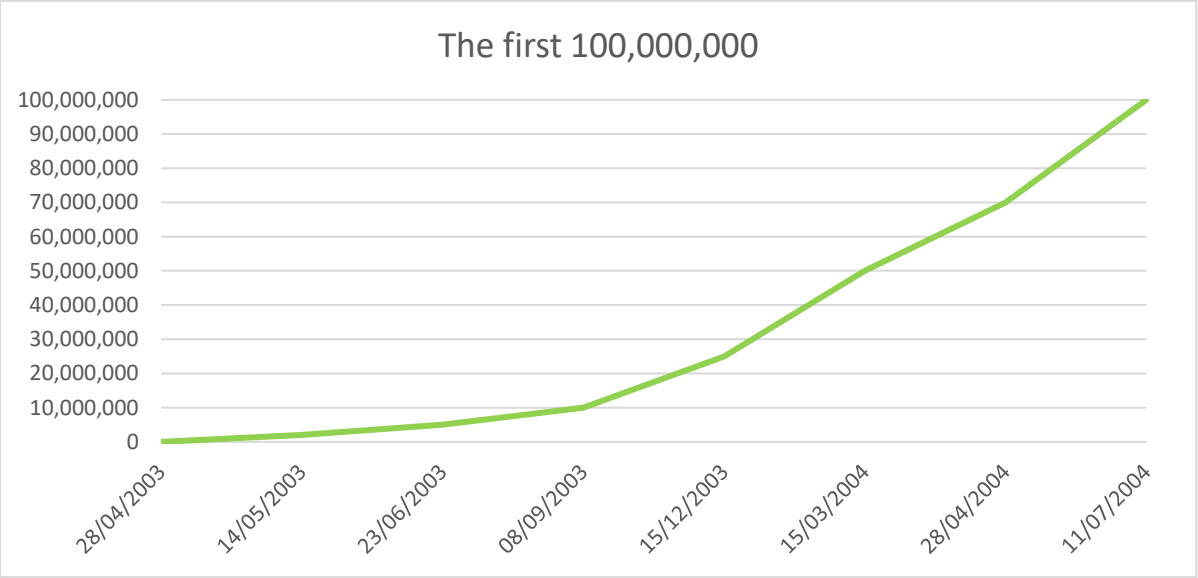


Figure 23: iTunes song sales between launch and the first one hundred million songs sold (Karp 2014).

Apple launched iTunes with the iTunes Music Store for Windows users on October 16th, 2003. The catalogue of a la carte offerings consisted of some 400,000 tracks from both major and independent labels. Thirteen million songs (Figure 22) had been purchased in the six months since its initial launch although analysts were keen to point out this paled against the numbers of files being shared illegally

[192] Strauss of the New York Times estimated that "Less than 1 percent of the country's home computers are Macintoshes that are compatible with the iTunes Music Store, and only a fraction of those have a broadband connection to the Internet" (2003)
[193] Except EMusic.com which sold open MP3s but still lacked a lot of major label content
[194] Older iPods had a firmware update to be able to play the files.

on services like KaZaa (5.4.8.3) (Holland and Garrity 2003). One million copies of iTunes for windows were downloaded in the first three and a half days and 1 million songs were downloaded in the same period.

When Napster 2.0[195] launched at the end of October 2003 Apple issued a special press release just to point out that although Napster sold 300,000 songs it had sold 1.5 million songs during the same period and that it held 80 percent of the market-share for legally purchased downloads that week. The iTunes Music Store became available in the United Kingdom, France and Germany in June 2004 after further negotiations with labels to secure content in the different territories and was available to the rest of Europe before the end of the year. On July 12th Apple announced that by purchasing Somersault (Dangermouse remix) by Zero 7 Kevin Britten had downloaded the 100 millionth song.

7.5.3 Apple's Walled Garden

Apple's refusal to license its FairPlay system became increasingly controversial amongst its competitors as it locked out rival digital stores who used alternative DRM. RealNetworks were particularly vocal about the inability of their users to transfer files from its recently launched RealPlayer Music Store[196] onto the iPod. After Apple rebuffed overtures by RealNetworks' CEO Rob Glaser to "commit to universal use, interoperability and consumer convenience" (Garrity 2004 p.8) RealNetworks developed Harmony a technology that allowed tracks from the RealPlayer Music Store, which used RealNetworks' proprietary Helix DRM, to be played on a huge number of portable MP3 players including the iPod[197]. Apple responded by accusing RealNetworks of adopting "the tactics and ethics of a hacker to break into the iPod" and that they "strongly caution Real and their customers that when we update out iPod software from time to time, it is highly likely that Real's Harmony technology will cease to work with current iPod features" (quoted in Flynn 2004; quoted in Banerjee 2004 p.78).

As part of the Harmony promotion, which RealNetworks distributed freely as part of an update RealPlayer 10.5, the company announced its Freedom of Choice campaign reducing prices across its music store catalogue of 630,000 tracks. Songs could be purchased for $0.49 whilst albums were on sale for $4.99[198]. They also encouraged users to sign a petition under the banner "Hey Apple! Don't

[195] Built by Roxio from the bankrupt assets of Napster and the PressPlay service which Roxio had acquired from Universal and Sony Music in May 2003.
[196] A download only service developed as an update to its popular player software and to complement its streaming Rhapsody service which received an update within a few months to also work with Harmony and therefore the iPod for downloaded tracks.
[197] Harmony did not allow protected music meant for one device to work on another however, so iTunes Music Store tracks could not be played on the Samsung Yepp portable MP3 players for example.
[198] The lowest prices yet offered by a major download store.

Break My iPod!" (Anon 2004). The promotion failed to attract significant numbers of new users to RealNetworks and the campaign backfired with users calling RealNetworks disingenuous for attacking Apple; RealNetworks share price dropped as a result and Apple continued to ignore the request for interoperability between the various DRM systems and the portable MP3 players instead announcing it was the first digital store to have over 1 million tracks in its catalogue. New models of iPod appeared that did not work with Harmony and Apple forced through an update to all older models of iPod that stopped Harmony functioning altogether. Despite claims to the contrary at the time RealNetworks' Harmony never reappeared[199].

The iTunes update also stopped users being able to transfer songs back from users' iPods into the iTunes libraries. This angered some and combined with the Harmony issue resulted in an anti-trust lawsuit against Apple that accused Apple of using the update to secure a monopoly over the digital music market. The case took ten years to build and included testimony recorded by Jobs just six months before he died. In his deposition[200] Jobs said they had to secure iTunes against all hacks, so as not to violate contracts with the majors which could have resulted in them withholding music and in the process of fixing the hacks "it might screw up the Real technology anyway, as collateral damage" (quoted in Chen 2014)[201].

By December 2004 Apple had established roughly 70% of the total market share for digital music downloads in North America and 80% in the UK by September 2005 offering 1.7 million songs in its catalogue.

On February 6th, 2007, Jobs published an open letter on the Apple website titled Thoughts on Music. In it Jobs addressed the DRM system and how it was implemented and maintained at the behest of the majors and although Apple had managed to get the most liberal rights usages from the labels at the time Jobs suggested three possible paths for the future of DRM. The first was to continue the

[199] In their SEC filed for the year ending December 31st 2004, RealNetworks noted that they were uncertain of the acceptance of Harmony amongst consumers and that there was a risk that Apple would attempt to break the interoperability of Harmony and that this "could harm our business and reputation, or we may be forced to incur additional development costs to refine Harmony to make it interoperate again. Although we believe our Harmony technology is legal, there is no assurance that a court would agree with our position. If Apple decides to commence litigation against us in order to prevent interoperation with its products, we may be forced to spend money defending their legal challenge, which could harm our operating results." (RealNetworks Inc. 2004).

[200] During his 2011 deposition, when asked if he was familiar with RealNetworks Jobs displayed some of the edge he was known for asking "Do they still exist?"

[201] The class action anti-trust suit which was eventually resolved in 2014 when the eight members of the federal jury in California took just three hours to unanimously decide that the frequent iTunes updates for iPods legitimately improved the devices, and were not used to block competitors and reduce consumers' choices (Yuhas 2014)

current course with iTunes selling songs that only played on the iPod, Microsoft Zune Store selling songs that only played on the Zune and Sony Connect selling songs that only played on Sony's players. The second alternative was for Apple to license FairPlay as RealNetworks had asked it to do to achieve interoperability between the different players and music stores. Apple were reluctant to do this as it would involve disclosing "some of its secrets to many people in many companies" (Jobs 2007). The third alternative was to abolish DRM. Jobs pointed out that 2 billion DRM-protected songs were sold in 2006 compared to 20 billion songs sold free of DRM "on CDs by the music companies themselves"[202]. Jobs said DRM did not halt music piracy because as no DRM system was developed for CD-DAs pirates ripped them and uploaded them to the internet, therefore distributing digital music with DRM was essentially futile. Jobs added that the labels should be convinced "to license their music to Apple and others DRM-free will create a truly interoperable music marketplace" and that "Apple [would] embrace this wholeheartedly" (Jobs 2007).

In April 2007, EMI and Apple announced that it would begin selling DRM-free tracks with an increased bit-rate up to 256kbps through iTunes Plus for $1.29[203]. Apple expanded the iTunes Plus service in September 2007 to include several key independents offering their tracks DRM-free and at the increased bit rate. The price of all DRM-Free tracks was lowered to $0.99 and covered over 2 million titles becoming the largest catalogue of DRM-free music available. In February 2008, Apple announced that it had over taken Best Buy and Walmart to become the largest music retailer in the US (Neumayr and Roth 2008a). The iTunes Store had an 18% market share[204] of all music sales and due to the size of the of the US market, iTunes had become the largest music retailer in the world (Neumayr and Roth 2008b).

7.5.4 Conflict resolution between the majors and their biggest customer

In January 2009 Apple announced that the iTunes Store catalogue had grown to 10 million tracks and that 8 million of them were to be made available as DRM-free AAC files almost immediately with Apple promising the remaining 20% would be available by March covering all four majors. Apple also introduced three tiered prices $0.69, $0.99 and $1.29[205]. The introduction of tiered pricing was something the majors had pushed for since the introduction of the iTunes Music Store. Apple and Jobs had been reluctant to vary single track prices from the $0.99 position because of the simplicity and consistency it created. The labels however were interested in being able to vary prices based on

[202] It was also estimated that 15 billion tracks were shared on illegal file-sharing sites collectively in 2006 (Bruno 2007)
[203] Those who already owned EMI tracks could purchase the upgraded tracks for the additional $0.30
[204] Rhapsody its closest digital only rival had 1%
[205] £0.59, £0.79 and £0.99 in the UK

demand. Conflict between iTunes and two of the majors was apparent when iTunes Japan[206] launched with key artists such as Beyoncé missing from the Sony and Warner catalogues; in the summer of 2007 Universal Music Group announced it would not renew its iTunes contract if Apple remained firm on fixed pricing (Carr 2007).

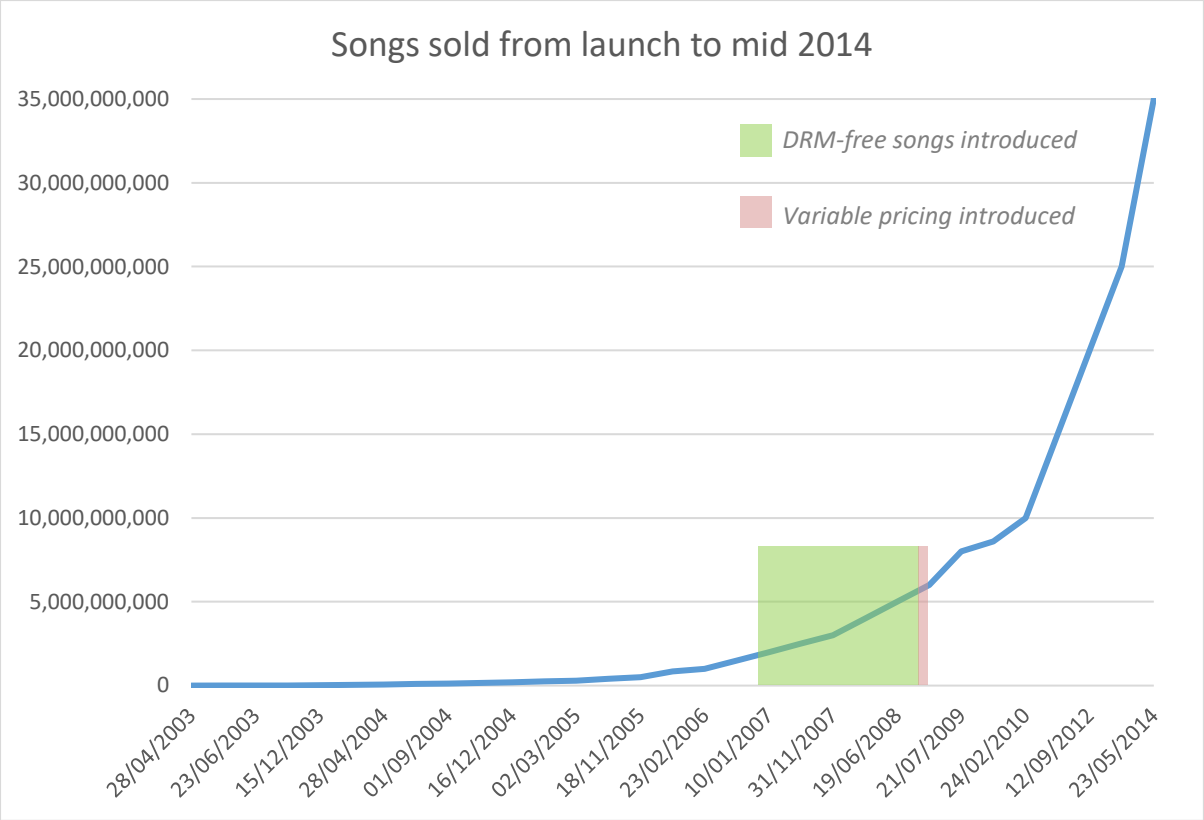


Figure 24: Apple's total iTunes Store sales figures

Andrew Lack[207] discussed the issue that some music executives had with Apple using their music to sell Apple's iPods creating two revenue streams for Apple but only one for the music industry (Leeds 2005). The acrimonious relationship between Apple and the majors, some commentators suggested, resulted in the compromise on DRM-free tracks introduced at the same time as tiered pricing (Van Buskirk 2008). Other commentators however suggested that Apple accepted tiered pricing as a response to tiered pricing existing already in the marketplace and that they believed interoperability could spur a new round of growth (Christman 2009). The Amazon Music store, which launched to the public in September 2007, had DRM-free MP3s from all four majors available by January 2008. Universal Music Group had announced that it would license its music back when the service first

[206] Japan is the world's second largest music market
[207] Chief Executive of Sony BMG

launched along with licensing it to Wal-Mart and RealNetworks among others, all of which had variable pricing. Several commentators reported that music executives allowed these rival services access to their catalogues without the DRM restrictions in order to strengthen them, diminishing Apple's advantage and therefore its negotiating power in maintaining $0.99 position (Leeds 2007; Reisinger 2007)[208].

Some of the majors priced all their catalogue at the $1.29 price point for "super star" acts such as Led Zeppelin which saw sales dampened. Through February 28th, 2010 the band's year to date U.S. sales had been 280,000, down 42% from 482,000 the year before. Several factors were touted as being responsible for the flattening sales growth. The introduction of the three tiered system may have put customers off purchasing tracks outside of the top 100 singles[209], the market was maturing and so there were fewer new customers to purchase bands like Led Zeppelin and there had also been an 8% year on year decline in iPod sales (Christman 2010). Others pointed out that the rise in streaming services may also be responsible (7.5). Sales growth began declining in 2013 for the first time since the store opened with track sales falling 5.7%. This decline has continued despite the iTunes store remaining the largest music retailer in the world.

In 2013, although the 25 billionth song was sold in February, digital sales declined for the first time since the iTunes store opened. Track sales fell 5.7% from 1.34 billion units to 1.26 billion units; digital album sales which had been selling more strongly as a result of tiered pricing and the introduction of the iTunes LP[210] in 2009 also declined by 0.1% to 117.6 million units from 117.7 million (Christman 2014). Whilst the iTunes Store still retained by far the greatest market share of digital retailers, Apple announced that it was launching a new music streaming service Apple Music on June 30th, 2015. Streaming music, which was always considered the poor-quality relation useful initially for talk radio and not much else had been over-shadowed by the rise of the iTunes Music store, but Rhapsody had been joined by several other services in the interim period many of which changed the way consumers interacted with music. Increased bandwidth on convergent mobile phones had also made such services portable for the first time and consumers had started to gravitate towards the different streaming models to the detriment of paid for download stores.

[208] The initial effect of tiered pricing was to reduce the sales of the 33 songs in the top 100 priced at $1.29 but increase the overall revenue although as there is a natural ebb and flow of song popularity it was difficult to ascertain the exact effect. Peoples estimated however that sales fell by 6.9% stating that songs would have to sell 23.3% fewer tracks to reduce revenue (Peoples 2009).

[209] The top 100 had remained largely unaffected by the increased prices

[210] An enhanced digital download that included an additional multimedia bundle as well as the music for an increased price typically around $17.

7.6 Streaming services

Streaming services had appeared early in the development of the niche but they were always inferior in terms of sound quality to services that offered downloads (see 6.1). MP3.com's my.mp3.com service was the first large scale attempt to monetise music streams but with the technology purchased by Vivendi Universal and used in MusicNet the technology failed to flourish due to the restrictive DRM which met few users were willing to engage with it. Other new services appeared around this time which included listen.com's Rhapsody. Prior to the iTunes music store launch Rhapsody had 60,000 artists, streamed 3,000,000 songs a day and was the number one rated digital music service[211]. Webcasters and services like Rhapsody represented the two models of streaming that have continued to be developed since: non-interactive streaming and interactive streaming. Such services utilised existing technology but adapted them still further often marrying them to new innovations that modified user practices.

7.6.1 Non-interactive streaming

The proliferation of radio online followed a fit-stretch pattern whereby it was initially handicapped by the confines of the long-established radio regime that stifled additional innovation. Despite essentially being used as just another method of carrying a radio signal the potential of internet on the radio began to stretch out with innovative approaches fixing perceived flaws.

One long standing problem of radio was "bad music"[212]. Pandora, offered personalised radio stations that allowed users to "skip" the tracks they did not want to hear. By submitting an artist's name or a song as a "seed" Pandora creates a radio station of songs. Users could listen to 10 hours of music before having to subscribe so many created multiple accounts with different email addresses which led Pandora to develop a free ad-supported model whilst maintaining an ad free subscription service. The service proved popular with users who had become accustomed to accessing music without having to pay for it.

Pandora's initial ad supported model was workable because of the low rate of royalty paid but the issues of royalties was something that affected all non-interactive streaming services and represented years of arbitration with the RIAA's SoundExchange. Radio broadcasters in America pay no performance fee to record labels, only performing right societies, but Webcasters who lacked the lobbying power[213] of the National Association of Broadcasters fell within the RIAA's control.

[211] Although Rhapsody offered a free tier it was predominantly a paid for service.

[212] Whereby a radio station might play a song that the listener did not like and was un able to do anything about it save for switching stations.

[213] In 1971, Congress passed the Sound Recordings Amendment which altered federal copyright protection to grant protection for reproductions of sound recordings in an attempt to restrict the growing bootleg industry.

Webcasters too were initially unlicensed but the DMCA mandated that internet broadcasters and record labels create a licensing system for webcasters wishing to play music that was under copyright on the internet.

In developments that mirrored the restrictive legislation put in place to control the sharing of copyrighted sounder carriers online the RIAA developed SoundExchange to collect and distribute U.S. performance revenue for non-interactive digital performance royalties launching it at the end of 2000. The distinction between interactive and non-interactive services was critical for the development of many innovative services. The distinction between service types was critical as to the amount paid which led to the Digital Media Association (DiMA)[214] to petition the Copyright Office in April 2000 seeking to determine if a user influenced webcast was interactive or non-interactive. At the same time, the U.S. Copyright Office ruled that simulcasts were also eligible to pay fees[215] which saw the unlikely allying of broadcast radio with non-interactive streaming services against SoundExchange.

In June 2001, Rep. Rick Boucher and Rep. Chris Cannon spoke out against the RIAA for being anti-competitive in response to the RIAA suing several services[216]. Cannon said:

> "Unfortunately, the DMCA left some questions unanswered, and the result of that ambiguity is litigation. It appears to me that the RIAA is resorting to lawsuits to protect their oligopoly, instead of embracing competition and the future of music distribution. These types of lawsuits highlight the need for Congress to clarify certain aspects of the Copyright Act" (quoted in Holland 2001a p.108).

In February 2002, the Copyright Arbitration Royalty Panel handed down its suggested rates. Both the RIAA and the DiMA affiliated Webcasters appealed the rates judgement, with Webcasters claiming they were unable to afford the rates, especially as they were retroactively payable to the introduction of the DMCA in 1998. On July 28th, Boucher and 11 bipartisan co-sponsors introduced legislation that passed with a unanimous vote in the house after being amended which covered small Webcasters up

---

Congress upheld radio's decades old pay nothing for play relationship as over-the-air broadcasters lobbied and successfully argued that the record industry benefitted from the free mass audience exposure.

[214] DiMA was established in June 1998. Its charter members were a2b music, broadcast.com, CDnow, ENSO Audio Imaging, Liquid Audio, RealNetworks and TCI Music. Future members would also include MP3.com whereas in 2015 its members were Amazon.com, Apple, Live365, Microsoft, Pandora, RealNetworks/Rhapsody, Slacker, Sony and YouTube

[215] BRS Media estimated that of the 4398 radio stations streaming as of November 2000, 451 were internet only (Saxe 2000).

[216] On 8th June the RIAA sued file-sharing service Aimster as well as Launch Media, Listen.com MTVi Group (owned by Viacom) and ACT Radio in a separate action and followed on from the RIAA's successful infringement suits against MP3.com, Scour and Napster although DMCA provisions were not applicable in the cases against Aimster, Napster of Scour.

to $1 million and passed in the Senate November 15th, 2002. Although the smaller Webcasters feared they would have been forced out of business the RIAA's and SoundExchange executive director John Simson, called the bill misguided saying that Congress should not be legislating "so that Webcasters can maintain business models that have not proved themselves able to succeed in the free market" (quoted in Holland 2002b p.3). Congress' Small Webcaster Settlement Act created a time limited space for novelties to develop; Simson's comments showed that the RIAA found such a development to be unpalatable. Again, the RIAA sought to put itself in a position of dominance over developments within niches. When the act expired in 2005, many ad-based Webcasters services became untenable[217] which once again stifled technological innovation within the niche.

The Webcasters once again sought to improve their situation and launched a campaign called SaveNetRadio organised by DiMA. It gained support from key actors such as influential consumers, decision makers, legislators and even artists themselves. By May 2007 over 5,000 artists had sent letters to their congressional representatives. In July 2007, DiMA struck a deal that capped the $500 minimum fee per channel to $50,000 for DiMA members which included Pandora in return for more detailed reporting of the music that they played. Congress passed the Webcaster Settlement Act of 2008 to encourage negotiation between all parties on the rates. The rates set were the same as those agreed to by the NAB earlier the same year for simulcasts which allowed for a more competitive playing field between the older radio regime's foray onto the internet and more innovative nascent services.

7.6.2 Interactive Streaming Services

The freemium model emerged in Europe where restrictions were reduced in favour of supporting the services through advertising or by subscribing to better feature premium tiers. Elsewhere several services emerged that offered on-demand content for free as a way of drawing users to the sites in a way reminiscent of the early portal sites like Yahoo! and AOL. Two of these sites in particular are responsible for enrolling many users in the on-demand for free user practice and are detailed here because of their ubiquity.

[217] The CRB rejected the revenue based model for five reasons: 1) services pay more royalties when they stream more music with a per stream metric as revenue can be influenced by other factors and so did no represent the intrinsic value of the performance, 2) Neither the SoundExchange nor DiMA revenue based models increased royalty payments in direct proportion to revenue increase, 3) percentage of revenue models are complicated when services offer more than just music content, 4) no party offered an unambiguous definition of revenue that properly related to the royalty of performance and 5) a revenue based metric created auditing problems depending on how revenue is allocated where as a per-stream payment is comparatively straightforward (Butler 2007)

MySpace.com, launched in 2003, was a social network. Users and artists flocked to the site and it gained a reputation as *the* indie music portal. Users could stream music from the site for free that had been uploaded and shared by artists. The artists benefited from the promotion of music to MySpace's built in audience of millions. By July 2005, MySpace featured over 350,000 such band profiles which included many major label artists. As the marketing departments for the labels started to see the potential of MySpace promotions became more elaborate. Artists, not fully engaged with online promotion of their music, hosted "listening parties" on the site whereby their entire album was available to stream before the albums were released[218] utilising the service in a way few had done with IUMA and MP3.com.

Like MySpace, YouTube which launched in November 2005, became a service utilised by thousands of bands for promoting their music. Many users submitted content they did not have permission to upload, despite confirming to YouTube that they did. At this point in 2006, YouTube licensed no content and removed it upon request under the DMCA but both MySpace and YouTube concerned the labels because of the copyright infringing actions of their users. Many thousands of music videos were already on YouTube without the approval of the record labels. In August 2006, YouTube announced that it had entered talks with labels to license thousands of music videos for the service: "what we really want to do is in six to 12 months, maybe 18 months, is to have every music video ever created up on YouTube" co-founder Steven Chen said and that it was YouTube's intention to offer them to users in a way that was different from pay-per-view or download services (quoted in Walsh 2006b p.8).

In September 2006 Doug Morris[219] said during an investors' conference that "the poster child for [for user-generated media] sites are MySpace and YouTube. These new businesses are copyright infringers and owe us tens of millions of dollars…How we deal with these companies will be revealed shortly" (quoted in Walsh 2006 p.8) implying that YouTube would have to enter into a settlement to cover past infringement before any future deal could be struck (Garrity 2006a). At the end of September, Warner Music announced that it had reached a licensing deal with YouTube making its existing catalogue of videos available on YouTube as they had already been made available through AOL and Yahoo's music portals. The licensing agreement also covered user generated videos featuring Warner Music songs. The deal with Warner Music formed the model for deals with Universal and Sony BMG just weeks later

[218] MySpace also had a significant impact on the way unsigned artists were discovered. Unsigned acts could now point A&R people to their MySpace which not only contained examples of their music (replacing the need to send "demo-tapes/CDs") but could also gauge their potential due to certain metrics such as play counts, friend numbers and comments all being available.

[219] Universal Chief executive

supported by the announcement that Google was to purchase YouTube for $1.65 billion in stock. As part of the licensing deals the labels also took minority stakes in YouTube. At the time of Google's acquisition YouTube was delivering 21 million Video-On-Demand streams per day of which music was a leading sub-set[220] (Garrity 2006b). MySpace suffered from the control of music and users migrated to other services and social networks such as Facebook. YouTube remains the world's largest music streaming service that continues to outperform newer subscription models, particularly those that are ad-supported or require a subscription.

Spotify is the leading example of a service that offers both an ad-supported freemium model as well as a subscription model for streaming music across a range of devices. It launched in 2008 operating an invitation only service initially. Invitation only models of recruitment promote services through a sense of exclusivity which creates a false sense of demand for a product. Spotify exploited this to both attract new users and to allow scaling of its service. Until 2014 Spotify relied on P2P technology[221] like that of the Napster imitators to share the load of streaming high volumes of music. The difficulty Spotify, and other similar services, has faced is in converting users who listen to the advert supported free tiers into subscription customers. In 2015 only 20 million of Spotify's 75 million users were active subscribers. Commentators have noted that this reluctance to start paying for the services comes from years of being able to access on-demand content for free and that a few advertisements for the privilege does not seem to bother most people (Dredge 2015). In 2014, there were 41 million paid subscriptions across all services, increased from 8 million in 2010; the number of streams in 2014 totalled 164 billion up from 106 billion in 2013. Apple Music launched a rival service in June 2015 which indicates how disruptive streaming had become to the download model of consumption. The fact that Apple, the world's largest music retailer felt compelled to launch its own streaming service serves as an indicator as to which why they feel consumers are heading in terms of music consumption. However, Apple allegedly encouraged record labels to remove their content from the free, ad-supported models of competing service such as Spotify to drive adoption of their new service (Kafka 2015). This tactic is similar to the collusion between labels in establishing their own download services as a way of mitigating the impacts of technologies that the music industry sees as detrimental to their bottom line and represents the ongoing control that the music industry attempts to exert to reassert control of innovation.

[220] Yahoo was averaging 350 million music video streams per month

[221] Specifically, Spotify used a form of bit-torrent technology. One of the lead developers at Spotify had been Ludvig Strigeus, the original creator of the BitTorrent client uTorrent and Daniel Ek, founder of Spotify had been uTorrent's CEO. Spotify had turned millions of users into legal file-sharers without them knowing and with the music industries blessing.

Streaming Services represent a continuation of a user practice developed in the early days of music file sharing and seems to be driven by consumer desires more so than any other actor. Early attempts to control the non-interactive services were successful in so much as the record industry could monetise the niche and through this process of monetisation legitimised “free music” for the first time. This legitimisation preferable to music piracy. However, the restrictions put in place stifled innovation of non-interactive streaming services. Interactive streaming services are a refinement of both the technology of the late 1990s and the user practices that were established. The ability to access targeted music for free is a major driver to the success of services like Spotify. As data transfer speeds improved services such as Spotify could fulfil the promise of earlier services whose offering had always suffered in terms of quality. Spotify could exploit the ongoing piracy and subsequent drop in album sales to provide an innovative response that could monetise user practices that had been detrimental to the music industry. However, as had been the case with the iTunes download market the record labels once again attempted to exert control of content licensing suggesting that the music industry tolerates such innovation until such time that it can impose restrictions and exert control once more.

7.7 Summary

The difficulty faced by the early online market places was both in acquiring content to sell and in demonstrating the robustness of their offerings as being of equal value to their physical counterparts. The major labels did not wish to engage with these nascent markets for fear of legitimising dematerialised sound-carriers and as discussed, attempts to do so were widely condemned by the RIAA and other labels. This meant that the legitimate market places instead licensed music from smaller labels which allowed them to at least show the value of legitimate online music marketplaces to consumers. With the major labels via the RIAA having won successful law suits against both MP3.com and Napster, and with other unlawful means of online distribution still rampant the major labels used the newly acquired technology to launch their own online market places which were heavily restricted and proved unfavourable with consumers who did not wish to use them. With the threat of congressional interference however, caused by the continued refusal to license content to third parties, the major labels began to license content to other online market places which finally allowed for content parity and the enrolment of new actors. Chief amongst those was the technology company Apple whose iPod had already proved popular as an MP3 player. They launched the a la carte iTunes service for Mac users and subsequently for Windows users which saw sales explode and positioned them as market leader. Apple’s success in this area took a great deal of control away from the content providers who were only able to reassert control through the enrolment of rival service by offering different price point deals to weaken Apple’s dominance. In doing so, consumer confidence

was affected, and this provided a window of opportunity for streaming technologies such as Spotify and Pandora who also acquired users who had hitherto continued obtaining music unlawfully.

What is notable about the online market places is seemingly how unaware the actors were of the potential resource implications of their decisions. Outside of Nordic, the other record labels and online marketplaces did not produce any kind of explicit environmental statements that addressed or acknowledged the environment in their decision making. Instead, the decisions made seem to have been responses to other stimuli as made explicit for the different actor groups identified through chapters 5 – 7.

8 Dematerialising systems

8.1 Introduction

The previous three chapters detailed the socio-technical history of the music industry with a focus on the way people listen to music from the 1980s to the 2010s. What became clear is that music consumption continues to be multifaceted with no one consumption model. Even though the CD became dominant in the mid-1990s other consumption models continued to exist, such as the cassette, and new models began to emerge. The result is that today music continues to be consumed in several ways that frequently overlap with one another and are frequently context dependent. How long this may continue is unclear, although it is doubtful any one consumption model will ever truly dominate. What has occurred however, is the coming together of very different technologies with varied user practices into single pieces of hardware. These convergent technologies represent a somewhat new approach to music consumption wherein new driving forces steer consumers to make consumption decisions that music consumption alone does not dictate.

This chapter explores these complicated usage patterns further by considering the resource use of the different consumption models identified during the historical narrative of the previous chapter. It does so by employing the MIPS methodology as discussed in chapter 3.5.3. In taking the bills of material for different pieces of hardware and applying the MIPS methodology it was possible to ascertain the resource backpacks for each. This chapter explores several listening scenarios based on these resource backpacks and the associated service units. The scenarios were developed in such a way as to create a worst-case scenario in which the sole purpose of the hardware is to play music and a typical use scenario informed by both the historical narrative and additional literature on music consumption. The scenarios rely on simplified patterns of consumption by necessity forming three over-arching consumption types: physical product, downloading and streaming. The physical product scenario considers the resource demand of CDs and Hi-Fi hardware. The downloading and streaming scenarios both consider the use of PCs and smartphones. Both PCs and smartphones are convergent technologies which bring together otherwise disparate functionalities such as the ability to word process and listen to music or take photographs and talk on the phone respectively.

The following section develops and analyses the scenarios. Subsequently the consequences of convergence are explored and the implications this has for analysing socio-technical transitions from a resource usage perspective. Further, the use of methodologies such as MIPS are discussed in relation to convergence and complex socio-technical transitions. The chapter concludes with a discussion about actor influence on transition pathways. The more complex tables used to derive the MIPS and MIPLS can be found in the Annex. In establishing illustrative resource usage this chapter develops the basis for claims of dematerialisation. The subsequent chapter then analyses and defines the actor

groups that influenced the transitions which had an impact on resource use and considers whether the resource reductions were in turn a source of influence on the actor groups.

8.2 The scenarios and MIPLS

The MIPS methodology allows for consistency between different scenarios using service units. Two types of service unit were developed and utilised here which allow for comparisons to be made between the different modes of consumption addressed in the scenarios. The delivery service unit is 56 minutes of music whilst the consumption service unit is a device capable of playing that 56 minutes of music. As detailed in the methodology chapter, 56 minutes was based on albums published by EMI in the year that Türk *et al.* (2003) conducted their study. The 56 minutes was retained for ease of comparison between their research and the research here. For the scenarios developed here two delivery service units are considered to form one listening session. The basis for this rationale was informed by a study by Edison Research in which American users kept a 24-hour listening diary that showed that the average consumer listens to four hours of music a day of which AM/FM radio makes up 50%. Therefore, the assumption is made that listeners spend the other two hours listening to music from another source, this two-hour figure was amended to 2 x 56 minutes rather than the full two hours to allow for consistency between the service and delivery units as well as between the different scenarios. The following sections outline the MIPLS for each of the different consumption methods: physical products, downloads and streaming before comparing them to each other and drawing conclusions about the material intensity of dematerialised music consumption.

8.2.1 Scenario 1: Physical product

For scenario one it is assumed CDs are purchased to be listened to on a Hi-Fi. This pattern of consumption has existed since the launch of the CD and remains a popular way of listening to music. It is also analogous to the consumption of other physical media such as vinyl records and cassette tapes whereby the physical sound carriers required specialised single function (music consumption only) hardware to listen to music. Like all sound-carriers, hardware is required for playback. However, in the case of the Hi-Fi no bill of materials exists which proved problematic in calculating a rucksack. Instead, the rucksack of a PC base unit was used as a proxy for Hi-Fi equipment as both are composed of metal cases and silicon-based processing boards. Unlike the PC, the Hi-fi required no further hardware as no equivalent or alternative to the monitor is factored into this scenario. Speakers are not factored into these scenarios as they are assumed to be a constant across all scenario types as the means of producing sound.

Table 9: A 56-minute CD album and Hi-fi system's material intensity (data from annex and Türk *et al.* (2003))

	Abiotic Material	Biotic Material	Air
	kg	Kg	kg
1 CD	*0.77*	*0.06*	*0.37*
Hi-fi System	*324.62*	*1.74*	*16.25*
Total	*325.39*	*1.80*	*16.62*

Table 9 shows both the delivery unit and service unit required to listen to a 56-minute CD album. The rucksack of the CD covers its production only. Whilst it is reasonable to assume that the actual rucksack would be larger when accounting for production site resources, distribution and transport from the retailer to consumer, such life-cycle phases contribute little to the overall rucksack (typically less than 1%). Consumer transport is also not included in this figure. Türk *et al.* (2003) in comparison did include consumer transport but worked on the assumption consumers were travelling 10 miles to purchase 3 items, one of which was a CD. However, with the near collapse of major music retailers, CD purchasing has shifted online and to supermarkets. When consumers do purchase CDs from supermarkets it is likely to be part of a weekly shop and therefore the contribution of the delivery life-cycle phase to the overall material intensity is likely now marginal. Those who purchase physical albums online for delivery pose similar logistical problems in terms of ascertaining the material intensity of delivery. Again, as delivery vehicles will be making only part of their journey to deliver the CD the rest of the journey may be delivering many hundreds of items. Therefore, it was assumed that any contribution made by the delivery mechanism to the overall material intensity will be insignificant. However, it should be noted this would add to the backpack of this scenario but not others. As such, for the purposes of the scenarios discussed here these additional life-cycle phases are excluded as being outside the scope of study to ensure compatible comparisons with the other scenarios.

Table 9 shows that the CD itself has a material intensity that is a fraction of the total Hi-Fi system. The combined Abiotic and Biotic material intensity of a CD is 0.83 kg and the Hi-Fi system is 326.36 Kg. This gives a combined material intensity of 327.19 Kg (Abiotic + Biotic) required to listen to a CD on a Hi-Fi in its most basic configuration although this calculation excludes the material intensity of the power required for the Hi-Fi to listen to it.

Table 10: The material intensity of 12 56-minute albums and a hi-fi system (data from annex)

	Abiotic Material	Biotic Material	Air
	kg	kg	kg
12 CDs	*9.24*	*0.72*	*4.44*
Hi-Fi System	*324.62*	*1.74*	*16.25*
Total	*333.86*	*2.46*	*20.69*

Table 10 assumes a heavier consumption of CDs per month with a consumer purchasing 3 CDs a week. The combined material intensity of 12 CDs and a Hi-Fi is 336.32 Kg (Abiotic + Biotic). Table 11 extends such a consumption pattern over the course of a year and represents the accumulation of a medium to large CD collection. The total material intensity of 144 CDs and a Hi-Fi system is 445.88 Kg (Abiotic + Biotic).

Table 11: 144 56-minute albums and a hi-fi system, heavy yearly consumption (data from annex)

	Abiotic Material	Biotic Material	Air
	kg	kg	Kg
144 CDs	*110.88*	*8.64*	*53.28*
Hi-Fi System	*324.62*	*1.74*	*16.25*
Total	*435.50*	*10.38*	*69.53*

Even with many CDs purchased, the Hi-Fi remains the largest contributor to the material intensity of collecting and listening to the CD sound format. For them to become equal in Abiotic + Biotic terms a consumer would have to amass around 393 CDs (assuming the Hi-Fi is used exclusively for CD consumption). Many consumers will never have come close to collecting this many CDs whereas for others the Hi-Fi itself may need replacing before the consumer nears the 393 CDs figure.

Table 12: Comparison between the different levels of CD consumption (data from annex)

	Abiotic	Biotic	Abiotic + Biotic
	kg	kg	Kg
1 CD (Table 9)	*0.77*	*0.06*	*0.83*
12 CDs (Table 10)	*9.24*	*0.72*	*9.96*
144 CDs (Table 11)	*110.88*	*8.64*	*119.52*

These basic scenarios created using MIPS prove insufficient however when attempts are made to compare different usage patterns. A study by Edison research in which American users kept a 24-hour listening diary showed that the average consumer listens to four hours of music a day of which 2 hours

is AM/FM radio. Whilst it is not clear if this AM/FM consumption occurs at home it suggests that up to half the material intensity of a Hi-Fi could be excluded from these calculations as the Hi-Fi is multi-function (if not multi-purpose) hardware which can allow for multiple ways of consuming music.

Utilising the Edison Research data as well as the desire to further utilise the MIPS methodology to allow for comparisons across multiple resource demands of music carriers and consumption patterns gave rise to the listening-session calculations. An assumption based on the Edison Research data was that if consumers listen to four hours of music a day with two hours being AM/FM radio the other two hours could reasonably be said to be CD based, download based or streaming based consumption. To fit with the existing literature and to retain the 56-minute figure a listening session was defined as 112 minutes (2 x 56 minutes) as this is approximately the same as the two-hour figure from Edison Research. The Material Intensity Per Listening Session is therefore the resource consumption required to be able to listen to 112 minutes across the different scenarios and is specifically designed to allow for comparability across the different sound carriers. The MIPLS figure also includes the material intensity of the energy required for 112 minutes of listening an example of which is shown in Table 13.

Table 13: The energy required to listen to 112 minutes of music on a Hi-Fi assuming 50w average consumption (data from annex)

	Energy to listen on Hi-Fi	
Time	kWh	Material Intensity Abiotic (Kg)
112 minutes	*0.074*	*0.118*

Each MIPLS figure is arrived at based on several assumptions each of which are explained and justified in the subsequent sessions along with tables that present the different material intensities for each scenario.

8.2.1.1 CD consumption – worst case scenario

Table 14: The yearly total and per listening session (112 minutes) material intensity of listening to music from a CD on a Hi-Fi (data from annex)

(worst case scenario)

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
	kg	kg	kg	Kg
24 CDs	*18.48*	*1.44*	*19.92*	*0.05*
Hi-Fi system	*324.63*	*1.72*	*326.35*	*0.89*
HiFi power	*64.59*	*0*	*64.59*	*0.18*
Total	*343.23*	*3.16*	*346.27*	*1.12*

The worst-case scenario for CD consumption assumes that a Hi-Fi has a life span of one year and that the consumer purchased 24 CDs. It assumes that 112 minutes of music are listened to on the Hi-Fi every day for a year. Table 14 shows the components that make up the MIPLS figure. The physical products and the energy required to power the Hi-Fi for 112 minutes on 365 days. The material intensity per listening session figure is 1.12Kg (*abiotic + biotic*). The relationship between the hardware and sound carrier is consistent in that should a two-year life cycle be introduced the per session figure for the CDs (if only 24 were bought over the two-year period) would halve as would the MIPLS of the Hi-Fi. The energy requirement would however double, giving a final figure of 0.83 Kg (*abiotic + biotic*) per listening session.

8.2.1.2 CD Consumption – regular use scenario

Table 15: The yearly total and per listening session (112 minutes) material intensity of listening to music from a CD on a Hi-Fi assuming the Hi-Fi has a functional life-cycle of 4 years and is used for 300 listening sessions per year (regular use scenario) (data from annex).

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
	kg	kg	kg	Kg
24 CDs	*18.48*	*1.44*	*19.92*	*0.07*
Hi-Fi system	*324.63*	*1.72*	*326.35*	*0.27*
HiFi power	*53.08*	*0*	*53.08*	*0.18*
Total	*343.23*	*3.16*	*346.27*	*0.52*

The regular use scenario assumes that the Hi-Fi has a life span of four years and that 24 CDs were purchased over the course of the year. It is also assumed that music is consumed for 112 minutes for 300 days a year. Table 15: The yearly total and per listening session (112 minutes) material intensity of listening to music from a CD on a Hi-Fi assuming the Hi-Fi has a functional life-cycle of 4 years and

is used for 300 listening sessions per year (regular use scenario). Table 15 shows that based on these assumptions a MIPLS figure of 0.52 Kg (abiotic+biotic) is achieved. The increased MIPLS for the CDs compared to the worst-case scenario can be accounted for by the decreased number of days that music is consumed. The MIPLS for the power remains the same as power was only used on 300 days instead of 365 for 300 listening sessions. The MIPLS for the Hi-Fi is decreased by nearly 75% as only a quarter of its material intensity is applicable over the first year of its life-cycle.

The difficulties with basing MIPLS on such assumptions are a problem in all the scenarios developed here and are discussed at length in section 6.4. The MIPLS for physical media are relatively simple in terms of arriving at final figures. Downloading and streaming have the potential to be more complicated in part because of the number of different compressed audio formats that are in use by the different download stores and streaming services. Like the physical media MIPLS the variations of such scenarios have been restricted to retain clarity.

8.2.2 Scenario 2: Downloading

Scenario two assumes that songs are downloaded from digital music stores such as iTunes or Amazon and stored as the original files which undergo no further transformation such as being transferred to an MP3 player or being burnt to CD. Of the many file types, available the scenario uses AAC (256kbps) as this is the file type used by iTunes and despite increasing competition iTunes remains the largest seller of downloadable music content. The file type is not as important as the size of the file however when calculating material intensity. As noted in section 5.5.1, AAC files are like MP3s and were developed by the MPEG committee as a technologically improved (compared to MP3) audio compression that could reduce the file size still further without reducing sound quality. The effect of compression on the audio file is to reduce the overall file size. As such 56 minutes of uncompressed ‘CD-quality’ audio is around 578mb whereas 56 minutes of AAC files are 105mb and 56 minutes of FLAC files are around 280mb. These file sizes affect the speed at which the files can be downloaded, and the space required to store them. The effect therefore is a linear one whereby as file size increases so does the material intensity per unit.

PCs are no longer required to download AAC files (MP3 originally) through the internet although they remain a popular method of doing so. Other supporting hardware capable of accessing downloadable content, such as smart-phones and tablets, have risen in popularity since their relatively recent introductions and have distinct material intensities of their own. Somewhat distinct from PCs is also the way smart-phones (and some tablets) can access downloadable content. Although the 3G and 4G networks that smartphones connect to have a different material intensity to that of the internet the resource intensity of the different methods comes down to the transfer rate of the different download

technologies. 3G and 4G networks as well as broadband connections are not included in these scenarios however as the material intensity of the file transfer hardware represents a miniscule contribution per MB given the tens of thousands of Terabytes the network transfers they have been excluded. For the sake of comparison, it is assumed that the iPhone obtains content across a Wi-Fi home network in the same manner as a PC or laptop rather than introduce a sub-scenario for 3G and 4G technologies.

Table 16: Download times for sound carriers for different download speeds (data from annex)

	Time to download (hh:mm:ss)				
File type and size	22.8 mbps	153 mbps	80 mbps (4G)	7.2 mbps (3G)	56 kbps[222]
AAC 105 mb	*00:00:38*	*00:00:05*	*00:00:11*	*00:02:02*	*04:22:28*
FLAC 280 mb	*00:01:43*	*00:00:15*	*00:00:29*	*00:05:26*	*11:39:03*
WAV 578 mb	*00:03:32*	*00:00:31*	*00:01:00*	*00:11:13*	*24:03:02*
MP3 (128kbps) 56 mb	*00:00:20*	*00:00:03*	*00:00:05*	*00:01:05*	*02:19:48*

The speed at which files can be downloaded differs significantly dependent on the transfer technology. Table 16 highlights the lengths of time it would take to transfer the 56 minutes of music in the different sound carrier formats across the different transfer technologies. Ofcom reported that the average internet speed in the UK in November 2014 was 22.8 mbps whilst the fastest advertised speed was 153mbps (Ofcom 2015). The table also includes 4G and 3G network information as well as 56kbps which was the speed of dial up modems in the "Napster" years through to the early 2000s. Speeds increased considerably as broadband networks were implemented across the UK from 2000 with average speeds in the UK surpassing 512kbps in 2004 when iTunes launched. The increasing speeds has reduced the per MB energy consumption of file transfer on the end user equipment.

Although the hardware materials fall outside of the scope of the MIPLS, the energy used to transfer from the data centre across the network to the end user hardware does fall within the boundaries of the project. Several studies have attempted to ascertain the energy usage of the internet. Existing

[222] The speeds here were calculated using www.download-time.com, however Türk *et al.* state that the download time in their 56kbps scenario was 233 minutes as they used a "realistic speed" rather than the theoretical speeds in Table 16. This was because they reasoned that the internet connection would not be used exclusively for transferring the file. However, given the speeds with which data is currently transferred such additional data downloading during the download time is likely to be minimal as the overall download time has decreased significantly.

studies however vary by a factor of 20,000 between the highest and lowest estimates. Koomey *et al*, put energy use at 136 kWh / GB where as Baliga *et al.* (2011) place it at 0.0064 kWh / GB. For the purposes of the scenarios a figure of 0.057 kWh / GB has been selected based on the work into media transfer over the internet by Schien *et al.* (2012). This study did not include end user equipment within its estimate and specifically targeted the transfer of media data and usage (although there should be no difference between different types of data as data is data whether it be music, video or ASCii pictures of cats). The figure of 0.057 kWh / GB differs from that of the Türk *et al.* (2003) study which used a per hour figure to calculate internet usage. Such a figure is no longer fit for purpose given the massive increases in speed and efficiency experienced in internet downloads. Instead, the figure for downloads is derived from the kWh / GB figure and the assumption that the user used their equipment for 5 minutes to browse before purchasing an album. Türk *et al.* (2003) assumed 15 minutes based on figures obtained in 2003 about browsing habits, however with the introduction of one touch purchases as standard for most online retailers and the increased "savviness" of consumers in terms of knowing what they're doing this figure can reasonably be said to have decreased. The five minutes assumes that users turn their computer on solely to purchase an album and do not use it for anything else between start up and the end of the download.

The MIPLS calculation is more complicated for PCs and smart-phones than for Hi-Fis. It is unlikely that a PC or smart-phone are purchased for and used solely for consuming music given their multi-functionality. However, for the purposes of the worst-case scenarios it is assumed that these devices are bought exclusively for consuming music.

Table 17: The energy required to download the different dematerialised sound carriers and the corresponding Material Intensity (data from annex)

	Energy to download	
File type and size	W	Material Intensity Abiotic (Kg)
AAC 105 mb	*5.99*	*0.009*
FLAC 280 mb	*15.96*	*0.025*
WAV 578 mb	*32.95*	*0.052*
MP3 (128kbps) 56mb	*3.19*	*0.005*

Table 18: Time to browse for and download a 56-minute album on a PC and the material intensity of the energy required to perform these tasks (data from annex).

	Energy to purchase and download (download time + 5 minutes browsing) on PC (hh:mm:ss)					
	22.8 mbps		153 mbps		56 kbps	
File type and size	Time	MI Ab. (Kg)	Time	MI Ab. (Kg)	Time	MI Ab. (Kg)
AAC 105 mb	*00:05:38*	*0.029*	*00:05:05*	*0.026*	*04:27:28*	*1.336*
FLAC 280 mb	*00:06:43*	*0.034*	*00:05:15*	*0.026*	*11:44:03*	*3.522*
WAV 578 mb	*00:08:32*	*0.043*	*00:05:31*	*0.028*	*24:08:02*	*7.245*
MP3 (128kbps) 56 mb	*00:05:20*	*0.027*	*00:05:03*	*0.025*	*02:24:48*	*0.720*

A PC uses between 65 and 250 watts of energy per hour dependent on the nature of the equipment. Türk *et al.* (2003) assumed PCs used 150 watts per hour or 0.15 kWh with an additional 40 watts included for the PC's monitor. Whilst this figure has almost certainly dropped, accurate averages for computer energy consumption are difficult to obtain. The time taken to download the service unit (56 minutes of music) was added to a five-minute browse time and the material intensity was calculated based on the energy used to perform this task (Table 18).

The same calculation was not performed for smart phones. The energy required to operate them is very small (typically using 5 watts to charge a day or around 1.8 kWh annually). As such the material

intensity for downloading and browsing on a smart phone is the same as the figures shown in Table 16. Comparatively the energy required to use a PC and monitor for 112 minutes is 0.354 kWh. This is approximately 4.8 times greater than the energy required to listen to a CD on a Hi-Fi.

Table 19 shows the combination of contributory material intensities combining data from Table 16, Table 17 and Table 18. Similar to the Hi-Fi and CD listening session (Table 14 and Table 15) it makes the following assumptions: it assumes that 24 albums were purchased over the course of the year using the average download rate of 22.8 mbps; that browsing took 5 minutes; and that the PC is used only to listen to music over the course of one year. The total material intensity of the PC and monitor as well as the energy required to listen to 112 minutes of music per day are included.

Table 19: The total abiotic + biotic material intensity of listening to downloaded music (worst case scenario) (data from annex)

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
	kg	kg	Kg	kg
24 AAC downloads from server	*0.225*	*0*	*0.225*	*0.0006*
24 AAC browse and downloads on user equipment time	*0.675*	*0*	*0.675*	*0.0018*
PC	*324.63*	*1.72*	*326.35*	*0.89*
Monitor	*92.7*	*0.64*	*93.34*	*0.26*
PC & monitor power for 112 mins 365 days	*204.531*	*0*	*204.531*	*0.56*
Total	*418.781*	*2.36*	*420.581*	*1.7124*

As with the Hi-Fi scenario the major contribution to the overall abiotic and biotic material intensity is from the hardware. This is a worst-case scenario however presenting the highest MIPLS based on the assumptions outlined above. It is reasonable to assume however that a multi-functional device such as a PC will be used for multiple functions and that it was also have a life-span greater than one year. Türk *et al.* assumed a functional life of 4 years for a PC which would reduce the figure of 0.89 kg by 75%. Table 20 shows what this per listening session figure might look like; it assumes that a PC is used 300 days a year for 6 hours of which 112 minutes is used to listen to music; it also assumes a functional life cycle of four years for the PC. The regular use scenario sees a 60% reduction in the MIPLS compared to the worst-case scenario when based on the assumptions above. Both scenarios show that the contribution made by downloading and browsing for the music to be only a very small part of the overall footprint at 0.11% and 0.34% for the regular use scenario respectively.

Table 20: The total abiotic + biotic material intensity of listening to downloaded music on a PC (regular use scenario) (data from annex)

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
	kg	kg	Kg	kg
24 AAC downloads from server	*0.225*	*0*	*0.225*	*0.0008*
24 AAC browse and downloads on user equipment	*0.696*	*0*	*0.696*	*0.0023*
PC	*324.63*	*1.72*	*326.35*	*0.09*
Monitor	*92.7*	*0.64*	*93.34*	*0.026*
PC & monitor power	*168.112*	*0*	*168.112*	*0.56*
Total	*343.22*	*3.18*	*420.602*	*0.679*

Table 21 assumes the same type of browse and download scenario but replaces the PC and monitor hardware requirement with that of an iPhone 5. The worst-case scenario assumes that the phone is used only to consume music and has a life-span of one year.

Table 21: The total abiotic + biotic material intensity of listening to downloaded music on an iPhone 5 (regular use scenario) (data from annex)

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
	kg	kg	Kg	kg
24 AAC downloads from server	*0.225*	*0*	*0.225*	*0.0006*
24 AAC browse and downloads on user equipment	*0.696*	*0*	*0.696*	*0.0019*
iPhone 5	*111.95*	*1.49*	*113.44*	*0.018*
Total	*112.871*	*3.18*	*346.28*	*0.0205*

The regular use scenario (Table 21) assumes a life cycle of two years for the iPhone 5. It also assumes that users turn off the phone whilst they sleep. Of the 16 hours (960 minutes) that the smart-phone is turned on each day, 112 minutes are used to listen to music whilst no other activity occurs. It also assumes that as it is a phone it is used 365 days a year.

8.2.3 Scenario 3: Streaming

Developing the download scenarios further it was possible to create scenarios for streaming music. Streaming music works in much the same way as downloading music except that a local copy of the file is only kept for repeated listens of the same album. Should a user listen to different albums every time they stream music they are in effect downloading a new album with all the resource implications that entails. There is some small variation across the different streaming services in terms of the file sizes streamed but to keep comparisons consistent with the download scenarios, the streaming scenarios assumed a user was using Apple Music which had a rate of 25kbps and streams as an AAC file. Spotify for comparisons has two rates dependent on the subscription models and streams at either 192kbps or 320 kbps and uses the Ogg Vorbis sound carrier format. Streaming scenario one, the worst-case scenario (see Table 22), assumes that the user is streaming music from the streaming service Apple Music on a computer that is used solely for streaming 112 minutes of music a day and with a life-span of one year. The scenario assumes that 730 albums (2 albums a day for 365 days) are streamed in total over the course of the year and that all albums are different so that they are not stored locally on the user's hard drive. For streaming it is the hard ware once again that is the most resource intensive.

Table 22: The total abiotic + biotic material intensity of listening to streaming music (worst case scenario) on a PC (data from annex)

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
	kg	kg	Kg	kg
730 service unit streams from server	*6.9*	*0*	*6.9*	*0.019*
PC	*324.63*	*1.72*	*326.35*	*0.89*
Monitor	*92.7*	*0.64*	*93.34*	*0.26*
PC & monitor power	*204.5*	*0*	*204.5*	*0.56*
Total	*343.22*	*3.18*	*420.602*	*1.729*

The regular use scenario for streaming music on a PC (see Table 23) assumes that the PC has a life-span of four years and is used to stream 600 albums over 300 days. Like the regular use PC download scenario, it also assumes that the PC is used for 6 hours a day of which 112 minutes are used to listen to music exclusively. The largest resource demands come from the supporting hardware although the total contribution to the overall MIPLS figure is reduced.

Table 23: The total abiotic + biotic material intensity of listening to streaming music (regular use) on a PC (data from annex)

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
	kg	kg	Kg	kg
600 service unit streams from server	*5.67*	*0*	*5.67*	*0.019*
PC	*324.63*	*1.72*	*326.35*	*0.09*
Monitor	*92.7*	*0.64*	*93.34*	*0.026*
PC & monitor power	*168.112*	*0*	*168.112*	*0.56*
Total	*343.22*	*3.18*	*420.602*	*0.695*

Streaming scenarios were also developed for the iPhone 5. Like the other scenarios a worst and regular use case are presented. For the worst-case scenario (see Table 24) it was assumed that the iPhone was used to stream 730 albums over the course of the year (for 56 minutes each), that the phone had a life-span of one year and was not used for any other purpose.

Table 24: Streaming 730 AAC albums and listening to them for 112 minutes every day on an iPhone 5 (worst case scenario) (data from annex)

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
	kg	kg	Kg	kg
730 service unit streams from server	*6.9*	*0*	*6.9*	*0.019*
iPhone 5	*111.95*	*1.49*	*113.44*	*0.31*
Total	*112.86*	*1.49*	*114.35*	*0.329*

The regular use scenario (see Table 25), like that of the downloading scenario, assumed that the iPhone 5 had a life-cycle of two years, is used 365 days a year, that it was turned off whilst the user slept and that of the 16 hours it is used a day 112 minutes are used exclusively for the consumption of music. In this scenario, the contribution to the total MIPLS for the sound carrier exceeds that of the hardware by 0.001kg which is unique to this scenario. Further comparisons between the different scenarios form the basis of the following discussion.

Table 25: Streaming 600 AAC albums and listening to them for 112 minutes every day on an iPhone 5 (regular usage scenario) (data from annex)

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
	kg	kg	Kg	kg
600 service unit streams from server	*5.67*	*0*	*5.67*	*0.019*
iPhone 5	*111.95*	*1.49*	*113.44*	*0.018*
Total	*112.86*	*1.49*	*114.35*	*0.037*

8.2.4 Comparing the scenarios

The previous section detailed three different ways of obtaining music which were developed into five different scenarios of music consumption based on several assumptions. The assumptions allowed for consistency amongst the different scenarios producing sets of MIPLS that can be compared and allow conclusions to be drawn about the nature of dematerialisation in music consumption. For clarity, the total MIPLS for each 'regular use' scenario is reproduced in Table 26, the hardware resource usage in Table 27, the power requirements in Table 28 focuses on the material intensity of the hardware alone and does not consider the additional elements such as energy use and sound carrier formats. The result is one that gives a clearer indication of the effects of convergence on the different hardware. The Hi-Fi, used almost exclusively for music consumption, is the most materially demanding of the three pieces of hardware with the iPhone highlighting the results of convergence still further as Figure 25 shows. The implications of convergence are discussed more fully in section 6.3. The other thing to note between the different hardware is the impact power consumption has on the overall MIPLS. PCs have historically consumed a lot of power. Power consumption was enough to place the PC based scenario MIPLS above that of the Hi-Fi and CD (see Table 26) in terms of the energy required to listen to the music on those devices. Although the development of the MIPLS measurement makes direct comparisons with the Türk *et al.* study impossible it is worth noting that the scenarios developed here broadly support the same conclusions made by both Türk *et al.* (2003) and Weber *et al.* (2009) discussed in section 4.4. That is, digital only delivery scenarios support the notion that the consumption of music has dematerialised or as Türk *et al.* worded it when referring to a larger transition away from CDs to digital delivery "resource savings could be made". The MIPLS scenarios when compared below take into consideration the supporting hardware etc in a way that neither previous study did and find evidence to

suggest that the transition away from physical media to digital media even when taking into consideration consumption, as well as production, of music that there has been a reduction in resource use.

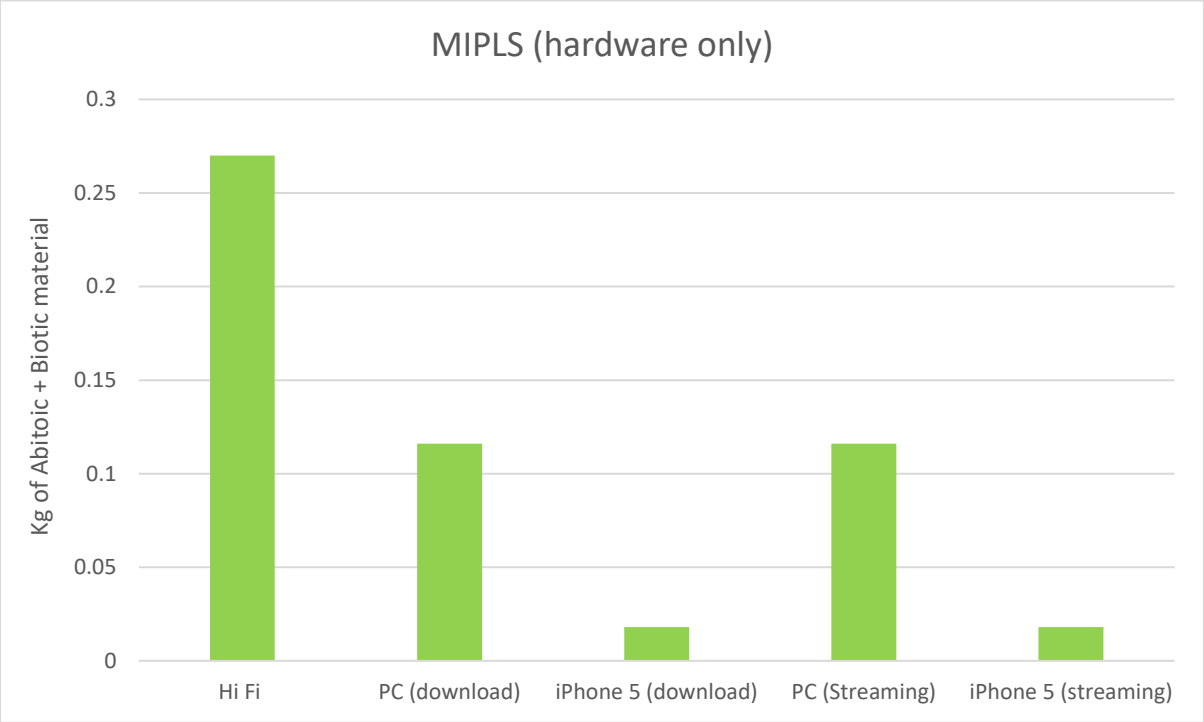


Figure 25: Material Intensity per Listening Session for hardware only

Table 26: A comparison between the different consumption scenarios showing both the total abiotic + biotic material intensity and the abiotic + biotic material intensity per listening session (MIPLS) for regular use scenarios (data from annex).

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
Scenario (Total)	kg	kg	Kg	kg
Hi Fi w/ 24 CDs	*343.23*	*3.16*	*346.27*	*0.52*
PC download	*343.22*	*3.18*	*420.60*	*0.679*
iPhone 5 download	*112.86*	*3.18*	*346.28*	*0.0205*
PC Streaming	*343.22*	*3.18*	*420.60*	*0.695*
iPhone 5 streaming	*112.86*	*1.49*	*114.35*	*0.037*

There are considerable differences between the modes of music consumption in terms of their total material intensity per listening session the starkness of which is highlighted in Figure 25. It is surprising that against perceived wisdom on dematerialisation that the PC based methods of consumption appear to be the most resource intensive. PCs are clearly materially intensive and high-power

hardware. Even when considering the absence of a bill of materials for the Hi-Fi led to a PC being used as a proxy the power demanded by the PC plus the addition of a computer monitor leads to its larger MIPLS by some 30%. Ignoring the scenarios however the total resource intensity of the different hardware is notable because the iPhone's material intensity is around 1/3rd that of the Hi-Fi and PC hardware. Also, although the Hi-Fi and PC appear to have similar values the Hi-Fi total material intensity is also made up of the material intensity of 24 CDs. There is little significant difference between downloading and streaming (2.3% more materially intensive to stream) in terms of the additional resource intensity of streaming in comparison to the overall material intensity for that consumption type.

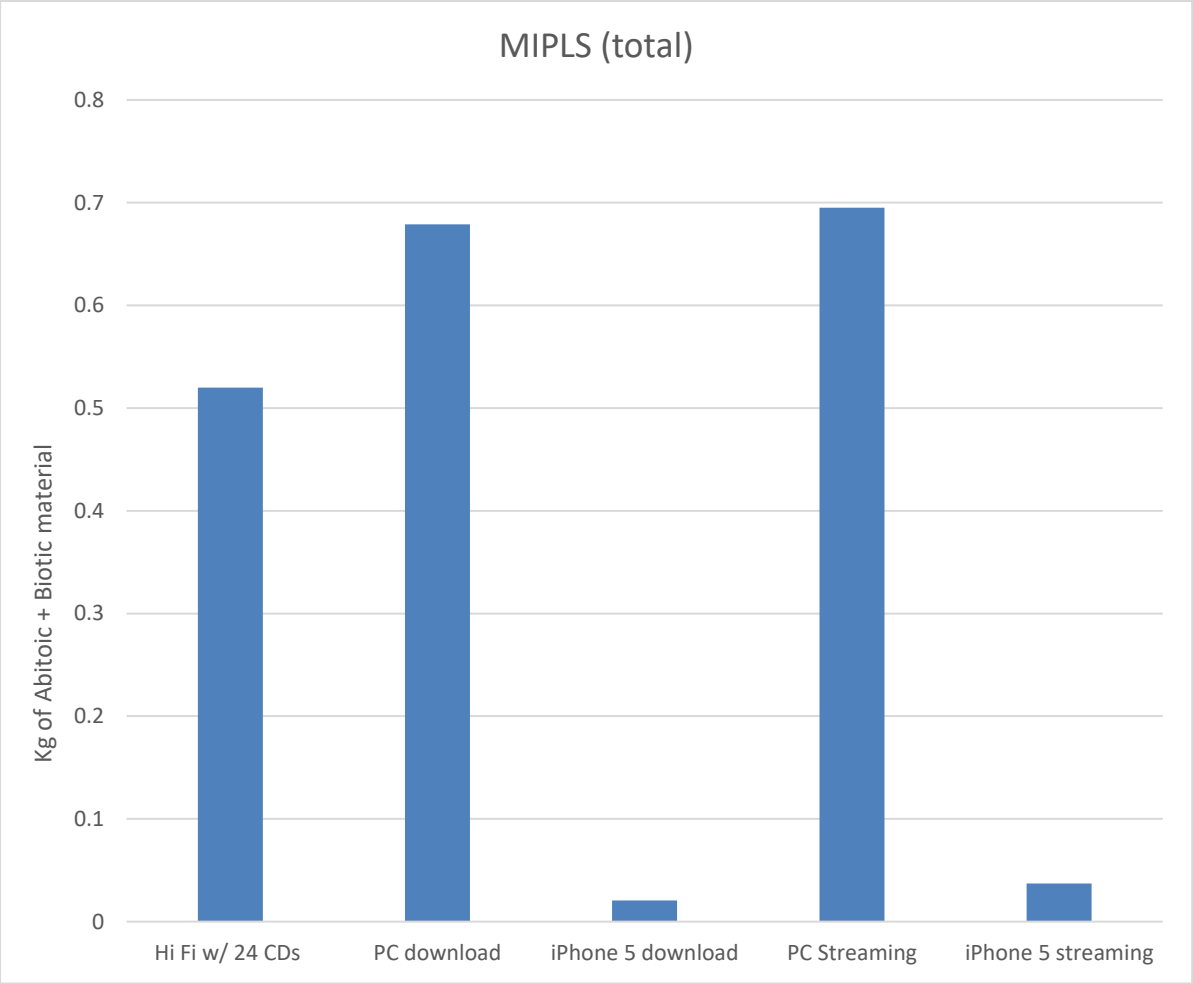


Figure 26: Bar chart showing the difference between the total MIPLS of the different consumption scenarios per session considering multi-functionality of devices

Table 27: A comparison between the different consumption scenarios hardware resource demands showing both the total abiotic + biotic material intensity and the abiotic + biotic material intensity per listening session (MIPLS) for regular use scenarios (data from annex).

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
Scenario (hardware)	kg	kg	Kg	kg
Hi Fi	*324.63*	*1.72*	*326.35*	*0.27*
PC (download)	*417.33*	*2.36*	*419.69*	*0.116*
iPhone 5 (download)	*111.95*	*1.49*	*113.44*	*0.018*
PC (Streaming)	*417.33*	*2.36*	*419.69*	*0.116*
iPhone 5 (streaming)	*111.95*	*1.49*	*113.44*	*0.018*

Table 27 focuses on the material intensity of the hardware alone and does not consider the additional elements such as energy use and sound carrier formats. The result is one that gives a clearer indication of the effects of convergence on the different hardware. The Hi-Fi, used almost exclusively for music consumption, is the most materially demanding of the three pieces of hardware with the iPhone highlighting the results of convergence still further as Figure 26 shows. The implications of convergence are discussed more fully in section 6.3. The other thing to note between the different hardware is the impact power consumption has on the overall MIPLS. PCs have historically consumed a lot of power. Power consumption was enough to place the PC based scenario MIPLS above that of the Hi-Fi and CD (see Table 26) in terms of the energy required to listen to the music on those devices.

Table 28, shows this in more explicit detail. The energy required to listen to the music on the PC is higher by more than three times that of the Hi-Fi and considerably higher than that of the iPhone whose energy contribution to the overall MIPLS is so small it is excluded.

Table 28: A comparison between the different consumption scenarios energy resource demands showing both the total abiotic + biotic material intensity and the abiotic + biotic material intensity per listening session (MIPLS) for regular use scenarios (data from annex).

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
Scenario (energy)	kg	kg	Kg	kg
Hi Fi w/ 24 CDs	*53.08*	*0*	*53.08*	*0.18*
PC download	*168.808*	*0*	*168.808*	*0.5623*
iPhone 5 download	-	-	-	-
PC Streaming	*168.112*	*0*	*168.112*	*0.56*
iPhone 5 streaming	-	-	-	-

Finally, Table 29 highlights the differences between the different sound carriers alone. CDs are considerably more resource intensive to produce than the same number of albums downloaded or streamed. Similarly, due to the nature of streaming the streaming MIPLS figure is greater than that of the download only scenarios. Focus on the aspect alone has typically led to the conclusion that downloading is less resource intensive than purchasing physical products (Weber *et al.* 2010). However, the experience of listening is but a small part of the whole in terms of consuming music. Once hardware and the energy required to operate that hardware are considered then the conclusions that are drawn can be more fully informed by the different resource demands the methods of consumption make.

Table 29: A comparison between the different sound carriers showing both the total abiotic + biotic material intensity and the abiotic + biotic material intensity per listening session (MIPLS) for regular use scenarios (data from annex).

	abiotic	biotic	abiotic + biotic (Total)	abiotic + biotic (per session)
Scenario (format)	kg	kg	Kg	kg
24 CDs	*18.48*	*1.44*	*19.92*	*0.07*
24 downloads (PC)	*0.225*	*0*	*0.225*	*0.0008*
24 downloads (iPhone)	*0.225*	*0*	*0.225*	*0.0006*
600 Streams (PC)	*5.67*	*0*	*5.67*	*0.019*
600 streams (iPhone 5)	*5.67*	*0*	*6.9*	*0.019*

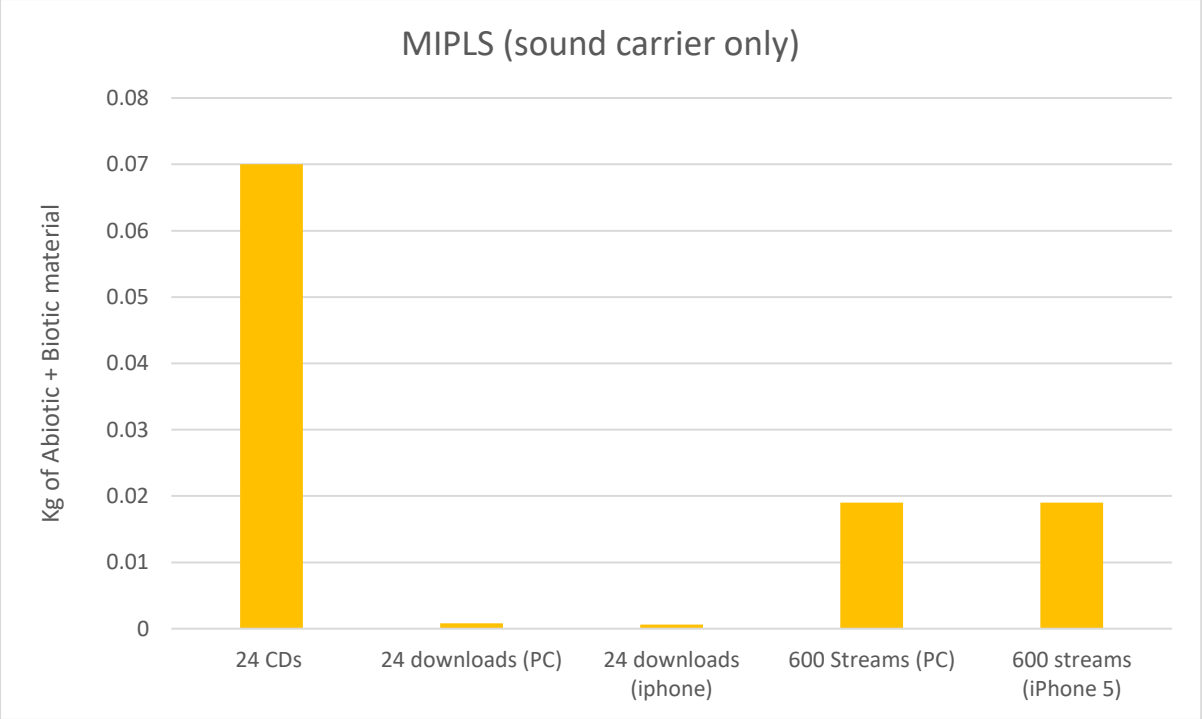


Figure 27: Material intensity per listening session of sound carrier only

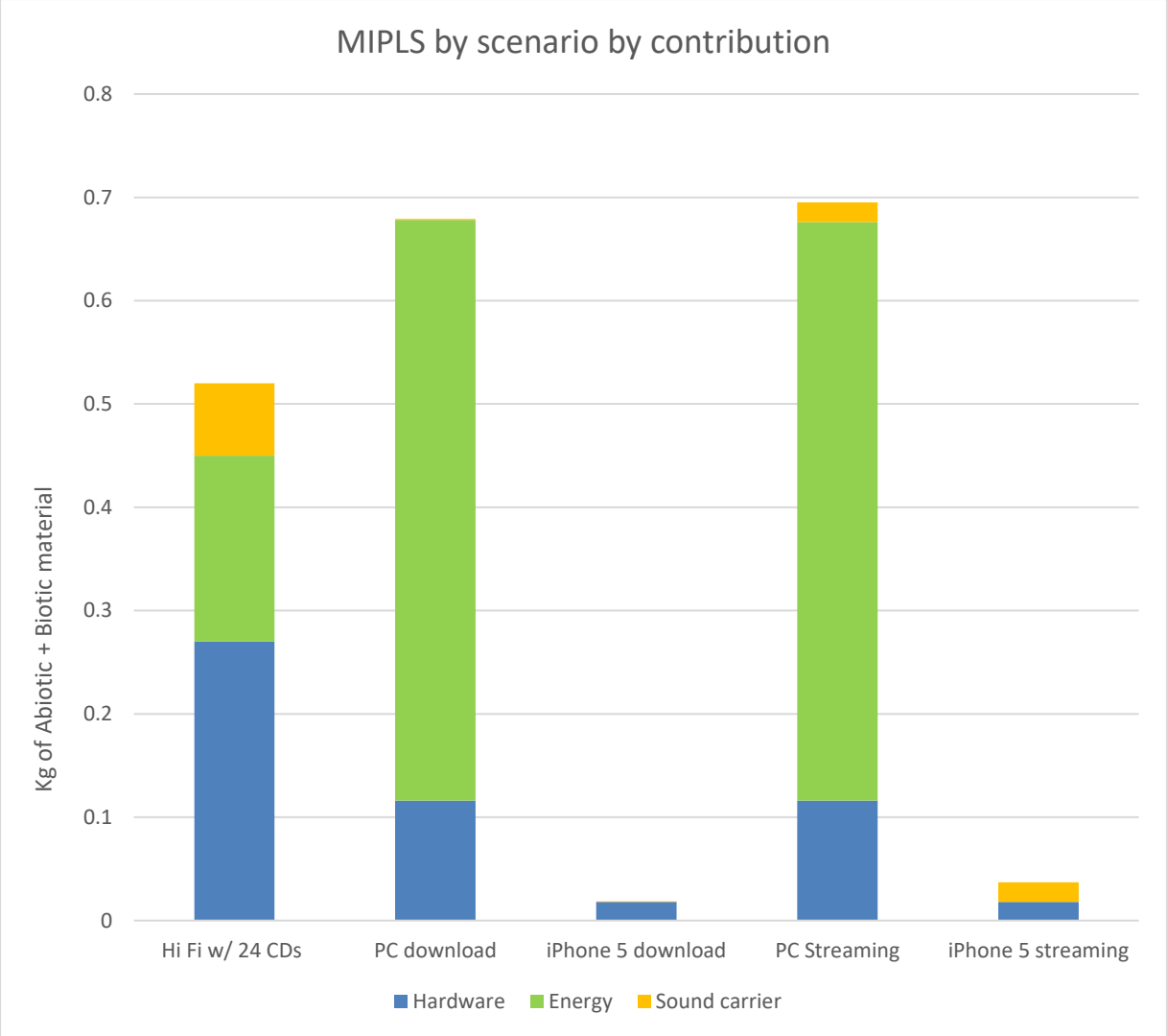


Figure 28: Bar chart showing the difference between the total MIPLS of the different consumption scenarios and the elements that contribute to their total abiotic + biotic material intensity

Figure 28 shows the same data as Figure 25 but with the contributory elements of the total MIPLS distinguished. The hardware contribution of the Hi-Fi is more than double that of the PC, yet as the PC uses a considerable amount of energy, nearly 3 times that of the Hi-Fi, its overall material intensity is greatest. It is plausible however that newer models of PC and certainly battery powered laptops have a much smaller energy demand which would see the total MIPLS figures for PCs drop below that of the Hi-Fi. This difficulty in being able to accurately capture the materiality of hardware and their energy demands is one of the subjects of discussion in section 8.4.

It is also notable that the iPhone with its much smaller energy requirement has the smallest MIPLS of the three hardware. The iPhone's small form factor contributes to its smaller overall material intensity, further its multiple uses reduce the MIPLS still further, whilst this is also true of the PC, which sees its hardware MIPLS reduced by some margin over the Hi-Fi. However, the obsolescence of the various

technologies is difficult to predict. Some high-end audio equipment has a life span of decades whereas many mobile phones are replaced after only a year. This obsolescence is difficult to account for and demonstrates a weakness of methodology. However, given the differences between the hardware's MIPLS several iPhones could be used over a ten-year period and they would still not exceed the MIPLS of the Hi-Fi. Mobile phones seemingly represent good resource value because they are not single job items. This issue of multiple functionality and the resulting convergence of disparate technologies requires further discussion as to its impact of both the MIPLS figure, material intensity of products more broadly and the culture of technological curation it enables.

8.3 The consequences of convergence and technological changes in other regimes

When the multi-media PC first appeared at the end of the 1980s it brought many previously distinct functions together for the first time. PCs had long been used only for word-processing and data manipulation but with increased processor power and additional boards, functionality increased considerably. PCs were capable not only of word processing but playing music and video, playing computer games, browsing the internet (as it came into being in the early 1990s), send emails, make phone calls, print images, scan images and a host of other functions.

Similarly, to the growth of the PC, the introduction of the multiprocessor (see section 5.3.1) chips into MP3 players led to a growth in handheld electronics capable of multiple functions such as hand-held PCs. Hand-held computers continued to acquire additional functions in a bid to make them more marketable eventually converging with mobile phone technology. Although "smart-phones" which could be used for more than just making phone calls began to appear in the mid-2000s it was the launch of the iPhone in early 2007 that acted as a cultural accelerant for the smart-phone concept. The iPhone, itself based on the iPod, brought with it a range of functionality in a small and discrete product. Along with its phone functionality the iPhone could also playback MP3s, access the iTunes store, send emails, browse the internet, take photos and be used as a GPS device among other things.

The MIPLS data found in section 6.2 seems to suggest that convergent devices, due to their multi-functionality resulting in their ability to substitute for single function devices are capable of massively reducing the end-user's resource use for listening to music (among the many other functions). Although such an assumption is challenged if a user does not stop owning the individual devices. Section 6.4 is intended to look more closely at the problems with relying on MIPLS or MIPs alone to capture and understand the resource implications of complex socio-technical transitions. However, the consequence of convergence is itself a subject that requires further exploration to more fully understand the resource implications.

Technology convergence can both increase and decrease resource demands. Certainly, from the MIPLS evidence presented the resource demands of music consumption are decreased significantly when using a convergent device – either a PC (assuming lower energy demand due to increased efficiency than presented in the scenarios) or an iPhone. However, several factors should be considered when ascertaining if the MIPLS figure above is accurate, despite being based on sensible assumptions informed by the literature. The extent to which convergence occurs depends on the user and their behaviour. It is possible for a smart-phone, designed with all its multi-functionality, to be used only as a phone and MP3 player either because the user retains or has purchased other single function devices such as a digital SLR camera for their photography requirements or a tablet computer for web browsing. Such behaviour makes the assumptions found in the scenarios less safe.

More worrisome in ascertaining the implication of convergence however, is the lifestyle such a product creates and supports. Smart-phones are high demand products that offer leading-edge technology. They are both essential items of communication and iconic technology through which users express individual identities. Such consumer demands have significantly lowered the life-span of these products and those associated with them such as tablet computers (Lim and Schoenung 2010). In particular manufacturers exploit the desire to have the latest technology by building products that have "planned obsolescence" in which certain features are held back and introduced on another future iteration of the product (Rivera and Lallmahomed 2015). This rapid turn-over of devices results in sub-optimal recycling and reuse patterns where by the phone's end of life phase as assumed by the MIPS methodology is not met which has implications for resource demand. Smart-phones are not alone in this criticism however. A lot of technology is sub-optimally processed at the end of its life which creates doubts about the conclusions that can be drawn from MIPs and most other resource use indicators. Additionally, if the end of life phase is brought forward, due to accidental damage or a consumer's decision to replace the device, the MIPS calculation would need to be modified to account for this.

The consequences of convergence are therefore difficult to ascertain and rely on the user of the technology itself. Whilst MIPLS can measure the benefits of convergence based on several assumptions it is not possible to conclude categorically that a converged product will have reduced resource demands over a single function product such as a Hi-Fi. Well-built Hi-Fis can and do last for decades where sound quality is prized over features, gimmicks and bleeding edge features. The same cannot be said for PCs and smart phones which have limited life spans due to high turn-over because of consumer desirability demands, planned obsolescence and simple product failure due to their intense usage. This problem warrants further discussion therefore, to ascertain the usefulness of attempting to capture the resource implications of complex socio-technical transitions.

8.4 Capturing a complex socio-technical transition's resource implications

The conclusions above, about the resource use of different music consumption scenarios, are based on a small number of the ways in which people currently consume music identified in section 5.6. Determining the key modes of music consumption is difficult; selecting the most common music consumption methods relies on the underlying assumption that they somehow represent real world usage. Whilst it is certain that people are consuming music in the ways described in the scenarios, such scenarios fail to capture the many quirks of music consumption and the inter-related ways people may consumer music. This has a knock-on effect for any attempt to capture an entire socio-technical transition's resource use. The problem lies not with the methodology, although that is not without fault as discussed in section 6.4.2, but with the availability of data complicated by the many different real-world scenarios of consumption. This section looks first at the over-arching problems associated with trying to obtain data about technological products that have been encountered before critiquing the MIPs methodology.

8.4.1 Impossible data

Life cycle analysis of technological products is a rarity in academia and those companies that do publish their data about a product rarer still. Apple, keen to establish environmental consciousness, or to at least appear like they have, publish LCAs for their products. The information they contain however is difficult to work with, consisting of percentages rather than weight of materials. This too is only a recent development; older products lack any such bills of materials. Stripping products down to their component material is a costly process and to date only one publication details a computer with its monitor's bill of materials (Malmodin *et al.* 2014). The computer was already several years old at the time of publication meaning it was approaching two decades old as utilised here. As such, any attempt to capture the extent to which resource use has changed can only ever be illustrative and attempts to do so in the future will remain the same unless companies begin documenting and publishing what the products they sell are made of. This seems unlikely however as even moves towards labelling products with resource use in abstract terms is a distant hope (Jungbluth *et al.* 2012).

The problem extends beyond academia especially historically. Those who are responsible for designing products often design them based on the components of others. The Apple iPod was almost shelved in the design process because the designers and engineers were unable to source a storage component upon which they felt happy to base the iPod concept. Instead, a chance demonstration of a new Microdrive renewed interest in producing the iPod. The development of the iPod was therefore, essentially the combining of multiple existing components into a single functioning device. The complexity of the supply chain for the components are further complicated by the fact these components were also constructed from other components in turn. The CD comparatively benefitted

from a relatively simple bill of materials that Turk *et al.* (2003) were able to analyse by ascertaining the raw materials used at the pressing plant and the number of CDs the materials produced. Therefore without breaking down the finished product into its constituent materials, as was done with the PC and laptop by Maga *et al,* (2013), it is unlikely that the true bill of materials for any complicated piece of technology can be known.

Without the knowledge of what these products consist of, in their entirety, two problems are encountered. The first is that any attempts to steer technology transitions in a direction that might be more environmentally sustainable is severely hampered. The idea of moving towards dematerialised music consumption seems an elegant way of reducing resource use but as the illustrative examples above demonstrated, changes in upstream and downstream sectors and the way users interact with new technology *inter alia* can have a considerable impact on the overall socio-technological transitions impact on resource demand and therefore the environment. Any attempt to understand the impacts on environmental resources is reduced to retrospective analysis. Whilst the potential is there to guide future transitions based on the understanding of resource use and life cycle analysis of existing products, the reality as suggested by Chapter 5, is that innovation moves ahead quickly and unless resource use is an over-arching concern many other developments within the process of successfully breaking through will be prioritised. Where innovations are successful, environmental concerns might be considered as refinements to the original innovation as is done in other sectors such as Nuclear energy and Construction industries (Nian *et al.* 2014; Asdrubali *et al.* 2013). The second problem is that the tools for retrospective analysis struggle to fully get a hold of the impacts that have and continue to occur. Whilst it is not necessary to review different methods again (see Chapter 3), some review and discussion of the MIPs methodology is important.

8.4.2 Awkward methodology?

The MIPS methodology was chosen because it appeared to be an appropriate indicator for measuring changes in material consumption and not just energy, as is typical of other environmental indicators. In many ways, the MIPS methodology met its requirements, but it is not without fault and it is important to critique these issues to ascertain the true benefit of using the MIPS methodology in ascertaining dematerialisation in other socio-technological transitions in the future.

The first issue was addressed more broadly in section 8.4.1. The MIPS methodology is nothing without high quality data being fed into it. Without a bill of materials for products the methodology fails. Within the analysis here, several bills of materials were ascertained but other products had to be estimated using the other products' bills of materials as proxies. The Hi-Fi bill of materials is that of a PC without its monitor. It is difficult to say how reliable this is in terms of accurately portraying a Hi-

Fi's rucksack within the scenarios. However, as the scenario demanded resource information a best guess of resource demands was the only option available. Expanding on incomplete information using "qualified" estimates is an acknowledged part of the MIPS methodology (Ritthoff *et al.* 2002) but each time data is filled in with a best guess the accuracy of the overall MIPS figure is reduced. Türk *et al.* (2003) avoided some of this inaccuracy by drawing a different boundary around their investigation so that the actual consumption of music was not included. In redrawing this boundary however, uncertainty of products was the trade-off.

Once the actual resource used is ascertained or "best guessed" and included within the rucksacks the large Wuppertal Institute database could be consulted for MI Factors. Transport of products for example, does not necessarily require bills of materials for each stage of the transport chain as transport's MI Factor is included with distance travelled the variable that is unknown. Electricity too, is well served with different electricity mixes from different countries being covered. However, not all materials are so well covered and a scarcity of information about other MI Factors leads to a second issue with the MIPS methodology.

Despite the Wuppertal Institute's attempts to populate their database many important materials are missing. Rare earth metals such as yttrium, the lanthanide series and scandium are common components of modern electronic devices such as mobile phones. Such elements are not well served within the database. Ignoring the social impact of these metals, the environmental resource demands are likely considerable (Alonso *et al.* 2012). Most rare earth metals are used in trace amounts but their inclusion in the product and exclusion from the calculations likely lead to an underestimation of the true MIPS of a device. This links back to earlier concerns of product composition. Even if the Wuppertal Institute could ascertain the MI Factors of rare earth metals it is unlikely that a comprehensive bill of materials would be forthcoming. Apple for example, lumped all their metals together in their percentage breakdown of the iPod and iPhone. As such, rare earth metals which are known to have a considerable ecological burden are likely to remain excluded from MIPS calculations.

The final issue with the MIPS methodology concerns its usage. It was intended initially to be used as a method through which competing designs could be benchmarked to transitions towards the most environmentally friendly option. However, there is little published evidence to suggest that it is used during the design phase. Instead, it appears to be utilised by academics and the Wuppertal Institute itself as a retrospective benchmark to give illustrative examples of competing technologies in much the same way as has been done here. Despite optimistic intentions the development of socio-technical transitions, particularly those in the music industry, are beyond the control of those concerned with environmental matters as it is simply not one of many competing priorities in bringing music to

market. The absence of environmental concern therefore raises another question: what motivated the different actor groups to move towards the apparent dematerialisation of music consumption if not for resource concerns?

8.5 Summary

This chapter established several illustrative scenarios of music consumption using MIPLS which allowed for comparison between the different ways in which music is obtained and consumed. In doing so it found that as products converge the resource use for the consumption activity is reduced, that downloading music requires fewer resources than buying physical CDs and that streaming increases the resource use but to a level still considerably below that of physical product. The chapter also considered the complexities in capturing resource use as the data sources are reliant on third party databases and the bills of materials for the products and devices are outdated. In the next chapter the actors who influenced the socio-technical transitions are considered and any resource use considerations they may have considered when developing new novelties.

9 Actor influence on transition pathways

9.1 Introduction

As identified in section 2.4.4 of the literature review, actor related transition mechanisms and pathways have yet to come to the fore in multi-level perspective transition studies. This section specifically seeks to answer research question 1(c), "What are the roles of actors in transition pathways?". The historical analysis of Chapters 5 through 7 identified several actors whose interactions introduced changes to the incumbent regime. The actors were both individual in intent as well as capable of forming into groups to effect change. The purpose of this section is to draw out these actions and demonstrate their influence of the socio-technical transitions within the music industry. For analysis, the actors have been identified as one of four types which help define motivation rather than imply that the actors identified actor as part of a group. These five actor types, in many ways, are the essence of the narrative of socio-technical transition in music consumption and are found at the various levels of the multi-level perspective (see sections 9.1 - 9.6). They are presented here in a loose chronology which accounts for the order in which they exert their influence on the socio-technical niche and later the socio-technical regime. Disruptive Entrepreneurs are those actors who play with innovation, pushing the boundaries of new and existing technology in ways otherwise unthought-of (section 9.1). The Cartel of Condemnation and Litigation are those actors who seek to halt innovation, using litigation and the courts to delay technological advancement that they deem to be detrimental to their way of doing things and the current status quo (section 9.2). Reluctant Partners are those who are forced to accept the impact of the socio-technical changes brought about by the Disruptive Entrepreneurs and the failures of the cartels of litigation (section 9.3). The Reinvigorated Regime Actors are those who eventually benefited from socio-technical transition and regained their once threatened control over music-consumption (section 9.4). Common to all these actors however are consumers who have interacted in a variety of ways throughout the transition and have acted as curators of the available and emerging technologies. The Consumer Curators are those who have perhaps had the most influence on the socio-technical transition in terms of supporting niche technologies and warrant a section and definition all to themselves (section 9.5). The chapter closes with a section with an overview of the interactions between the various actor groups and contains high-level insights about the dematerialisation transition of music consumption (section 9.6).

9.2 Disruptive Entrepreneurs

Entrepreneurs exist at all levels of the multi-level perspective. What makes Disruptive Entrepreneurs a type apart is the way in which they interact with new technologies. The Disruptive Entrepreneurs found in the socio-technical transition of music are part of a long line of self-serving tinkerers who play about with and pull apart new technologies to see how they work. With the emergence of home-

computing these tinkerers could play about with far more sophisticated technologies than before. The difference between technology tinkerers and Disruptive Entrepreneurs is both minor in terms of definition and major in terms of impact. Disruptive Entrepreneurs are those capable tinkerers whose innovations find success beyond their own computers and whose impact translates into new radical social and technological change. In this section, the actions of two Disruptive Entrepreneurs are analysed to better understand disruptive entrepreneurism and the impact on the niche, regime and landscape that they have.

In the cases of Frankel and Fanning (WinAmp and Napster respectively), a very similar set of characteristics emerge. Both were young and lacked any serious commitments short of attending high school and university. Both were capable programmers but more importantly both could spot ways in which radical innovation could be reconfigured to create new, more capable technologies. Neither seemed motivated, initially at least, by anything more than the thrill of creating. Frankel, created to overcome shortcomings he felt existed in existing solutions whilst Fanning did so to meet the requirements of a friend who also felt existing systems were insufficient. Monetisation of their creations came later and typically through the input of other parties. This stitching together of different elements by capable Disruptive Entrepreneurs is a particularly fine example of how innovative elements are brought together to form new novelties. Frankel and Fanning, and those Disruptive Entrepreneurs just like them, take radically new technologies and begin domesticating them for wider consumption (Lie and Sorensen 1996). They are smart in the sense of being able to cognitively recognise the restrictions and potential of new radical innovation and in combining them to develop new capacity for radical innovations. They're also free from restriction as the protective space of their own computers and social setting allow for far greater agency of experimentation (Raven *et al.* 2012). The dissatisfaction with existing solutions and the existing regime is a form of structural condition as identified by Geels and Schot (2010). However, Frankel and Fanning both tied their innovations to social movements.

Frankel and Fanning both pointedly framed their innovations as anti-establishment. This had the effect of amassing appeal with other actors (in this case consumers) who used a conflict with the incumbent regime, the major record labels, to unite together around freedom of all information on in the internet. MP3 was fast achieving pariah status within the established music industry and technologies that interacted with this became pariahs by association. This cultural framing of MP3 as an underdog meant that Winamp and Napster could court fans of the nascent format linking their software to the wider visions and values of the free dissemination of knowledge on the internet. Therefore, we can see the same message occurring again and again with the sharing of music online, from the beginnings of IUMA, through Robertson's MP3.com, Winamp, Napster, the PirateBay and the many other

disruptive entrepreneur dependent companies that attempted to legitimise the concept of "free music". When these innovations first appeared, they lacked the resources of the existing regime. However, through the enrolment of other actors and specifically social movements these innovations could increase their resources.

The appeal of social movements centred around innovations are the opportunities they present to actors from other sectors looking to diversify. They do so by adding resources to the novelty to help steer the trajectory of the niche. These additional actors are themselves forms of Disruptive Entrepreneurs who seek to exploit innovations. The potential benefit to them if they can exert influence over the trajectory can be considerable. AOL, whose mission was to become *the* entertainment portal at the expense of other entertainment-based regimes, invested heavily in Nullsoft (Winamp's parent company); similarly, Hummer Winblad had invested heavily in Napster (and Liquid Audio before it). Such investment supports an increased dissemination of the innovation increasing its likelihood of becoming the dominant design through which the existing socio-technical regime is challenged when a window of opportunity opens.

Through the domestication of radical innovation and considerable investment Winamp and Napster became hugely successful. However, the line of innovation neither started nor stopped with Frankel and Fanning. They are distinguished only by their apparent success in linking together other innovations in a way that found commercial success and mass cultural appeal. There were and are many other potential Disruptive Entrepreneurs busy tinkering away, constantly refreshing the innovation before finding ways to piece together innovation in a construction like manner, or by pushing the boundaries of the radical still further. Winamp and Napster managed both, paving the way for technological mimics, and more importantly for other Disruptive Entrepreneurs to continue innovating as they had done.

The record industry, in refusing to engage with the Disruptive Entrepreneurs and the novelties they were developing sought to exude control over these technologies to stifle them. The result was that in not incorporating the new technologies into their existing models they further invigorated the trajectory of the new innovations. The demand for dematerialised music consumption was apparent but the negative social interactions between incumbent and novelty meant that more consumers became involved in the niche altering their purchasing habits and modifying the rules that they had become accustomed to when consuming music. This effectively increased the resources of the niche so that when landscape pressures, such as congressional acts, had an impact of the incumbent regime, the niche could destabilise the incumbent regime and force it to re-orient its approach as the following section discusses.

9.3 Cartel of Condemnation and Litigation

The Cartel of Condemnation and Litigation is, in many ways, the antithesis of the disruptive entrepreneur type. Whereas Disruptive Entrepreneurs and the actors they enrol into their movement seek to challenge the incumbent regime in a bid to transform it, the cartel seeks to preserve the incumbent socio-technical regime. The cartel, consisting primarily of the RIAA and its members but also other recording industry bodies worldwide, opted for several strategies to stop the stabilisation of innovation found in the technological niches. These strategies fell broadly into two categories as identified in the historical narrative analysis: publicly condemning innovation and litigating against it.

The RIAA was relatively quick to begin litigating against those who posted music freely online. In doing so, they linked MP3 to a narrative they had used before about perceived music piracy (see "home taping is killing music", the legal battle against the DAT technology and similar campaigns). Therefore, through taking legal action against the early online file sharers, those who shared MP3s, they were quite reasonably attempting to stop a new online version to a recurrent offline problem. In their fight against these early unlawful online archives the RIAA began attempting to delegitimise the MP3 format as they portrayed it as a device for piracy and not just a neutral audio compression format. This narrative was rapidly expanded to all aspects of MP3 culture as MP3 began to be embedded at a social level through different channels such as MP3.com, the increasingly widespread use of MP3 software such as Winamp and through unlawful MP3 sharing websites. However, as much as the RIAA attempted to delegitimise MP3 to retard public acceptance of the technology, in a twist of rich irony they highlighted the technology to many potentially interested parties who had hitherto been unaware. The RIAA vs Diamond case, which came about due to Diamond attempting to launch what would become the first popular portable MP3 player, raised the profile of MP3 considerably. With the cartel litigating against MP3, the MP3 as underdog cultural construct was also legitimised fuelling the belief that MP3 was a legitimate channel through which to "bring down" the existing music industry. Any attempt to frame MP3 in a negative manner failed as the much-maligned RIAA (and the rest of the cartel) became the Goliath to MP3's David.

Not only were there those who felt they were joining the fight against the cartel as some sort of moral crusade in which they were attempting to free music from the clutches of a despicable empire but also those who were slower to adopt the new technology. The second wave adopters appear to have had different motivations spurred on by the unintentional cultural framing from the cartel of free music. As such, users either sought to free music, or sought out free music or some combination of the two. It was from this platform of public acceptance, and the difficulties users had in obtaining high quality music (in terms of both compression and listenability – see section 6.5.3), that Fanning developed Napster as a means of truly freeing entire catalogues of music for free.

Due to the cartel litigating against Napster its vulnerabilities to the law were exposed. Imitators sought to circumvent the elements of the technology that the cartel had successfully stopped in the courts. Napster with its central database of files was deemed unlawful and imitators stepped in with decentralised databases. Once the idea of peer to peer file sharing had become accepted by a significant number of people in the general population there was little that the cartel could do except litigate further. Such litigation included petitioning individuals, some of which were children, who the cartel claimed had infringed on RIAA member's copyright. This was a deeply unsuccessful tactic that strongly influenced public opinion further against the cartel.

Attempts to delegitimise the technology through negative discourses and associations (file sharing as theft) were unsuccessful for the cartel (Geels and Verhees 2011). The creation of the MP3 format as part of the MPEG standard created unintended problems for the Record Industry and opportunities that Disruptive Entrepreneurs could exploit. The opportunities led to further innovation becoming available within the niche that helped stabilise the MP3 novelty leading to an innovation cascade that saw new combinations of technologies that the Record industry sought to influence. The institutional change that was occurring lead to struggles between the new entrants and the incumbent regime. Weakened by the continuing and increasing use of peer to peer file sharing despite some successful attempts in the law courts and damaged by their own litigation against individuals the cartel was forced to look for alternatives to the Cartel of Condemnation and Litigation approach.

9.4 Reluctant Partners

The Disruptive Entrepreneurs sought to implement a technological substitution and a deep institutional change in the way music was controlled and consumed. With the cartel's attempts to assert control over the niche innovations largely unsuccessful two important developments occurred in the way the incumbent regime dealt with the increasingly stable niche. The cartel had seen some success in the courts and had been able to obtain some technology at the heart of some niche actors which enabled both downloads and streaming to PCs. With access to this technology the labels tried and failed to launch their own lawful alternatives to the unlawful file sharing networks which enabled the downloading of files. Whereas the niche had previously been attempting to substitute the incumbent regime for a very different model of music consumption, in legitimising dematerialised sound-carriers for the first time, by launching their own market places, the incumbent regime shifted the transition path of the niche from that of one intent on substitution to one of transformation. This legitimised file sharing but because of the record labels' heavy-handed restrictions was unsuccessful. There was still little impetus for those using unlawful file sharing services to switch to lawful download channels that offered small catalogues and awkward allowances with what they could do with the files they obtained (see section 9.5). However, the launch of these services showed a significant change in

the cultural framing of file sharing from the cartel who now chose to engage with the technology rather than attempt to destroy it through the courts (assuming one does not interpret the lacklustre offerings of the labels as an attempt to sabotage and make the technology untenable as Judge Patel suggested in her ruling). For the first time, labels recognised public demand for new technology which provided new windows of opportunity. It also meant that the earlier struggles between the two actor types were also reconfigured as new alliances between the incumbents and the new entrants emerged to an extent. Rothaermel (2001) noted in his analysis of alliances in the pharmaceutical industry that incumbents can maintain control because they have access to complimentary assets within their boundaries that the niche actors require to progress their novelty and that this interfirm cooperation is typically exploitative towards niche actors. What we see in the music industry however is that the key asset of the music industry, copyright, was being shared widely with the music industry unable to exert control in a way that could stop file sharing as a rapidly adopted new user practice.

In the face of both landscape pressures from congress inter alia, and the loss of control over their most important asset the music industry was forced to begin co-operating with regime actors in a way that meant they shared copyright works to establish a new lawful marketplace.

Apple, a new entrant to the niche who replicated and refined existing MP3 technology to launch their own hardware, successfully negotiated licensing terms with the labels providing for the first time the first end to end purchase and listening system (iTunes and the iPod) that could be used simply by consumers. Music was of relatively high quality and transferred quickly to portable players. When Apple launched the iTunes store for Windows PCs sales exploded. Although dematerialised music could be purchased legally before the launch of the iTunes store, sales were relatively small. Apple changed the cultural framing of dematerialised sound carriers; those who used MP3s were no longer seen purely as criminals. Apple changed dematerialised music into a proper mainstream commodity. As such, the niche technology had successfully broken through to the socio-technical regime despite the attempts made by the record labels to stop this happening. Piracy did not go away, but the success of a legitimate method of dematerialised consumption meant that the technology had successfully navigated the many potential pitfalls of technological niches breaking through to the socio-technical regime. The interfirm alliance entered into by the record industry and Apple (and other smaller firms) was clearly done under a form of duress. The record industries attempt to transform the incumbent regime by retaining exclusivity to their assets had failed. In striking a strategic alliance with Apple under such conditions the music industry lost a lot of control of its copyrighted works once again. Crucially however, where file sharing meant a total loss of control the deal with Apple allowed them to retain some control and influence. However, the transition pathway changed once again from a transformation and reverted to a substitution pathway in which Apple, as a new entrant, challenged

the incumbent regimes distribution models in a way that more closely resembled that of file sharing except with some monetary exchange.

This initial reconfiguration of the regime, in many ways, inverted the power of the incumbent regime. Whilst the major record labels still controlled copyright, their earlier reluctance to engage with niche actors and their novelties resulted in them seceding control of copyright distribution to a new entrant which was able to exert power over them as they became increasingly reliant on that distribution model.

9.5 Reinvigorated Regime Actors

The key actors in the incumbent regime did not really change in the adjusted socio-technical regime. The major labels remained powerful actors although clearly affected by the change. What distinguishes them from the role they had in the incumbent regime is the nature of their control. Within the incumbent regime the record labels were essentially all powerful. They controlled the content and the means of distribution. Due to regime reconfiguration, the labels were no longer solely responsible because their content was distributed unlawfully by other actors. They further lost control when new distribution actors emerged such as Apple and when traditional record stores, unable to adapt sufficiently to the new regime configuration, began to close which saw a shift in copyright distribution channels and ultimately a destabilisation of the incumbent regime.

Whilst the music industry did not immediately rebound to the level of profits it had been making pre-Napster the success of legitimate online sales saw record labels acknowledging that online market places were going to become a major source of revenue. Apple however was by the far the most powerful of the online retailers. This led to record labels attempting to increase competition between different market places in an apparent attempt to force Apple to increase prices or risk losing licence agreements. This bid to enrol additional actors saw once again the transition path change to one of transformation in which the incumbent regime, albeit a reconfigured music industry, attempt to cultivate more interfirm alliances in a bid to exert control over Apple's radical new distribution model. In doing so, consumers turned away once more from pay to download services as they disapproved of the tiered pricing and issues of some services offering artists whilst others did not which led to confusion in the market place. This provided new windows of opportunity for music streaming services which offered advert supported streaming music. Music streaming had long been the technologically poorer cousin of music downloads. Early attempts to stream music had struggled with poor bandwidth which had forced content providers to use very low bit-rates making music all but unlistenable. Even with somewhat faster speeds, with the launch of the music industry's own online platforms, consumers had found it difficult to hear the appeal of streaming music. As such, music streaming had

little internal momentum and failed to break through. As discussed in section 8.3, once speeds had increased and quality improved, streaming technology was able to break through because of the attempted manipulation of online markets by the major labels. It also appealed to those who had continued downloading music through unlawful means as the various technologies that continued to be utilised by file sharers were either closed through litigation or sharing became untenable as user numbers declined. This once again shifted the transition pathway to one of a substitution in which the existing distribution models of physical media and downloads of AAC files saw further new entrants challenged by streaming services. The streaming services had benefited from legislation that enabled their novelties to be lawful and had put the major labels in a position in which they were forced to license their copyright works in a way that offered parity with the existing distribution models. Further, the continued existence of "free music" and the dislike of the download distribution models tiered pricing created new space within the market for consumers who continued to be disillusioned by DRM (digital rights management) and the ongoing conflict of labels and digital distributors.

9.6 Consumer Curators

Constant through the transitions has been the consumer influence, both as individuals and as collectives, that have shaped transition pathways. Consumer response to the other key actors detailed above cannot be understated. The term Consumer Curator comes from the willingness of these consumers to select and bring together various new technologies into their existing consumption patterns to create new behaviours of procurement and consumption. A normal consumer might be presented with an already complete solution contained within a single product. Consumer Curators however are presented with a number of competing technologies that alone require additional products and changes to user practice. Early MP3 players for example were nothing without the technologies required to obtain music even through ripping or downloading (see section 6.5.3). There appear to be at least two types of Consumer Curator predicated to either seeking out new technology to solve specific needs they may have or adopting new technology into their lives as it is proving popular with others. Failure to attract the first group leads to a failure of the product whereas failure to attract the second group tends to lead to further innovation. Consumer Curators appear distinct from the normal consumer type although are not necessarily unique to the music consumers. Indeed, the types of consumers detailed here likely have the same appetites and willingness to engage with new technologies across a range of regimes. Consumer Curators have an appetite for risk not present in mass-market consumers. The first Consumer Curator group are bigger risk takers than the second. They willingly engage with unlawful activity as well as adopt nascent technology that is often expensive to support their new and emerging consumption habit. Further this willingness extends across regimes allowing for important combinations of new technologies through multi-regime

interaction. This can be seen throughout the historical analysis such as in the combining of computers with music consumption via CD-ROM drives as a novel means of consuming music. Within their involvement of niche actors and regime incumbents they appear to believe that any unlawful activity on their part is because the law and the incumbent regime has yet to catch up to new ways of thinking (for example MP3.com users in section 6.8.1). The second group who are more risk adverse view the activity of the first group as having legitimised both the technology and the unlawful activity in so much as they may not even recognise that downloading music through services such as Napster was unlawful as it appeared to be an increasingly popular method of obtaining music. This greater naivety and willingness to tread the path already created by the first group helps propagate adoption of technology and behaviour change more rampantly (see section 6.5.3 for examples of this). The following section will consider these two groups and their interactions with the other actors, highlighting specific adoption of Napster and rejection of PressPlay and MusicNet.

Acquisition of music online in the late 1990s was a somewhat complicated affair open only to those with high-speed connections and armed with the knowledge of the websites used to host pirated music, the so-called "internet music archive sites" (see section 6.5.4). The specific sites were not well advertised and for many the introduction to them came via well publicised legal challenges from the RIAA. The legitimate online stores that did exist required payment, specifically bank accounts with credit or debit cards linked to them and offered a very limited choice to consumers offering little to appeal to young people and students who lacked the means and impetus to purchase the MP3s (and its alternatives). Indeed, within this socio-technical transition it seems that the Consumer Creator groups identified consisted largely of younger people and students as they had less established user practices in terms of consuming music and access to higher speed internet connections through their colleges and universities. Fanning recognised the issues as eschewed by his dormmate at the time. His response in creating Napster brought together those that were already familiar with accessing the unlawful internet music archives and those consumers who found it a neat solution to accessing MP3 collections for the first time. That both the software and the music archives offered were free undoubtedly helped the software spread as barriers to entry were minimised in a way both the unlawful sites and the lawful sites experienced. Existing pirate groups found Napster a suitable means through which to disseminate "their" product. The major motivation for such groups was to provide high quality MP3s across a range of genres simply for the kudos of doing so. These groups always attached their name to the MP3s they disseminated. Certain groups were considered more trustworthy than others by consumers although there were multiple instances of "forgery" where by individuals and other groups would seek to release lower quality MP3 rips under the name of the most popular groups.

Consumers responded to Napster because it met many of the innovation needs of a group of consumers who were willing and able to engage with technological innovation alongside being music fans, it provided a safer space to download music easily as downloads could be resumed which meant slower less stable internet connections could access the files with far fewer interruptions. Further, the question of legality was obscured by the software itself. The response was to enrol additional actors into this far more stable and reliable technology in a way the other methods of online music distribution was failing to do at the time. Indeed, this type of distributed system still formed the theoretical basis of Spotify over a decade later. Consumers spread word of Napster through internet forums and offline discussions propelling the software into the spotlight and onto the computers of millions of users. That Napster lowered the barriers of entry required to obtain MP3s compared to all other distribution models at the time was the major attraction for Consumer Curators who through individual action elected Napster to become the primary distribution channel of music on the web. Access was an all important factor for music fans, indeed it's a known contradiction that those who downloaded the most illegal content via P2P services such as Napster were also likely to be the biggest consumers of lawfully obtained music (Fisher 2006; Cheng 2009). It should be noted that issues of access surrounding new technologies is likely not unique to music fans and the ability to access and engage with technological innovation is something that would have an impact on consumers more widely. The major labels made it difficult for consumers to purchase individual tracks often combining old demos and hastily recorded tracks into an album package which increased the cost to access the one song that consumers wanted (see Bhattacharjee *et al.* 2003 for further discussion of CD cost impacts on piracy). What Napster did for consumers was to give them a means through which to cherry pick. Indeed, it was this mode of consumption that was attempted by the major labels in the fall out of their legal obstructions as part of the Cartel of Condemnation and Litigation against the most popular Disruptive Entrepreneurs.

With the shutting down of Napster and the rise of alternatives Consumer Curators still had a lot of choice for obtaining music in a manner similar enough to Napster to largely not notice much of a difference. However, because of the litigation the major labels had been able to obtain much of the music distribution technology behind software such as Napster and sites such as MP3.com. PressPlay and MusicNet were based on two fundamentally incompatible services backed by Microsoft and RealNetworks respectively and who were in a fierce conflict with one another. Barriers to entry were once again increased for Consumer Curators i.e. those music fans who sought to obtain music online, as discussed in section 7.3.2, the major labels launched services that were severely hobbled with DRM and restrictions into the number of tracks that could be downloaded and streamed. Furthermore, the services were expensive and did not work well with the portable music players that were increasing

in availability. Those consumers that did start to use the services found many problems such as the inability for the music to be played on portable MP3 players they already owned, an issue not found with music catalogues of other unlawful distribution channels. As a result, those Consumer Curators who did adopt the service did not encourage others to do the same as issues around innovation and access proved difficult to overcome. Consumers recommending a service to other potential consumers who are more risk averse is an important motivating factor in encouraging new consumers to engage with new technology and create new transition pathways. When the initial wave of innovation seeking, Consumer Curators fail to enrol the second wave of potential consumers these technological offerings stall and fail to find a footing in the market.

It is worth noting that the Consumer Curators' motivations seem rather transparent through their actions. Throughout the socio-technical transition from physical media to digital services Consumer Curators have opted for those services that offered innovative means of music consumption selected from different regimes combined with providing the means to access music without complex rules dictating what can be streamed or downloaded and on what systems they can be played on. That entirely free services, however unlawful, are still available but are now dwarfed by lawful online services (Spotify, Apple Music etc) suggests however that ease of use without the ethical dilemma of "stealing" music is a more important factor for most Consumer Curators than simply having unlimited access to an entirely free library of music. Throughout questions about the reduction in environmental resource use because of the various methods for music consumption seems to have been moot to almost all Consumer Curators. Indeed, the resurgence in a market for resource heavy vinyl records seems to suggest that any environmental resource reduction in the socio-technical transition of the music industry over the last three decades has been entirely coincidental to the availability of new innovative means of music consumption that has increased access and lowered costs.

9.7 Conclusion

This chapter endeavoured to answer research questions 1(c) to 2(b). It has shown that the music industry has experienced dematerialisation in the modes of consumption for the personal consumption of music. The key implication from the illustrative examples is that convergent technologies have enhanced any dematerialisation that has occurred: the more uses to the user a piece of technology has the smaller the environmental impact of the function. However, as individuals purchase converged technology at an increased rate, particularly smart phones, and for a resurgence in tactile purchases of physical products such as Vinyl albums, suggests there is the potential for any reduction in resources to be eroded.

This section also highlighted how actors influence transition, the movement of actors and their shifting coalitions and the control this exerts on the transition. The impact of such influence alters the transition path fundamentally between the niche and the regime effecting whether the transition is that of substitution or transformation. The roles of five types of actors were highlighted. Those within the niche organised around technological capabilities and influenced actors outside of the incumbent regime to force substitution of the existing technology. Actors within the regime, used their economic position to attempt to either halt such substitution or adapt to it allowing for a more regime-controlled transformation. Additionally, new entrants from external regimes could seize opportunities afforded by changes in the regime to exert additional pressures on the regime as well as to introduce their own novelties, such as Apple with the iPod and iTunes store. Ultimately, as the incumbent regime actors accepted the new technologies and the rule changes that went with them as selected by Consumer Curators the music industry saw the institutionalisation of the novelties. This provided further windows of opportunity for additional actors in related niches to attempt to substitute or transform the regime with further novelties that lowered the barriers of entry for Consumer Curators.

In the final chapter, these discussions are brought to their conclusions and assessed against the questions that initiated the research and discussions initially. Further the implications of the findings for the literature and contributions to it.

10 Conclusion

10.1 Research Overview

This thesis sought to question a flippant remark made by a visiting lecturer "CDs used fewer resources than vinyl and Mp3s fewer still". It quickly became clear in trying to find evidence for this assertion that there was little that supported the hypothesis or indeed much that invalidated it. Formed around this, the investigation has sought to explore the resource impact, and the how, why and by what means the socio-technical transition of music sound carriers has occurred. This dissertation also tested the assertion that dematerialisation was occurring within these transitions.

In answering these questions, two distinct but ultimately compatible approaches to addressing the research questions were utilised. The multi-level perspective was used as a framework through which to construct a historical narrative and later provide insight during analysis of the different transition patterns and actor related mechanisms. The Material Intensity Per Service (MIPS) methodology was used as a tool to measure and provide illustrative accounts of the resources used for different modes of music consumption. As such, the research was situated in the field of technology transition analysis, chiefly that of the socio-technical transition literature (Geels 2002; Geels 2005b; Geels and Kemp 2007; Rip and Kemp 1998; Raven 2007; Smith *et al.* 2005). In identifying criticism of the existing multi-level perspective methodology, a more refined approach utilising primary and secondary sources more in tune with historical methodologies was developed. The multi-level perspective, allowed for the construction of a detailed historical narrative and allowed for the examination of the complex socio-technical transitions occurring across the music industry and technology sectors through the 1970s into the present day. Where the multi-level perspective provided the how and why of the investigation, the MIPS methodology allowed for the illustration of the transitions' impact on the resource use of music consumption. Together, the two distinct approaches allowed for a much clearer understanding of the processes of dematerialisation in music consumption.

The historical narrative was extensive and constructed using some thousand primary sources and a few hundred secondary sources. The sources were stitched together temporarily and thematically into a detailed historical narrative document addressing technology and the music industry from the mid-1970s through to the present. A clearer story of socio-technical transition and the actors involved the transition from physical to dematerialised sound-carriers was then distilled from this. Once this narrative was derived and current consumption patterns established the MIPs methodology was used to create a series of music consumption-based scenarios. These scenarios were used to highlight the differences in resource use between the different scenarios and as such the impact of the different music consumption technology transitions on resource usage.

The MIPS methodology allowed for the testing of the assertion that music consumption had dematerialised over the course of the socio-technical transitions. Where dematerialisation had been discussed previously in the literature the conclusions drawn tended to state that when any transition occurs any initial dematerialisation is eventually replaced by substitution of the original material. Hence a period of dematerialisation is always followed by a period of rematerialisation. Such studies however, had been looking at material consumption at the state level and very few studies exist which question such a hypothesis at the level of regular household and personal consumption.

10.2 Research findings

10.2.1. Dematerialisation in music consumption

This thesis has sought to test the hypothesis that dematerialisation was occurring in the processes of music consumption. Addressing this hypothesis has allowed for an understanding of dematerialisation not previously addressed in the literature and has given an understanding of the nature of resource use in complex socio-technical transitions and the difficulties in quantifying resource use.

In examining the Material Intensity per Listening session of the most popular ways people consume music the dematerialisation of music consumption became apparent. It also identified that the most recent transition to streaming services has seen an increase in resource use over that of downloading music, something Weber *et al,* (2010) suggested may happen. This overall streaming resource use is likely to be reduced over time as efficiencies in data centres and in transferring data around the internet improve. Due to the nature of streaming it is likely to always be a more resource intensive way of consuming music over downloads. The research also revealed the importance of convergence in reducing resource use. The lifestyle of high consumption of technology that this type of convergence has created, poses a risk to the continued reduction in resource use. High turnover of personal technology products such as smart phones means that the life cycle of these items is reduced artificially as still functional items are rejected in favour of newer models where expanding their life would significantly reduce the overall environmental effect (Proske *et al.* 2016; Seland 2015).

Consequently, this thesis has challenged the existing thinking on the sustained nature of dematerialisation demonstrating that resource use has decreased continuously over the course of nearly two decades. Although the increased resource use of streaming seems to suggest some rematerialisation is as predicted in the literature, as stated above this, rematerialisation represents a different type of music consumption and the associated resource use is likely to continue to decrease. What form of consumption is likely to become truly dominant is difficult to predict although the continued growth of streaming services suggests it will begin to dominate although such predictions are not within the remit of this research.

10.2.2. Facilitating and controlling transition

The thesis has identified several actor types present within the socio-technical transition of music consumption as well as the influence these actors have namely, Disruptive Entrepreneurs, Cartels of Condemnation and Litigation, Reluctant Partners, Reinvigorated Regime Actors and Consumer Curators. It also identifies the transition mechanisms through which the actors exert their influence on the transitions. Focus was paid to those actors who it was felt were the most prominent at different stages of transition and it should be noted that other actors and groups also played their part in the socio-technical transition. Within each of these actor groups specific actors were used to illustrate the nature and motives of the wider group as well as to assess their influence on the transition pathways. The research highlighted how the five actor groups used, developed or attempted to hinder technological development to shift music consumption in a manner through which they increased their control over it. It highlighted the role of unlawful downloading of music. The groups all interacted with it in different ways. In summary, the Disruptive Entrepreneurs used it with wild indifference, overwhelmingly they saw it as the future of music consumption and tailored their products to embrace this. The Cartel of Condemnation and Litigation sought to halt any attempts to promote such a consumption pattern either through condemnation of it in the wider media and by refusing to allow artists to promote their music through dematerialised sound-carriers. When condemnation failed the cartel (chiefly the RIAA and the major labels it represented) took litigative action in a bid to legally halt any legitimisation of dematerialised sound-carriers. When this too failed to halt the increasing consumption of dematerialised sound-carriers the major labels reluctantly began to partner with the technology they'd previously attempted to litigate out of existence, this allowed other technology companies such as Apple to massively improve market conditions as well as redefine the process through which dematerialised sound-carriers could be purchased and legitimised. Having reinvigorated the market the major labels attempted to regain control as throughout unlawful file sharing was still rampant, particularly in markets in which Apple alone seemed to dominate. Interacting with these actors throughout were the Consumer Curators, it was they who accepted or rejected new technologies and means of consumption in a bid to seemingly access music in a manner that wasn't dictated to them by the major labels who were frequently viewed with distrust and distaste. Rarely was the environmental impact of the socio-technical transition considered, instead consumers were motivated by the adoption of exciting new technologies which increased ease of use and access to music. The interaction between the actor groups also demonstrated that the complex relationships between regime and niche dictate whether technological substitution or transformation was occurring.

Without environmental concern for dematerialised sound-carriers the socio-technical transitions and the motivations for the actor groups has to be understood in a different way. The analysis charted how the socio-technical transition developed in the hands of technologists and tinkerers whose own motives were not overt but appear to have been unmotivated by economic reasons. In many cases, as with Frankel and Fanning, innovation occurred because of experimentation of what was technologically possible along with adaptation to address certain perceived problems. These new technologies were typically shared for free and allowed consumers to access and playback music for free. The analysis identified how consumers, much like the Disruptive Entrepreneurs acted with little responsibility. Expectations change as the result of the availability of free software which gave access to free music however with internet users increasingly coming to expect that music obtained online would and should be free. The analysis linked this expectation to the wider culture disseminating data for free online in the manner of a free knowledge utopia.

The analysis identified the way in which the RIAA and record labels worked in a cartel like way to halt the innovation through both legal channels and through condemnation by association. This cartel like behaviour can be linked to other multi-level perspective studies and this finding contributes to this. The analysis demonstrated the multifaceted way in which the RIAA and record labels attempted to force their will upon the innovators. Identified was the manner through which the cartel attempted to control dissemination of innovation. Through attempting to discredit the technological innovations in court the cartel attempted to frame the entire file sharing and compression technologies culturally as illegal methods for wholesale copyright infringement as they had done previously with other technologies. This behaviour exceeds that of other cartels identified in the literature who typically acted only as a single-minded group in adopting or not committing to new technology. Instead the cartel of litigation and condemnation demonstrated a single mindedness in protecting themselves as actors within the incumbent regime from what they saw as a threat and went to great extents to suppress it either through the courts or through public opinion. The analysis highlighted how this was an ultimately ineffective set of actions to attempt to stabilise the regime and provided windows of opportunity for niche actors and new entrants to influence the technological substitution pathway resulting in a destabilised regime. The cultural narrative of music being freed from the shackles of the evil record labels proved more popular especially amongst a music consuming public who were increasingly unwilling to support the status quo as they felt they were being exploited.

The analysis demonstrated how after a combination of court room defeats, a wider inability to halt the spread of peer to peer file sharing technologies, the unsuccessful attempts to delegitimise music compression technologies and the failure of their own compressed audio market places, the record labels became more accepting of the new technologies as a means through which to regain control.

Discussed and explained was the way the labels began striking deals with technology companies and opening their content catalogues for licensing by third parties. They did so reluctantly, with pressure from both the courts and congress added to the wider consumer pressures. The analysis also discussed how the most successful partnering came from Apple, a technology company, who paired the vast content libraries of the music industry with a product designed to hold vast amounts of content. When this offering became available to all personal computer users and not just Apple consumers, sales of both MP3s and Apple's Mp3 player far exceeded predictions and expectations at the time. The success of Apple's iTunes saw other competitors also become more successful although Apple maintained market dominance.

The analysis revealed how this market dominance was problematic for the record labels and demonstrated the methods used to try and increase competition amongst the different online marketplaces. In a bid to increase the value of their content the record labels pressured Apple to change the pricing structure of MP3s. Consequently, uncertainty in pricing confused consumers but did in some way increase competition across the different marketplaces. However, the analysis showed that this uncertainty provided an important window of opportunity for streaming content as consumers aggravated by the increase in price of newly released songs searched for alternative methods through which to hear them. As shown in the analysis digital music sales have been in decline since this period with the streaming subscription models growing by 25% year on year. As with the digital music marketplaces these streaming services were developed by technologists rather than those within the music industry. As Reinvigorated Regime Actors, the record industry failed to regain control of their content in the meaningful way they seemed to intend. The analysis reflects on this loss of control and the failed attempts to steer the emerging transitions by the music industry.

10.2.3. Transition pathways and mechanisms

The analysis identified and discussed several transition pathways and transition mechanisms. The multi-level perspective literature typically identifies one pathway or mechanism per transition. However, the way transitions are presented in the literature are often in far more abstract terms than those presented in the analysis. As such, given the complex nature of the transitions and the length of time over which they occurred the analysis identified several pathways and mechanisms for different parts of the transition which together formed part of the overall transition.

These dynamic transition elements were identified within the niche, the incumbent regimes and from other socio-technical regimes. The earliest innovations were developed in the hands of technologists and Disruptive Entrepreneurs who originally sat entirely outside the music industry regime. The impact the computer industry in seeking to utilise the CD as a means of data storage was likely never predicted. As these new technologies gained footholds with consumers however, these niche

innovations could sustain themselves and subsequently attract further innovation, consumers and users which in turn led to innovations that directly impacted the music industry regime. Individual dematerialised sound carriers, were identified as forming part of the wider innovation of dematerialised sound carriers of which MP3 was the most well-known. The accumulation of the various sound carriers and associated technologies was somewhat protracted, in part because of the attempts to control it by actors within the incumbent regime, but also because of a technological deficit in other regimes. The analysis identified several areas in which this was the case: the proliferation of broadband internet for example, was an important development in terms of accessing files in a timely manner that aided consumer adoption of dematerialised sound carriers. Earlier iterations of online "marketplaces" had always suffered with the length of time and high failure rate of music downloads. As identified in the analysis consumers were hesitant to pay for music they could not download efficiently.

The analysis also identified and discussed several actor-related mechanisms, four of which were discussed at length in section 10.2.2. Other mechanisms were also identified in the analysis and the complex way these operated with one. As a result of these transition mechanisms and attempts to control innovation the incumbent regime was frequently forced to transform in a bid to stave of the substitution of the regime by niche innovation developed in the protective spaces of otherwise unrelated regimes. This multi-regime interaction highlighted that the interconnectivity of niche actors and new entrants resulted in a loss of stability of the incumbent regime whereupon broad diffusion of the dematerialised sound carriers occurred.

10.3. Research contributions

Analysis of dematerialisation at the level of an individual's consumption is particularly limited with few scant mentions in the existing literature. This research aims to addresses this deficit by focusing on the somewhat mundane everyday activity of listening to music. It was chosen chiefly because music consumption is considered innocuous and had appeared to have undergone processes of dematerialisation over the last two decades. By approaching dematerialisation from this perspective rather than at the supra-national level of existing studies this research presented an original and critical examination of dematerialisation of consumption. The research had a number of aims and objectives and these are revisited here so as to understand the research contributions made by the thesis.

The first objective was to understand the nature of dematerialisation in the music industry through the enhancement of methodological implementation of the multi-level perspective on socio-technical transitions. This aim had three associated research questions:

a. How do we enhance the methodological implementation of the multi-level perspective on socio-technical transitions to establish how socio-technical transitions in sound-carriers come about?

The research enhanced methodological implementation by utilising an historical analysis approach which adhered to strict guidelines around the quality of historical sources carefully building an archive of primary and secondary sources in a manner not detailed in the current literature. The thesis developed a large historical narrative (Chapters 5-9) that was analysed using the multi-level perspective on socio-technical transitions as a framework for identifying socio-technical regimes and socio-technical niches as well as transition patterns and mechanisms alongside influential actors (Chapter 9). The research design was implemented in such a way as to address existing criticisms of the multi-level perspective found in the literature as well as those made during the literature review. As such, the research made several practical contributions to the multi-level perspective methodology. Chiefly, the research sought ways in which to increase the credibility of the historical narrative. This was achieved by following exemplary methods, in particular those of Marwick (1989), for ensuring that primary and secondary sources were legitimate. As a result of observing these methodologies the research could construct an historical narrative from many primary sources which were well sourced and open in its construction, unlike many of the narratives found in the multi-level perspective literature. As a result, the multi-level perspective methodology was improved in its execution; the greater transparency of the sources made the narrative less susceptible to criticisms around the narratives presentation and provided a more robust and systematic methodology for narrative construction than the "illustrative" over-views that feature so heavily in the literature. The chief contribution of this research to the multi-level perspective literature was to demonstrate that despite the multi-level perspective being a complex ontology it is also capable of having a more developed and complex methodology without it being burdened by excessively rigorous procedures (Geels 2011: 36).

b. How do multi-regime interactions shape technological change and what impact do these have in enabling socio-technical transitions?

The research explored multi-regime interactions, in particular the "interrelated transformation dynamics in production, consumption and governance" (Konrad *et al.* 2008 p.1190). The analysis identified a number of multi-regime interactions such as the impact of developments in the Computer industry (CD-ROM inclusion in PCs – see section 5.3.1), and the combining of different technological niche innovations from across a number of audio-visual regimes in the development of the MPEG standard (see sections 5.3.2 and 5.3.3) as well as the role of Apple a hitherto purely technology based

company had in consolidating new user practices and technology to become the dominant music retailer (see section 7.4.3). The analysis added these multi-regime interactions to the wider narrative of technological change and demonstrated how these various multi-regime interactions were pivotal in the socio-technical transition of music consumption.

Focus was paid to the influence of niche innovations in the computing regime on the development of niches in several other regimes with emphasis the consumption of music. The MPEG meetings provided the context for these multi-regime interactions. This provided further weight to the argument made by Geels that niche innovations can require "interactions between two (or more) regimes" (2011 p.32) and provided concrete examples of the positive and negative influences the transitions and niche innovations have on each other such as the music industry actively attempting to halt the influence of the computer regime's innovations on their own without success.

The transition of music consumption transcended boundaries, it was at once an international transition to a mode of consumption that is often considered deeply personal to the point of using music consumption as part of one's personal identity. These territorial levels deliberately avoided turning the multi-level perspective into a hierarchical perspective, instead opting to explore the distinctive interactions between actors, technology, innovation and consumption providing explanations of the sequences of the transitions using the detailed historical narrative. This allowed for more explicit statements about why particular innovations were successful whilst other similar innovations failed to stabilise and invigorate transitions. In this way the thesis was responding to calls by Coenen *et al.* (2012) to implement geographical scale as a method through which to better understand the interactions at different scales of the transition such as the different reactions to the innovations developed by Disruptive Entrepreneurs by individual consumers and the global music industry.

c. How do actors lead or constrain transitions within the pathways?

This research questions are interrelated with the second aim of the research as both focus on the role of actors:

2. Determine the roles of actors in multi-regime interactions.

a. What impact to actors have on multi-regime interactions?

The analysis identified a number of actors and actor groups (see Chapter 9) that are pivotal in both leading or constraining transition pathways. Both types were shown to attempt to control the adoption of innovative technologies which were to lead to socio-technical transitions. The analysis showed that it was those actors who had an interest in maintaining the incumbent regime that were

likely to attempt to constrain any attempts to alter this. Those with far less interest in maintaining the position of the incumbent regime or those who actively sought to move away from it were therefore most prominent in leading innovations that would interrupt the incumbent regime.

The thesis third aim was to determine the implications of dematerialisation and it had two associated research questions.

a. How do we develop a method that is sympathetic to a multi-level perspective of socio-technical transitions to measure materialisation and dematerialisation for the consumption of music?
b. What are the processes of dematerialisation and how do they influence the personal consumption of music?

The research provides a number of illustrative examples of the dematerialisation occurring across a range of music consumption related products and consumption methods through the use of the MIPS methodology. Sections 3.4 and 3.5.3 in particular dealt with the development of a methodology that sympathetic to the multi-level perspective on socio-technical transitions where section 8.2 discussed how the historical analysis had provided illustrative examples of how music was consumed that were suitable for analysis using the MIPS methodology. In doing so, it revealed that dematerialisation of music consumption has occurred and continues to do so. It demonstrates, in defiance of existing literature that dematerialisation is an ongoing event with causes and consequences and is not a single event. It also reveals that the processes of rematerialisation found in the transition towards streaming music are likely to be offset by increased efficiency of data transfer. As such, although streaming music is likely to always be more materially intensive than downloading music, the rematerialisation of consumption remains considerably smaller than the consumption of physical media that it is in the process of succeeding. Therefore, this research suggests that consumption at this level contradicts the conclusions drawn about supra-national dematerialisation and rematerialisation patterns. Such literature always concluded that dematerialisation would be followed by a period of rematerialisation where the eventual substitution of the original material by another was almost guaranteed. Although the research stopped short of being able to counter Labys' (2002) assertion of transmaterialisation where reduced material sees its eventual substitution by other materials because of a focus on one sector alone it has highlighted the complexities in attributing responsibility for resource use. The Material Intensity Per Listening Session (MIPLS), allowed for an increased ability of the MIPS methodology to handle comparisons between the consumption of hardware, in converged hardware and for further exploration of the influence dematerialisation had on music consumption.

This research therefore made several original contributions specifically to the multi-level perspective both in terms of theoretical development but also more practically in refining its methodology to create a far more robust standard through which to develop narratives for analysis. It also developed new ways of thinking about dematerialisation and what rematerialisation means in the face of convergent technology and further defined the MIPS methodology as a tool for quantifying the impacts of complex socio-technological transitions.

10.4. Research limitations and future research

This research presented a detailed analysis of a specific set of socio-technological transitions occurring in the way that music is consumed and specifically in the context of dematerialisation. Future research should therefore focus on dematerialising socio-technical transitions in parallel regimes such as the publishing industry (magazine, newspaper, book inter alia), film and television industries, mobile phone industry and home computing industry. Whilst the music industry began transitioning first these industries have also experienced dematerialising socio-technical transitions which promise to give very different insights into dematerialisation and the potential impacts of it for consumption at a household level. The publishing industry is reliant on both computers (as in the music industry) and specialist devices (Ebooks) which have yet to experience the same level of convergence with other devices as seen with smart-phones. Focussing attention on the importance of convergence to dematerialisation of household level consumption of non-essential activities would enable an understanding of the factors that lead to sustained dematerialisation as opposed to consecutive periods of dematerialisation and rematerialisation. It would also allow for a far greater understanding of the role of actors and the way the socio-technical transitions occurred across the different regimes.

The research approach trialled in this research as a response to criticisms of the multi-level perspective should be used in analysing other socio-technical transitions, particularly those around moves towards sustainability. Further construction of primary source based historical narratives and subsequent analysis can only strengthen investigation into complex socio-technical transitions as well as strengthening the multi-level perspective. The multi-level perspective to date has proven itself to be a useful tool for illustrating socio-technical transition but few studies exist, barring this one, that utilise the multi-level perspective as a tool for in depth analysis. In doing so, a better understanding of the explanatory potential it offers can be developed.

Finally, the MIPS methodology, only suitable as an illustrative tool for this work, could be utilised for research into other technologies such as those suggested at the beginning of this sub-section taking on board the criticisms found in section 6.4.2. Alternatively, it could be further developed as an illustrative tool with which to infer resource use. In either manner, the MIPS has been demonstrated

in this research as a tool suitable for providing quantifiable evidence to otherwise abstract theories and analysis of socio-technical change but with clear issues for policy instrument choice for dematerialisation. Future research should test this potential further as a way in which to enrich our understanding of resource demands of complex socio-technical transitions.

Word count: 80,542.

11 References

Aaron, K. 2005. Behind the Music: Jon Rubinstein. *Cornell Engineering Magazine* (*Fall*).

Achat Meuble *mpMan - http://web.maxi-auto.com/mpman*.

Acheampong, E.N., Swilling, M. and Urama, K. 2016. Sustainable Urban Water System Transitions Through Management Reforms in Ghana. *Water Resources Management* 30(*5*), p.pp. 1835–1849.

Adriaanse, A. *et al.* 1997. Resource flows: the material basis of industrial economies. . Available at: http://www.getcited.org/pub/100265431 [Accessed: 29 July 2013].

Aksoy, A. 1992. Mapping the information economy: integration for flexibility. In: Robins, K. ed. *Understanding Information: Business, Technology and Geography*. London: Belhaven Press, pp. 43–60.

Alonso, E. *et al.* 2012. Evaluating Rare Earth Element Availability: A Case with Revolutionary Demand from Clean Technologies. *Environmental Science & Technology* 46(*6*), p.pp. 3406–3414.

Anon 2004. Freedom of choice is what you want! [Online]. Available at: http://web.archive.org/web/20040819005942/http://freedomofmusicchoice.org/ [Accessed: 26 June 2015].

Anon 2005. *Metro-Goldwyn-Mayer Studios Inc. v. Grokster, Ltd.*

Anon 2001. Napster Media Briefing Q&A [Online]. Available at: http://web.archive.org/web/20010222184009/http://www.napster.com/pressroom/010220-qanda.html [Accessed: 11 November 2014].

Anon 2000a. Napster Says Proposals Rejected By Industry. *Billboard* 112(*46*).

Anon 2000b. *Order of the Court of Appeals for the Ninth Circuit in A&M Records et al. v. Napster Inc.,*.

Anon 1999. *Recording Industry v. Diamond Multimedia Systems*.

AOL 1999. America Online Acquires Leading Internet Music Brands -- Spinner.Com, Winamp and SHOUTcast [Online]. Available at: http://www.timewarner.com/newsroom/press-releases/1999/06/01/america-online-acquires-leading-internet-music-brands-spinnercom [Accessed: 11 November 2012].

Apple 2006. Apple - Press Info - Bios - Tony Fadell [Online]. Available at: https://web.archive.org/web/20080319090215/http://www.apple.com/pr/bios/fadell.html [Accessed: 11 June 2015].

Apple 2007. Apple Reinvents the Phone with iPhone [Online]. Available at: https://www.apple.com/pr/library/2002/07/17Apple-Unveils-New-iPods.html.

Apple 2012. *iPhone 5 Environmental Report*.

Applefeld Olson, C. 1999. Ryko Licenses Songs for MP3. *Billboard* 111(*7*).

Archer, G.L. 1938. *History of Radio to 1926*. New York: American Historical Society, Incorporated.

Asdrubali, F., Baldassarri, C. and Fthenakis, V. 2013. Life cycle analysis in the construction sector: Guiding the optimization of conventional Italian buildings. *Energy and Buildings* 64, p.pp. 73–89.

ASSISTANT ATTORNEY GENERAL R. HEWITT PATE 2003. Regarding the Closing of the Digital Music Investigation. . Available at: http://www.justice.gov/atr/public/press_releases/2003/201946.htm [Accessed: 12 December 2014].

Attali, J. 1985. *Noise : the political economy of music*. Minneapolis: University of Minnesota Press.

Atwood, B. 1997a. Enter*Active. *Billboard* 109(*34*).

Atwood, B. 1997b. Nordic Bows Sales of Digitally Sent Music. *Billboard* 109(*17*).

Avelino, F. 2009. Empowerment and the challenge of applying transition management to ongoing projects. *Policy Sciences* 42(*4*), p.p. 369.

Baccini, P. and Brunner, P.H. 2012. *Metabolism of the Anthroposphere: Analysis, Evaluation, Design*. MIT Press.

Bagherian, J. and Lettice, F. 2014. A Multi-Level Perspective Towards Energy Regime Transitions: A wind Energy Diffusion Case Study. In: *International Conference on Sustainable Design and Manufacturing*.

Baliga, J., Ayre, R.W.A., Hinton, K. and Tucker, R. 2011. Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport. *Proceedings of the IEEE* 99(*1*), p.pp. 149–167.

Banerjee, S. 2004. Real Cuts Cost Of Downloads To Promote Harmony Technology. *Billboard* 116(*35*).

Barker, G. 2012. Assessing the Economic Impact of Copyright Law: Evidence of the Effect of Free Music Downloads on the Purchase of Music CDs. . Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1990153 [Accessed: 28 August 2012].

Barles, S., Chatzimpiros, P. and KIM, E. 2012. Urban metabolism: major flows, major issues for dematerialisation. Some results from French case studies. In: *ISEE 2012 Conference-Ecological Economics and Rio+ 20: Challenges and Contributions for a Green Economy*.

Barraclough, G. 1955. *History in a changing world*. Oxford: Blackwell.

Basset-Mens, C., Ledgard, S. and Boyes, M. 2009. Eco-efficiency of intensification scenarios for milk production in New Zealand. *Ecological economics* 68(*6*), p.pp. 1615–1625.

BBC 2001. Online music service Pressplay launches. *BBC*. Available at: http://news.bbc.co.uk/1/hi/entertainment/1719113.stm [Accessed: 3 June 2015].

BBC News 2001. The man behind Napster. *BBC*. Available at: http://news.bbc.co.uk/1/hi/business/1167876.stm [Accessed: 13 May 2015].

Bellini, F., D'Ascenzo, F., Ghi, A., Spagnoli, F. and Traversi, V. 2013. The Impact of e-Invoicing on Businesses Eco-Systems: Evidences from Italian Supply Chains and Suggestions for a Research Agenda. In: Mancini, D., Vaassen, E. H. J., and Dameri, R. P. eds. *Accounting Information Systems for Decision Making*. Lecture Notes in Information Systems and Organisation. Springer Berlin Heidelberg, pp. 325–336.

Benjamin, L.M. 2006. Historical Evidence: Facts, Proof and Probability. In: Godfrey, D. G. ed. *Methods of historical analysis in electronic media*. London: Lawrence Erlbaum Associates, pp. 25–46.

Benjamin, L.M. 1993. In search of the Sarnoff "radio music box" memo. *Journal of Broadcasting & Electronic Media* 37(*3*), p.pp. 325–335.

Benz, M. 2001. Sony Sees Improved Fiscal Year. *Billboard* 113(*19*).

Bergman, N., Haxeltine, A., Whitmarsh, L., Köhler, J., Schilperoord, M. and Rotmans, J. 2008. Modelling Socio-Technical Transition Patterns and Pathways. *Journal of Artificial Societies and Social Simulation* 11(*3*), p.p. 7.

Bergman, N., Whitmarsh, L. and Köhler, J. 2008. Transition to sustainable development in the UK housing sector: from case study to model implementation. *UEA: Tyndall Centre Working Paper*. Available at: http://tyndall.ac.uk/sites/default/files/wp120.pdf [Accessed: 30 September 2016].

Bergman, N., Whitmarsh, L., Köhler, J., Haxeltine, A. and Schilperoord, M. 2007. Assessing transitions to sustainable housing and communities in the UK. In: *International Conference on Whole Life Urban Sustainability and its Assessment*.

Berkhout, F., Smith, A. and Stirling, A. 2004. Socio-technological regimes and transition contexts. In: Elzen, B., Geels, F. W., and Green, K. eds. *System Innovation and the Transition to Sustainability: theory, evidence and policy*. Cheltenham, Glos: Edward Elgar, pp. 48–75.

Bhattacharjee, S., Gopal, R.D. and Sanders, G.L. 2003. Digital music and online sharing: software piracy 2.0? *Communications of the ACM* 46(*7*), p.pp. 107–111.

Binswanger, M. 2001. Technological progress and sustainable development: what about the rebound effect? *Ecological Economics* 36(*1*), p.pp. 119–132.

Blackowicz, J.U. 2001. RIAA v. Napster: Defining Copyright for the Twenty-First Century. *Boston University Journal of Science & Technology Law* 7, p.p. 182.

Boyatzis, R.E. 1998. *Transforming qualitative information: Thematic analysis and code development*. sage.

van Bree, B., Verbong, G.P.J. and Kramer, G.J. 2010. A multi-level perspective on the introduction of hydrogen and battery-electric vehicles. *Technological Forecasting and Social Change* 77(*4*), p.pp. 529–540.

Brewer, J. and Hunter, A. 1989. *Multimethod research: A synthesis of styles*. Newbury Park, California: Sage.

Bribián, I.Z., Capilla, A.V. and Usón, A.A. 2011. Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. *Building and Environment* 46(*5*), p.pp. 1133–1140.

Bringezu, S. and Moriguchi, Y. 2002. Material flow analysis. In: Ayres, R. U. and Ayres, L. W. eds. *A Handbook of Industrial Ecology*. Cheltenham, Glos: Edward Elgar, pp. 79–90.

Bruno, A. 2007. Revenue On Tap. *Billboard* 119(*6*).

Burger, E., Giljum, S., Manstein, C. and Hinterberger, F. 2009. Comprehensive ecological indicators for products: three case studies applying MIPS and ecological footprint. In: *Presentation held at 8th International Conference of the European Society for Ecological Economics, Ljubljana, Slovenia, 29th June–2nd July*.

Burnett, R. and Weber, R.P. 1989. Concentration and Diversity in the Popular Music Industry 1948-1986. In: San Francisco.

Butler, S. 2007. Inside the Webcaster Outcry. *Billboard* 119(*12*).

Campbell, B. and Sallis, P. 2013. Low-carbon yak cheese: transition to biogas in a Himalayan socio-technical niche. *Interface Focus* 3(*1*). Available at: http://rsfs.royalsocietypublishing.org/content/3/1/20120052 [Accessed: 28 August 2013].

Canning, J. 2017. Conceptualising student voice in UK higher education: four theoretical lenses. *Teaching in Higher Education* 22(*5*), p.pp. 519–531.

Carr, D. 2007. Steve Jobs: iCame, iSaw, iCaved. *The New York Times*. Available at: http://www.nytimes.com/2007/09/10/business/media/10carr.html [Accessed: 30 June 2015].

CBO 2004. *A CBO Paper - Copyright Issues in the Digital Media*. The Congress of the United States, Congressional Budget Office.

Chen, B.X. 2014. Apple Wins Decade-Old Suit Over iTunes Updates. *The New York Times*. Available at: http://www.nytimes.com/2014/12/17/technology/apple-antitrust-suit-ipod-music.html [Accessed: 26 June 2015].

Cheng, J. 2009. Study: pirates biggest music buyers. Labels: yeah, right [Online]. Available at: https://arstechnica.com/tech-policy/2009/04/study-pirates-buy-tons-more-music-than-average-folks/ [Accessed: 3 September 2016].

Christman, E. 2014. Digital Music Sales Decrease For First Time in 2013 [Online]. Available at: http://www.billboard.com/biz/articles/news/digital-and-mobile/5855162/digital-music-sales-decrease-for-first-time-in-2013 [Accessed: 30 June 2015].

Christman, E. 2010. Losing Track. *Billboard* 122(*11*).

Christman, E. 2009. The Price You Pay. *Billboard* 121(*4*).

Cirrus Logic 1999. Cirrus Logic Targets MP3 Internet Audio Players with Ultra Low-Power System-on-Chip Solution [Online]. Available at: http://www.cirrus.com/en/company/releases/P92.html [Accessed: 15 June 2015].

Cleveland, C.J. and Ruth, M. 1998. Indicators of Dematerialization and the Materials Intensity of Use. *Journal of Industrial Ecology* 2(*3*), p.pp. 15–50.

CMJ 1999. Lycos Acquires Sonique Maker. *CMJ Music Report* 59(*632*).

CNN 1994. IUMA on CNN. . Available at: https://www.youtube.com/watch?v=GT5LIEUJefM [Accessed: 1 December 2014].

Coenen, L., Benneworth, P. and Truffer, B. 2012. Toward a spatial perspective on sustainability transitions. *Research Policy* 41(*6*), p.pp. 968–979.

Coffey, A., Holbrook, B. and Atkinson, P. 1996. Qualitative data analysis: Technologies and representations. . Available at: http://socresonline.org.uk/1/1/4.html.

Cowell, R., Ellis, G., Sherry-Brennan, F., Strachan, P.A. and Toke, D. 2017. Energy transitions, sub-national government and regime flexibility: How has devolution in the United Kingdom affected renewable energy development? *Energy Research & Social Science* 23, p.pp. 169–181.

Creswell, J.W. 2011. Controversies in mixed methods research. In: Denzin, N. K. and Lincoln, Y. S. eds. *The SAGE Handbook of Qualitative Research*. London, UK: SAGE Publications Ltd, pp. 269–283.

Damore, K. 1993. Apps use JPEG to crunch images, MPEG for sound. *Infoworld* 15(*44*).

Datta, L. 1994. Paradigm wars: A basis for peaceful co-existence and beyond. In: Reichardt, C. S. and Rallis, S. . eds. *The qualitative-quantitative debate: New perspectives*. San Francisco: Jossey-Bass, pp. 53–70.

DCMS 1998. *Creative Industries Mapping Documents 1998*. Department for Culture, Media & Sport.

De Bruyn, S. 2002. Dematerialization and rematerialization as two recurring phenomena of industrial ecology. In: Ayres, R. U. and Ayres, L. W. eds. *A Handbook of Industrial Ecology*. Cheltenham, Glos: Edward Elgar, pp. 209–222.

Dehery, Y.F., Lever, M. and Urcun, P. 1991. A MUSICAM source codec for digital audio broadcasting and storage. In: *, 1991 International Conference on Acoustics, Speech, and Signal Processing, 1991. ICASSP-91*. pp. 3605–3608 vol.5.

Denegri-Knott, J. and Tadajewski, M. 2010. The emergence of MP3 technology. *Journal of Historical Research in Marketing* 2(*4*), p.pp. 397–425.

Denscombe, M. 2008. Communities of Practice: A Research Paradigm for the Mixed Methods Approach. *Journal of Mixed Methods Research* 2(*3*), p.pp. 270–283.

Denzin, N.K. and Lincoln, Y.S. eds. 2011. *The SAGE Handbook of Qualitative Research*. 4th Edition. London: Sage Publications, Inc.

Doctorow, C. 2004. Microsoft Research DRM talk. In: Redmond Offices.

Dredge, S. 2015. Spotify now has 60m users including 15m paying subscribers. *The Guardian*. Available at: http://www.theguardian.com/technology/2015/jan/12/spotify-60m-users-15m-subscribers [Accessed: 5 August 2015].

Dreier, T. 2001. iPod: Not Just iCandy. *PC Magazine* 20(*22*).

Driel, H.V. and Schot, J. 2005. Radical Innovation as a Multilevel Process: Introducing Floating Grain Elevators in the Port of Rotterdam. *Technology and Culture* 46(*1*), p.pp. 51–76.

easyboy 2001. MP3.com - Will Apple's iPod Fly Off Shelves? [Online]. Available at: http://web.archive.org/web/20011101124151/http://news.mp3.com/news/liststory/?month=200110&topic_id=2984 [Accessed: 10 June 2015].

Economic and Social Research Council 2010. Framework for Research Ethics. . Available at: http://www.esrcsocietytoday.ac.uk/_images/Framework_for_Research_Ethics_tcm8-4586.pdf [Accessed: 24 February 2012].

EE Times 1999. Cirrus spins general-purpose processor for Net audio players [Online]. Available at: http://www.eetimes.com/document.asp?doc_id=1139672 [Accessed: 13 June 2015].

Eisenberg, E. 2005. *The recording angel: explorations in phonography*. New Haven, Conn.; London: Yale University Press.

Elder-Vass, D. 2008. Searching for realism, structure and agency in Actor Network Theory1. *The British Journal of Sociology* 59(*3*), p.pp. 455–473.

Elzen, B., van Mierlo, B. and Leeuwis, C. 2012. Anchoring of innovations: Assessing Dutch efforts to harvest energy from glasshouses. *Environmental Innovation and Societal Transitions* 5, p.pp. 1–18.

Fader, P.S. 2000. *Expert Report of Peter S. Fader, Ph.D.*

Fine, M. 2000. *Report of Michael Fine*. Soundscan Inc.

Fisher, F.M. 1961. On the Cost of Approximate Specification in Simultaneous Equation Estimation. *Econometrica* 29(*2*), p.p. 139.

Fisher, K. 2006. Study: P2P users buy more music; apathy, not piracy, the problem [Online]. Available at: https://arstechnica.com/uncategorized/2006/03/6418-2/ [Accessed: 3 September 2016].

Fitzpatrick, E. 2000a. Metallica Sues Napster & 3 Universities. *Billboard* 112(*17*).

Fitzpatrick, E. 2000b. MP3.com Ruling Mulled. *Billboard* 112(*20*).

Fitzpatrick, E. 2000c. Napster Says Proposals Rejected By Industry. *Billboard* 112(*42*).

Fitzpatrick, E. 2000d. RIAA Seeks to Remove Songs From Napster. *Billboard* 112(*26*).

Flick, U. 2007. *Designing qualitative research*. London: Sage Publications Ltd.

Flynn, L.J. 2004. Apple Attacks RealNetworks Plan to Sell Songs for iPod. *The New York Times*. Available at: http://www.nytimes.com/2004/07/30/technology/30real.html [Accessed: 25 June 2015].

Flyvbjerg, B. 2011. Case Study. In: Denzin, N. K. and Lincoln, Y. S. eds. *The SAGE Handbook of Qualitative Research*. London, UK: SAGE Publications Ltd.

Fuchs, D.A. and Lorek, S. 2005. Sustainable Consumption Governance: A History of Promises and Failures. *Journal of Consumer Policy* 28(*3*), p.pp. 261–288.

Fuenfschilling, L. and Truffer, B. 2016. The interplay of institutions, actors and technologies in socio-technical systems — An analysis of transformations in the Australian urban water sector. *Technological Forecasting and Social Change* 103, p.pp. 298–312.

Garrity, B. 2000a. Analysts Grapple With Napster. *Billboard* 112(*25*).

Garrity, B. 2001a. Big Cos. Seek Net Domain In Evolving Arena. *Billboard* 113(*22*).

Garrity, B. 2001b. Kazaa Going Dark? *Billboard* 113(*50*).

Garrity, B. 2002. Licensing Competition Emerging. *Billboard* 114(*4*).

Garrity, B. 2001c. Online Music Went Legit in 2001. *Billboard* 113(*52*).

Garrity, B. 2004. RealNetworks is lobbying Apple Computer. *Billboard* 116(*17*).

Garrity, B. 2000b. The Year Of Grappling With Napster. *Billboard* 112(*53*).

Garrity, B. 2006a. The YouTube Gamble. *Billboard* 118(*39*).

Garrity, B. 2006b. Your Other Tube. *Billboard* 118(*43*).

Garrity, B. and Fitzpatrick, E. 2000. Alanis Cuts Her Losses At MP3.com. *Billboard* 112(*50*).

Garrity, B. and Holland, B. 2001. Majors Face Antitrust Probe. *Billboard* 113(*33*).

Garrity, B. and Morris, C. 2003. Taking A Bite Of Apple. *Billboard* 115(*25*).

Garud, R. and Karnøe, P. 2003. Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. *Research Policy* 32(*2*), p.pp. 277–300.

Geels, F.W. 2007. Analysing the breakthrough of rock 'n'roll (1930–1970) Multi-regime interaction and reconfiguration in the multi-level perspective. *Technological Forecasting and Social Change* 74(*8*), p.pp. 1411–1431.

Geels, F.W. 2005a. Co-evolution of technology and society: the transition in water supply and personal hygiene in the Netherlands (1850–1930)—a case study in multi-level perspective. *Technology in society* 27(*3*), p.pp. 363–397.

Geels, F.W. 2004. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy* 33(*6–7*), p.pp. 897–920.

Geels, F.W. 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy* 39(*4*), p.pp. 495–510.

Geels, F.W. 2005b. Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. *Technological forecasting and social change* 72(*6*), p.pp. 681–696.

Geels, F.W. 2005c. *Technological transitions and system innovations : a co-evolutionary and socio-technical analysis*. Cheltenham ; Northampton, MA: Edward Elgar.

Geels, F.W. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy* 31(*8–9*), p.pp. 1257–1274.

Geels, F.W. 2005d. The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). *Technology Analysis & Strategic Management* 17(*4*), p.pp. 445–476.

Geels, F.W. *et al.* 2016. The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014). *Research Policy* 45(*4*), p.pp. 896–913.

Geels, F.W. 2013. The impact of the financial–economic crisis on sustainability transitions: Financial investment, governance and public discourse. *Environmental Innovation and Societal Transitions* 6, p.pp. 67–95.

Geels, F.W. 2011. The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions* 1(*1*), p.pp. 24–40.

Geels, F.W. and Kemp, R. 2007. Dynamics in socio-technical systems: Typology of change processes and contrasting case studies. *Technology in Society* 29(*4*), p.pp. 441–455.

Geels, F.W. and Kemp, R. 2012. The Multi-Level Perspective as a New Perspective for Studying Socio-technical Transitions. In: Geels, F. W., Kemp, R., Dudley, G., and Lyons, G. eds. *Automobility in transition? : a socio-technical analysis of sustainable transport*. New York: Routledge.

Geels, F.W., Kemp, R., Dudley, G. and Lyons, G. eds. 2012. *Automobility in transition? : a socio-technical analysis of sustainable transport*. New York: Routledge.

Geels, F.W. and Schot, J. 2010. The dynamics of transitions: a socio-technical perspective. In: Grin, J., Rotmans, J., Schot, J., Geels, F. W., and Loorbach, D. eds. *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*. New York: Routledge, pp. 9–87.

Geels, F.W. and Schot, J. 2007. Typology of sociotechnical transition pathways. *Research policy* 36(*3*), p.pp. 399–417.

Geels, F.W. and Verhees, B. 2011. Cultural legitimacy and framing struggles in innovation journeys: A cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986). *Technological Forecasting and Social Change* 78(*6*), p.pp. 910–930.

Geertz, C. 1988. *Works and lives : the anthropologist as author*. Cambridge: Polity Press.

von Geibler, J. *et al.* 2014. Forming the Nucleus of a Novel Ecological Accounting System: The myEcoCost Approach [Online]. Available at: https://www.scientific.net/KEM.572.78 [Accessed: 19 July 2018].

Geller, P. 2000. Copyright history and the future: What's culture got to do with it? *Journal of the Copyright Society of the USA* 47, p.p. 209.

Genus, A. and Coles, A.-M. 2008. Rethinking the multi-level perspective of technological transitions. *Research Policy* 37(*9*), p.pp. 1436–1445.

Giddens, A. 1984. *The constitution of society : outline of the theory of structuration*. Cambridge: Polity.

Gillen, M.A. 1994a. Alternative View On Cyberspace. *Billboard* 106(*29*).

Gillen, M.A. 1994b. Geffen Puts Aerosmith Music On Line. *Billboard* 106(*25*).

Gillen, M.A. 1995. Online Innovation Promises Instant Audio. *Billboard* 107(*15*).

Gillen, M.A. 2000a. The Future of Downloadable Music. *Billboard* 112(*4*).

Gillen, M.A. 2000b. The Legal Whirlwind. *Billboard* 112(*42*).

Gillen, M.A. 2000c. The Player's the Thing: Who's Got the Hardware? *Billboard* 112(*16*).

Glaser, B.G. and Strauss, A.L. 1967. *The discovery of grounded theory: Strategies for qualitative research*. Transaction publishers.

Glassman, R.B. 1973. Persistence and loose coupling in living systems. *Behavioral Science* 18(*2*), p.pp. 83–98.

Graves, M. 2001. Listen.com® Launches Rhapsody™ Digital Music Subscription Service [Online]. Available at: http://web.archive.org/web/20020810032017/http://www.listen.com/about.jsp?sect=press&subsect=release&page=rhapsody_launch [Accessed: 24 June 2015].

Graves, M. 2002. Listen.com Now Offers CD Burning Through Rhapsody [Online]. Available at: http://web.archive.org/web/20030214050918/http://www.listen.com/about.jsp?sect=press&subsect=release&page=rhapsodytwodotoh102902 [Accessed: 24 June 2015].

Graves, M. and Mullens, K. 2002. Rhapsody Digital Music Service [Online]. Available at: http://web.archive.org/web/20020715093710/http://www.listen.com/about.jsp?sect=press&subsect=release&page=umg_070102 [Accessed: 24 June 2015].

Greene, J.C., Benjamin, L. and Goodyear, L. 2001. The merits of mixing methods in evaluation. *Evaluation* 7(*1*), p.pp. 25–44.

Greene, J.C., Kreider, H. and Meyer, J. 2005. Combining qualitative and quantitative methods in social inquiry. In: Somekh, C. and Lewin, C. eds. *Research methods in the social sciences*. London: Sage, pp. 274–281.

Greening, L.A., Greene, D.L. and Difiglio, C. 2000. Energy efficiency and consumption—the rebound effect—a survey. *Energy policy* 28(*6*), p.pp. 389–401.

Grunin, L. 1991. Utility Coaxes CD-Audio Out Of Your ROM Drive. *PC Magazine*.

Hachman, M. 2000. Startup Portalplayer takes on chip giants in MP3 play [Online]. Available at: http://www.eetimes.com/document.asp?doc_id=1126147 [Accessed: 13 June 2015].

Hails, C., Loh, J. and Goldfinger, S. 2006. Living planet report 2006. *WWF International, Institute of Zoology, Global Footprint Network*.

Halme, M., Jasch, C. and Scharp, M. 2004. Sustainable homeservices? Toward household services that enhance ecological, social and economic sustainability. *Ecological Economics* 51(*1–2*), p.pp. 125–138.

Hardy, M.A. and Bryman, A. eds. 2004. *Handbook of data analysis*. London: Sage.

Harrison, N.E. 2000. *Constructing Sustainable Development*. SUNY Press.

Haupt, J. 2012. Spotify (review). *Notes: Quarterly Journal of the Music Library Association* 69(*1*), p.pp. 132–138.

Hellweg, E. 1999. Hooked on Sonique. *Spin* 15(*11*).

Hertwich, E.G. 2005a. Consumption and the Rebound Effect: An Industrial Ecology Perspective. *Journal of Industrial Ecology* 9(*1–2*), p.pp. 85–98.

Hertwich, E.G. 2005b. Life cycle approaches to sustainable consumption: a critical review. *Environmental Science and Technology* 39(*13*), p.p. 4673.

Hesmondhalgh, D. 2002. *The Cultural Industries: An Introduction*. London: Sage Publications Ltd.

Hietanen, O. 2010. Global challenges of eDevelopment: from digital divides towards empowerment and sustainable global information society.

Hilty, L.M. and Ruddy, T. 2002. Resource productivity in the information age. *Futura 21 (2002): 2*. Available at: https://doria17-kk.lib.helsinki.fi/handle/10024/22654 [Accessed: 30 July 2013].

Hinterberger, F. and Seifert, E.H. 1997. Reducing Material Throughput: A Contribution to the Measurement of Dematerialization and Sustainable Human Development. In: Tylecote, A. and Straaten, J. V. D. eds. *Environment, Technology and Economic Growth: The Challenge to Sustainable Development*. Cheltenham, Glos: Edward Elgar Publishing.

Hirsch, P.M. 1969. *The structure of the popular music industry: The filtering process by which records are preselected for public consumption*. Ann Arbor: Institute for Social Research, The University of Michigan.

Hochschorner, E., Dán, G. and Moberg, Å. 2015. Carbon footprint of movie distribution via the internet: a Swedish case study. *Journal of Cleaner Production* 87, p.pp. 197–207.

Hofmann, J., Guan, D., Chalvatzis, K. and Huo, H. 2016. Assessment of electrical vehicles as a successful driver for reducing CO2 emissions in China. *Applied Energy* 184, p.pp. 995–1003.

Holland, B. 1999a. Court Rules Against RIAA in MP3 Case. *Billboard* 111(*26*).

Holland, B. 1999b. RIAA Sues MP3 Search Site. *Billboard* 111(*37*).

Holland, B. 2001. Vivendi/MP3.com Deal Raises Fear of Cartel. *Billboard* 113(*22*).

Holland, B. and Garrity, B. 2003. Piracy Gambit Raises Stakes. *Billboard* 115(*27*).

Holsti, O.R. 1969. Content analysis for the social sciences and humanities. . Available at: http://admn502awiki.pbworks.com/Content-and-Discourse-Analysis.

Hoogma, R., Kemp, R., Schot, J. and Truffer, B. 2002. *Experimenting for sustainable transport: the approach of strategic niche management*. London, New York: Spon Pres.

Horkheimer, M. and Adorno, T.W. 1944. *Dialectic of Enlightenment: Philosophical Fragments*. Stanford, California: Stanford University Press.

Hracs, B.J. 2012. A Creative Industry in Transition: The Rise of Digitally Driven Independent Music Production. *Growth and Change* 43(*3*), p.pp. 442–461.

Huang, J., Yang, X., Cheng, G. and Wang, S. 2014. A comprehensive eco-efficiency model and dynamics of regional eco-efficiency in China. *Journal of Cleaner Production* 67, p.pp. 228–238.

Hung, M. and Morencos, E.G. eds. 1990. *World Record SAles - A Statistical History of the World Recording Industry*. The International Federation of the Phonographic Industry.

Huppes, G. and Ishikawa, M. 2005a. A Framework for Quantified Eco-efficiency Analysis. *Journal of Industrial Ecology* 9(*4*), p.pp. 25–41.

Huppes, G. and Ishikawa, M. 2005b. Eco-efficiency and Its Terminology. *Journal of Industrial Ecology* 9(*4*), p.pp. 43–46.

IFPI 2012. *Digital Music Report 2012: Expanding Choice. Going Global.*

IFPI 2013. *Digital Music Report 2013: Engine of a digital world*.

IFPI 2004. *The Online Music Report 2004*. The International Federations of the Phonographic Industry.

Immink, K.A. 1998. The Compact Disc Story. *Journal of the Audio Engineering Society* 46(*5*), p.pp. 458–465.

IPCC 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel o Climate Change*. Geneva, Switzerland: IPCC.

ISO 1993. ISO/IEC 11172-3:1993, Information technology -- Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s -- Part 3: Audio. *JTC 1 Information Technology* SC 29. Available at: http://citeseerx.ist.psu.edu/showciting;jsessionid=99BB2D7EEC8A82F1EF14C67C1AFE0FF5?cid=37468419 [Accessed: 1 April 2015].

Jackson, T. 2009. *Prosperity without growth : economics for a finite planet*. London ; Sterling, VA: Earthscan.

Jay, E.D. 2000. *Survey Of Napster Users*. Field Research Corporation.

Jeffrey, D. 1997a. Cos. Make Strides In Net Music Delivery. *Billboard* 109(*46*).

Jeffrey, D. 1997b. Downloading Songs Subject of RIAA Suit. *Billboard* 109(*25*).

Jobs, S. 2001. *Apple Music Event 2001-The First Ever iPod Introduction*.

Jobs, S. 2007. Thoughts on Music [Online]. Available at: https://web.archive.org/web/20070207234839/http://www.apple.com/hotnews/thoughtsonmusic/ [Accessed: 26 June 2015].

Johnson, R.B., Onwuegbuzie, A.J. and Turner, L.A. 2007. Toward a definition of mixed methods research. *Journal of Mixed Methods Research* 1(*2*), p.pp. 112–133.

Jones, P. 1982. Sony Denies Rift with Philips. *Billboard* 94(*40*).

Jørgensen, U. 2012. Mapping and navigating transitions—The multi-level perspective compared with arenas of development. *Research Policy* 41(*6*), p.pp. 996–1010.

Jungbluth, N., Büsser, S., Frischknecht, R., Flury, K. and Stucki, M. 2012. Feasibility of environmental product information based on life cycle thinking and recommendations for Switzerland. *Journal of Cleaner Production* 28, p.pp. 187–197.

Jurić, K. and Vogel, G. 2005. Does Immaterialization Satisfy the Sustainability Imperative? A Life Cycle Approach. *Consumption: The Contribution*, p.p. 267.

Kafka, P. 2015. Big Music Labels Want to Make Free Music Hard to Get, and Apple Says They're Right [Online]. Available at: https://www.recode.net/2015/3/6/11559876/big-music-labels-want-to-make-free-music-hard-to-get-and-apple-says [Accessed: 20 October 2015].

Kaplan, J. 2001. User-Unfriendly MP3 Hardware. *PC Magazine* 20(*22*).

Karp, H. 2014. Apple iTunes Sees Big Drop in Music Sales. *Wall Street Journal*. Available at: http://www.wsj.com/articles/itunes-music-sales-down-more-than-13-this-year-1414166672 [Accessed: 19 September 2018].

Kary, T. 2001. Retailers not sold on Apple's iPod [Online]. Available at: http://www.zdnet.com/article/retailers-not-sold-on-apples-ipod/ [Accessed: 10 June 2015].

Kemp, R., Schot, J. and Hoogma, R. 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. *Technology Analysis & Strategic Management* 10(*2*), p.pp. 175–198.

Kerr, W. and Ryan, C. 2001. Eco-efficiency gains from remanufacturing: A case study of photocopier remanufacturing at Fuji Xerox Australia. *Journal of cleaner production* 9(*1*), p.pp. 75–81.

Key, P.L. and Schlabach, T.D. 1986. Metals Demand in Telecommunications. *Mater. Soc.; (United States)* 10:3. Available at: http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=6668322 [Accessed: 27 August 2013].

Konrad, K., Truffer, B. and Voß, J.-P. 2008. Multi-regime dynamics in the analysis of sectoral transformation potentials: evidence from German utility sectors. *Journal of Cleaner Production* 16(*11*), p.pp. 1190–1202.

Koskela, M. and Vehmas, J. 2012. Defining Eco-efficiency: A Case Study on the Finnish Forest Industry. *Business Strategy and the Environment* 21(*8*), p.pp. 546–566.

Krigel, B.L. 1999. MP3.com flies in trading debut [Online]. Available at: http://news.cnet.com/MP3.com-flies-in-trading-debut/2100-1023_3-228821.html [Accessed: 16 January 2015].

Krigel, B.L. 1998. Music initiative raises questions - CNET News [Online]. Available at: http://news.cnet.com/Music-initiative-raises-questions/2100-1023_3-219163.html [Accessed: 21 March 2014].

Krohn, N. 1991. Lack of audio standard splits multimedia industry. *Infoworld* 13(*32*).

Kulak, M., Nemecek, T., Frossard, E. and Gaillard, G. 2016. Eco-efficiency improvement by using integrative design and life cycle assessment. The case study of alternative bread supply chains in France. *Journal of Cleaner Production* 112, Part 4, p.pp. 2452–2461.

Labys, W.C. 2002. Transmaterialization. In: Ayres, R. U. and Ayres, L. W. eds. *A Handbook of Industrial Ecology*. Cheltenham, Glos: Edward Elgar, pp. 202–208.

Larson, E.D., Ross, M.H. and Williams, R.H. 1986. Beyond the Era of Materials. *Scientific American* 254(*6*), p.pp. 34–41.

Latour, B. 1999. On recalling ANT. In: Law, J. and Hassard, J. eds. *Actor network theory and after*. UK: Wiley-Blackwell, pp. 93–95.

Latour, B. 2005. *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford: Oxford University Press.

Layer, D.H. 2001. Digital radio takes to the road. *IEEE Spectrum* 38(*7*), p.pp. 40–46.

Leblebici, H., Salancik, G.R., Copay, A. and King, T. 1991. Institutional Change and the Transformation of Interorganizational Fields: An Organizational History of the U.S. Radio Broadcasting Industry. *Administrative Science Quarterly* 36(*3*), p.pp. 333–363.

Leeds, J. 2007. Amazon to Sell Warner Music Minus Copy Protection. *The New York Times*. Available at: http://www.nytimes.com/2007/12/28/technology/28music.html [Accessed: 29 June 2015].

Leeds, J. 2005. Apple, Digital Music's Angel, Earns Record Industry's Scorn. *The New York Times*. Available at: http://www.nytimes.com/2005/08/27/technology/apple-digital-musics-angel-earns-record-industrys-scorn.html [Accessed: 29 June 2015].

Lettenmeier, M. *et al.* 2009. *Resource productivity in 7 steps: How to develop eco-innovative products and services and improve their material footprint*. Wuppertal Spezial, Wuppertal Institut für Klima, Umwelt und Energie.

Leyshon, A. 2009. The Software Slump? *Environment and Planning A* 41(*6*), p.pp. 1309 – 1331.

Leyshon, A. 2001. Time-space (and digital) compression: software formats, musical networks, and the reorganisation of the music industry. *Environment and Planning A* 33(*1*), p.pp. 49–78.

Li, J., Jiggins, J., van Bueren, E.T.L. and Leeuwis, C. 2013. Towards a regime change in the organization of the seed supply system in China. *Experimental Agriculture* 49(*01*), p.pp. 114–133.

Lie, M. and Sorensen, K.H. eds. 1996. *Making Technology Our Own?: Domesticating Technology into Everyday Life*. Oslo; Boston: Aschehoug AS.

Lieb, K. 1995. Underground Music Archive Comes of Age. *Billboard* 107(*23*).

Liebowitz, S.J. 2004. WILL MP3 DOWNLOADS ANNIHILATE THE RECORD INDUSTRY? THE EVIDENCE SO FAR. In: Libecap, G. D. ed. *Intellectual Property and Entrepreneurship (Advances in the Study of Entrepreneurship, Innovation & Economic Growth, Volume 15)*. Emerald Group Publishing Limited, pp. 229–260.

Liedtke, C. *et al.* 2014. Resource use in the production and consumption system—The MIPS approach. *Resources* 3(*3*), p.pp. 544–574.

Lim, S.-R. and Schoenung, J.M. 2010. Toxicity potentials from waste cellular phones, and a waste management policy integrating consumer, corporate, and government responsibilities. *Waste Management* 30(*8–9*), p.pp. 1653–1660.

Lincoln, Y.S. and Guba, E.G. 2000. Paradigmatic controversies, contradictions, and emerging confluences. In: Denzin, N. K. and Lincoln, Y. S. eds. *The handbook of qualitative research*. 2nd ed. London: SAGE Publications Ltd, pp. 163–188.

Lincoln, Y.S., Lynham, S.A. and Guba, E.G. 2011. Paradigmatic controversies, contradictions, and emerging confluences, revisited. In: Denzin, N. K. and Lincoln, Y. S. eds. *The SAGE Handbook of Qualitative Research*. London, UK: SAGE Publications Ltd, pp. 97–128.

Lodhi, M.F.K. 2016. Quality Issues in Higher Education: The Role of Methodological Triangulation in Enhancing the Quality of a Doctoral Thesis. *Journal of Research in Social Sciences* 4(*1*), p.p. 62.

Loewenstein, J. 2002. *The author's due: printing and the prehistory of copyright*. Chicago: University of Chicago Press.

Lord, R.D. 1993. MPEG Audio demo posted to a.b.multimedia [Online]. Available at: https://groups.google.com/forum/#!searchin/comp.dsp/Robert$20Daniel$20Lord$20/comp.dsp/E8kqY8nVmB4/_FUQ0qIc0m8J.

Lovering, J. 1998. The Global Music Industry: Contradictions in the Commodification of the Sublime. In: Leyshon, A., Matless, D., and Revill, G. eds. *The Place of Music*. London: Guildford Press.

Madlener, R. and Alcott, B. 2009. Energy rebound and economic growth: A review of the main issues and research needs. *Energy* 34(*3*), p.pp. 370–376.

Maga, D., Hiebel, M. and Knermann, C. 2013. Comparison of two ICT solutions: desktop PC versus thin client computing. *The International Journal of Life Cycle Assessment* 18(*4*), p.pp. 861–871.

Mahoney, J. and Thelen, K. 2009. *Explaining institutional change: ambiguity, agency, and power*. Cambridge University Press.

Malenbaum, W. 1978. *World demand for raw materials in 1985 and 2000*. New York: E/MJ Mining Information Services.

Malmodin, J., Lundén, D., Moberg, Å., Andersson, G. and Nilsson, M. 2014. Life Cycle Assessment of ICT. *Journal of Industrial Ecology*. Available at: http://onlinelibrary.wiley.com/doi/10.1111/jiec.12145/abstract [Accessed: 16 June 2014].

Mancini, L., Lettenmeier, M., Rohn, H. and Liedtke, C. 2012. Application of the MIPS method for assessing the sustainability of production–consumption systems of food. *Journal of Economic Behavior & Organization* 81(*3*), p.pp. 779–793.

March, J.G. and Olsen, J.P. 1979. *Ambiguity and choice in organizations*. 2nd ed. Bergen: Universitetsforlaget.

Markard, J., Raven, R. and Truffer, B. 2012. Sustainability transitions: An emerging field of research and its prospects. *Research Policy* 41(*6*), p.pp. 955–967.

Markard, J. and Truffer, B. 2008. Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy* 37(*4*), p.pp. 596–615.

Markoff, J. 2004. Oh, Yeah, He Also Sells Computers. *The New York Times*. Available at: http://www.nytimes.com/2004/04/25/business/oh-yeah-he-also-sells-computers.html [Accessed: 11 June 2015].

Marra Campanale, R. and Femia, A. 2013. An environmentally ineffective way to increase resource productivity: Evidence from the Italian case on transferring the burden abroad. *Resources* 2(*4*), p.pp. 608–627.

Marsden, T. 2013. From post-productionism to reflexive governance: Contested transitions in securing more sustainable food futures. *Journal of Rural Studies* 29, p.pp. 123–134.

Marwick, A. 1989. *The nature of history*. 3rd ed. Basingstoke: Macmillan Education.

Maximum PC 2004. Deciphering Digital Rights Management. *Maximum PC*.

Maxwell, R. and Miller, T. 2012. *Greening the Media*. Oxford University Press.

McGahan, A.M. 1991. Philips' Compact Disc Introduction (A) - Harvard Business Review. Harvard Business Review Case Study(*792035*). Available at: https://hbr.org/product/philips-compact-disc-introduction-a/792035-PDF-ENG [Accessed: 17 March 2015].

Meadows, D.H., Meadows, D.L., Randers, J. and Behrens III, W.W. 1972. *The limits to growth : a report for the Club of Rome's Project on the Predicament of Mankind*. London: Earth Island.

Menn, J. 2003. *All the Rave: The Rise and Fall of Shawn Fanning's Napster*. 1 edition. New York: Crown Business.

Merry, M. 2011. *Designing Databases for Historical Research*. Creative Commons Attributio 2.0 UK.

Mesarović, M.D. and Pestel, E. 1974. *Mankind at the turning point : the second report to the Club of Rome*. New York: New American Library.

Meyer, J. and Rowan, B. 1978. The Structure of Educational Organizations. In: Meyer, M. ed. *Environments and organizations*. San Francisco: Jossey-Bass.

Michelsen, O., Fet, A.M. and Dahlsrud, A. 2006. Eco-efficiency in extended supply chains: a case study of furniture production. *Journal of environmental management* 79(*3*), p.pp. 290–297.

Mickwitz, P., Melanen, M., Rosenström, U. and Seppälä, J. 2006. Regional eco-efficiency indicators – a participatory approach. *Journal of Cleaner Production* 14(*18*), p.pp. 1603–1611.

Miles, S. 1999. Sony's dilemma: Illegally copied music on Walkman [Online]. Available at: http://news.cnet.com/Sonys-dilemma-Illegally-copied-music-on-Walkman/2100-1001_3-230756.html [Accessed: 9 June 2015].

Miller, W.. *et al.* 2000. Recent development in aluminium alloys for the automotive industry. *Materials Science and Engineering: A* 280(*1*), p.pp. 37–49.

Mitchell, J.L., Pennebaker, W.B., Fogg, C. and LeGall, D.J. eds. 1997. *MPEG Video Compression Standard*. USA: Chapman and Hall.

Möller, A. and Schaltegger, S. 2005. The Sustainability Balanced Scorecard as a Framework for Eco-efficiency Analysis. *Journal of Industrial Ecology* 9(*4*), p.pp. 73–83.

Morse, J. 2003. Principles of mixed methods and multimethod research design. In: Tashakkori, A. and Teddlie, C. eds. *Handbook of mixed methods in social & behavioral research*. Thousand Oaks, CA: Sage, pp. 189–203.

MPEG 2010. Meetings [Online]. Available at: https://web.archive.org/web/20100210155305/http://mpeg.chiariglione.org/meetings.htm.

Musmann, H.G. 1990. The ISO audio coding standard. In: *, IEEE Global Telecommunications Conference, 1990, and Exhibition. "Communications: Connecting the Future", GLOBECOM '90*. pp. 511–517.

Nappi, C. 1990. The Food and Beverage Container Industries: Change and Diversity. In: Tilton, J. E. ed. *World Metal Demand: Trends and Prospects*. USA: Resources for the Future, pp. 217–254.

Negus, K. 1999. *Music genres and corporate cultures*. London: Psychology Press.

Nelson, C. 1999. Downloadable Tom Petty Single Pulled From "MP3.com" Site [Online]. Available at: http://www.mtv.com/news/512759/best-of-99-downloadable-tom-petty-single-pulled-from-mp3com-site/ [Accessed: 1 June 2015].

Nelson, C. 1998. RIAA Files Suit To Block New Portable Digital-Audio Player [Online]. Available at: http://www.mtv.com/news/502427/riaa-files-suit-to-block-new-portable-digital-audio-player/ [Accessed: 8 June 2015].

Neumayr, T. and Roth, J. 2008a. iTunes Now Number Two Music Retailer in the US [Online]. Available at: https://www.apple.com/pr/library/2008/02/26iTunes-Now-Number-Two-Music-Retailer-in-the-US.html.

Neumayr, T. and Roth, J. 2008b. iTunes Store Top Music Retailer in the US [Online]. Available at: https://www.apple.com/pr/library/2008/04/03iTunes-Store-Top-Music-Retailer-in-the-US.html.

Ngar-yin Mah, D., van der Vleuten, J.M., Chi-man Ip, J. and Ronald Hills, P. 2012. Governing the transition of socio-technical systems: A case study of the development of smart grids in Korea. *Energy Policy* 45, p.pp. 133–141.

Nian, V., Chou, S.K., Su, B. and Bauly, J. 2014. Life cycle analysis on carbon emissions from power generation–The nuclear energy example. *Applied Energy* 118, p.pp. 68–82.

Nilsson, M. and Nykvist, B. 2016. Governing the electric vehicle transition – Near term interventions to support a green energy economy. *Applied Energy* 179, p.pp. 1360–1371.

OECD 2005. *Working Party on the Information Economy, Digital Broadband Content: Music.*

Ofcom 2015. Broadband speeds research [Online]. Available at: http://consumers.ofcom.org.uk/news/broadband-speeds-feb15/ [Accessed: 29 November 2015].

O'Leary, Z. 2014. *The essential guide to doing your research project*. 2nd edition. Los Angeles: SAGE.

O'Neill, B. 2009. DAB Eureka-147: a European vision for digital radio. *New Media & Society* 11(*1–2*), p.pp. 261–278.

Onwuegbuzie, A.J. and Leech, N.L. 2005. On becoming a pragmatic researcher: The importance of combining quantitative and qualitative research methodologies. *International Journal of Social Research Methodology* 8(*5*), p.pp. 357–387.

O'Rourke, D. and Lollo, N. 2015. Transforming Consumption: From Decoupling, to Behavior Change, to System Changes for Sustainable Consumption. *Annual Review of Environment and Resources* 40(*1*), p.pp. 233–259.

Ouchi, W. 1978. Coupled versus Uncoupled Control in Organizational Hierarchies. In: Meyer, M. ed. *Environments and organizations*. San Francisco: Jossey-Bass.

Paoletta, M. 2000. MP3.com Service Raises Some Industry Eyebrows. *Billboard* 112(*29*).

Passman, D.S. 2011. *All You Need To Know About The Music Business*. 7th ed. England: Viking.

Patel, M.H. 2000. *Judge Marilyn Hall Patel's Ruling*.

Patterson, J. and Melcher, R. 1998. *Audio on the Web: Official IUMA Guide*. Berkeley, CA: Peachpit Press.

Penchansky, A. 1982. Digital Seen As Audio's Future. *Billboard* 94(*37*).

Peoples, G. 2009. Down Is The New Up. *Billboard* 121(*16*).

Pesch, U. 2015. Tracing discursive space: Agency and change in sustainability transitions. *Technological Forecasting and Social Change* 90, Part B, p.pp. 379–388.

Piolatto, A. and Schuett, F. 2012. Music piracy: A case of "The Rich Get Richer and the Poor Get Poorer." *Information Economics and Policy*. Available at: http://www.sciencedirect.com/science/article/pii/S0167624512000030 [Accessed: 28 August 2012].

Piterou, A. and Steward, F. 2011. Emerging innovation networks and the print-on-paper sociotechnical regime. *Procedia - Social and Behavioral Sciences* 10, p.pp. 104–122.

Poel, I.V.D. 2000. On the Role of Outsiders in Technical Development. *Technology Analysis & Strategic Management* 12(*3*), p.pp. 383–397.

Pohlmann, K.C. 1992. *The Compact Disc Handbook*. Oxford, New York: Oxford University Press.

Porra, J., Hirschheim, R. and Parks, M.S. 2014. The historical research method and information systems research. *Journal of the Association for Information Systems* 15(*9*), p.p. 536.

Prior, T., Giurco, D., Mudd, G., Mason, L. and Behrisch, J. 2012. Resource depletion, peak minerals and the implications for sustainable resource management. *Global Environmental Change* 22(*3*), p.pp. 577–587.

Proske, M., Winzer, J., Marwede, M., Nissen, N.F. and Lang, K.-D. 2016. Obsolescence of electronics-the example of smartphones. In: *Electronics Goes Green 2016+(EGG), 2016*. IEEE, pp. 1–8.

Quindlen, R. 1990. InfoWorld. *Infoworld* 12(*11*).

Raven, R. 2007. Co-evolution of waste and electricity regimes: Multi-regime dynamics in the Netherlands (1969–2003). *Energy Policy* 35(*4*), p.pp. 2197–2208.

Raven, R., Schot, J. and Berkhout, F. 2012. Space and scale in socio-technical transitions. *Environmental Innovation and Societal Transitions* 4, p.pp. 63–78.

Raven, R.P.J.M. 2004. Implementation of manure digestion and co-combustion in the Dutch electricity regime: a multi-level analysis of market implementation in the Netherlands. *Energy Policy* 32(*1*), p.pp. 29–39.

RealNetworks Inc. 2004. Form 10-K (filed March 10th 2005). . Available at: http://www.sec.gov/Archives/edgar/containers/fix037/1046327/0000950124-05-001417.txt [Accessed: 26 May 2015].

Reece, D. 1999. Give Labels Credit For Digital Music Initiative. *Billboard* 111(*2*).

Reece, D. 1998a. GoodNoise Takes Online Leap. *Billboard* 110(*28*).

Reece, D. 1998b. Industry Grapples With MP3 Dilemma. *Billboard* 110(*29*).

Reece, D. 1998c. Industry Wary As Wave Of Portable MP3 Players Looms. *Billboard* 110(*38*).

Reece, D. 1998d. Online Label GoodNoise To Buy Two MP3 Firms. *Billboard* 110(*43*).

Reece, D. 1998e. RIAA Files Suit Over MP3 Player. *Billboard* 110(*43*).

Reece, D. 1998f. Ruling Favors Digital Player Rio. *Billboard* 110(*45*).

Reijnders, L. 1998. The Factor X Debate: Setting Targets for Eco-Efficiency. *Journal of Industrial Ecology* 2(*1*), p.pp. 13–22.

Reisinger, D. 2007. Why iTunes is in jeopardy [Online]. Available at: http://www.cnet.com/news/why-itunes-is-in-jeopardy/ [Accessed: 30 June 2015].

RIAA 1998. Worldwide Recording Industry Announces Precedent-Setting Initiative to Address New Digital Music Opportunities [Online].

Richard R. Nelson (Richard Robinson) 1982. *An evolutionary theory of economic change*. Cambridge, Mass; London: Belknap Press.

Rip, A. and Kemp, R.P.M. 1998. *Technological Change. In: Rayner S., Malone EL (editors).* Battelle Press.

Ritthoff, M., Rohn, H. and Liedtke, C. 2002. *Calculating MIPS: Resource productivity of products and services*. Wuppertal Spezial, Wuppertal Institut für Klima, Umwelt und Energie.

Rivera, J.L. and Lallmahomed, A. 2015. Environmental implications of planned obsolescence and product lifetime: a literature review. *International Journal of Sustainable Engineering* 0(*0*), p.pp. 1–11.

Robbins, R.H. 1999. *Global Problems and the Culture of Capitalism*. Allyn and Bacon.

Robèrt, K.-H. *et al.* 2002. Strategic sustainable development — selection, design and synergies of applied tools. *Journal of Cleaner Production* 10(*3*), p.pp. 197–214.

Robèrt, K.-H., Holmberg, J. and von Weizscker, E.U. 2000. Factor X for Subtle Policy-Making. *Greener Management International* 2000(*31*), p.pp. 25–37.

Robertson, M. 1998. Can Music Be Secure? [Online]. Available at: http://web.archive.org/web/19991013124548/http://mp3.com/news/115.html [Accessed: 13 May 2015].

Rocco, T., Linda, Gallagher, S. and Pérez-Prado, A. 2003. Taking the Next Step: Mixed Methods Research in Organizational Systems. *Information Technology, Learning, and Performance Journal* 21(*1*), p.pp. 19–29.

Rohde, L. and Ferranti, M. 2000. The e-music trap. *Infoworld* 22(*34*).

Rosenberg, N. 1986. The impact of technological innovation: A historical view. In: Landau, R. and Rosenberg, N. eds. *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. National Academies.

Rosenbloom, D. 2017. Pathways: An emerging concept for the theory and governance of low-carbon transitions. *Global Environmental Change* 43, p.pp. 37–50.

Rothaermel, F.T. 2001. Complementary assets, strategic alliances, and the incumbent's advantage: an empirical study of industry and firm effects in the biopharmaceutical industry. *Research Policy* 30(*8*), p.pp. 1235–1251.

Sadler, D. 1997. The Global Music Business as an Information Industry: Reinterpreting Economies of Culture. *Environment and Planning A: Economy and Space* 29(*11*), p.pp. 1919–1936.

Sahni, S., Boustani, A., Gutowski, T. and Graves, S. 2010. *Personal computer remanufacturing and energy savings*. Technical Report, MIT Energy Initiative Report Series.

Saldaña, J. 2015. *The coding manual for qualitative researchers*. Sage.

Sanne, C. 2000. Dealing with environmental savings in a dynamical economy-how to stop chasing your tail in the pursuit of sustainability. *Energy Policy* 28(*6*), p.pp. 487–495.

Sarker, S., Sarker, S. and Sidorova, A. 2006. Understanding business process change failure: An actor-network perspective. *Journal of Management Information Systems* 23(*1*), p.pp. 51–86.

Sarnoff, D. 1968. *Looking Ahead: The Papers of David Sarnoff*. New York: McGraw-Hill.

Saurat, M. and Ritthoff, M. 2013. Calculating MIPS 2.0. *Resources* 2(*4*), p.pp. 581–607.

Schaltegger, S. and Sturm, A. 1989. Ökologieinduzierte Entscheidungsprobleme des Managements. Ansatzpunkte zur Ausgestaltung von Instrumenten (Ecology-induced management decision support: starting points for instrument formation). *WWZ-Discussion Paper* (*No.8914*).

Schien, D., Preist, C., Yearworth, M. and Shabajee, P. 2012. Impact of location on the energy footprint of digital media. In: *2012 IEEE International Symposium on Sustainable Systems and Technology (ISSST)*. pp. 1–6.

Schmidt-Bleek, F. 1997. MIPS and factor 10 for a sustainable and profitable economy. *Wuppertal, Germany: Wuppertal Institute*.

Schmidt-Bleek, F. 1993. Revolution in resource productivity for a sustainable economy. A new research agenda. *Fresenius Environmental Bulletin* 2(*8*), p.pp. 485–490.

Schmidt-Bleek, F. 1994. *Wieviel Umwelt braucht der Mensch?: MIPS - das Maß für ökologisches Wirtschaften*. Berlin: Birkhäuser.

Schot, J., Hoogma, R. and Elzen, B. 1994. Strategies for shifting technological systems: The case of the automobile system. *Futures* 26(*10*), p.pp. 1060–1076.

Segal, A.P. 1996. Dissemination of Digitized Music on the Internet: A Challenge to the Copyright Act. *Santa Clara Computer & High Tech. LJ* 12, p.p. 97.

Seibel, P. 2005. *Practical Common Lisp*. USA: Apress.

Seland, D. 2015. Future proofing and the death of planned obsolescence. *Quality* 54(*6*), p.pp. 6–7.

Seuring, S. and Müller, M. 2008. From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production* 16(*15*), p.pp. 1699–1710.

Seyfang, G. and Smith, A. 2007. Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics* 16(*4*), p.pp. 584–603.

Shapiro, C. and Varian, H. 1998. *Information Rules: A Strategic Guid*. Harvard Business Press.

Shapiro, E. 1998. Band's Free Web Releases Stoke Industry's Fears of Piracy Chaos. *Wall Street Journal*. Available at: http://www.wsj.com/articles/SB913875220908602000 [Accessed: 1 June 2015].

ShereKhan/MegaByte/MindRape of DAC 1996. DAC MP3 "Mnini How-To" V4.0.1. . Available at: http://www.mp3scene.info/media/files/dac-how_to.txt [Accessed: 11 November 2014].

Shove, E. and Walker, G. 2010. Governing transitions in the sustainability of everyday life. *Research Policy* 39(*4*), p.pp. 471–476.

Simmie, J., Sternberg, R. and Carpenter, J. 2014. New technological path creation: evidence from the British and German wind energy industries. *Journal of Evolutionary Economics* 24(*4*), p.pp. 875–904.

Simon, H.A. 1971. Designing Organizations for an Information-rich World. In: Greenberg, M. ed. *Computers, Communications and the Public Interest*. Baltimore: John Hopkins University Press.

Simon, H.A. 1996. *The sciences of the artificial*. 3rd ed. Cambridge, Mass; London: MIT Press.

Simon, H.A. and Ando, A. 1961. Aggregation of Variables in Dynamic Systems. *Econometrica* 29(*2*), p.p. 111.

Simon, J.L. 1980. Bad News: Is It True? *Science* 210(*4476*), p.pp. 1305–1308.

Skellern, K., Markey, R. and Thornthwaite, L. 2016. Identifying attributes of sustainable transitions for traditional regional manufacturing industry sectors – A conceptual framework. *Journal of Cleaner Production* In press, corrected proof. Available at: http://www.sciencedirect.com/science/article/pii/S0959652616310885 [Accessed: 1 September 2016].

Smith, A. 2007. Translating Sustainabilities between Green Niches and Socio-Technical Regimes. *Technology Analysis & Strategic Management* 19(*4*), p.pp. 427–450.

Smith, A., Stirling, A. and Berkhout, F. 2005. The governance of sustainable socio-technical transitions. *Research Policy* 34(*10*), p.pp. 1491–1510.

Smith, M. and Telang, R. 2012. Assessing the Academic Literature Regarding the Impact of Media Piracy on Sales. . Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2132153 [Accessed: 28 August 2012].

Spanias, A., Painter, T. and Atti, V. 2006. *Audio Signal Processing and Coding*. John Wiley & Sons.

Stake, R.E. 2003. Case Studies. In: Denzin, N. K. and Lincoln, Y. S. eds. *Strategies of Qualitative Inquiry*. Second Edition. London, UK: Sage Publications, Inc, pp. 86–109.

Startt, J.D. and Sloan, W.D. 1989. *Historical Methods in Mass Communication*. Hillsdake, NJ: Law.

Steen-Olsen, K., Wood, R. and Hertwich, E.G. 2016. The Carbon Footprint of Norwegian Household Consumption 1999–2012. *Journal of Industrial Ecology* 20(*3*), p.pp. 582–592.

Stern, N.N.H. 2007. *The economics of climate change: the Stern review*. Cambridge University Press.

Sterne, J. 2012. *MP3: The Meaning of a Format*. Durham: Duke University Press.

Strauss, N. 2003. Apple Finds the Future for Online Music Sales. *The New York Times*. Available at: http://www.nytimes.com/2003/05/29/arts/music/29POPL.html [Accessed: 25 June 2015].

Strauss, N. 1994. THE POP LIFE; Hit Makers Warily Explore the Computer Frontier. *The New York Times*. Available at: http://www.nytimes.com/1994/07/06/arts/the-pop-life-hit-makers-warily-explore-the-computer-frontier.html [Accessed: 29 November 2014].

Sutherland, S. 1986. The Compact Impact: CD Surge Leads Industry To Fresh Frontiers Beyond Sound Barrier. *Billboard* 98(*11*).

Swartz, A. 2002. MusicBrainz: a semantic Web service. *IEEE Intelligent Systems* 17(*1*), p.pp. 76–77.

Tapio, P., Banister, D., Luukkanen, J., Vehmas, J. and Willamo, R. 2007. Energy and transport in comparison: Immaterialisation, dematerialisation and decarbonisation in the EU15 between 1970 and 2000. *Energy Policy* 35(*1*), p.pp. 433–451.

Tapio, P. and Vähätalo, M. 2013. Decoupling environmental harm from material production and material production from economic growth: the case of energy and carbon dioxide in Finland, Norway, Russia and Sweden. In: Wråkberg, U. ed. *Futures of Norther cross-border collaboration: Proceedings of a conference held on the 26th-27th September 2011 in Moscow*. Tromsø, Norway: Munin Open Research Archive, University of Tromsø, p. 79.

Tashakkori, A. and Creswell, J.W. 2007. Exploring the nature of research questions in mixed methods research. *Journal of Mixed Methods Research* 1(*3*), p.pp. 207–211.

Tashakkori, A. and Teddlie, C. 2003. *Handbook of mixed methods in social & behavioral research*. SAGE.

Taylor, C. 2002. Hitting All the Wrong Notes. *Time*. Available at: http://content.time.com/time/magazine/article/0,9171,203524,00.html [Accessed: 3 June 2015].

Thelen, K. 2003. How institutions evolve: insights from comparative historical analysis. In: Mahoney, J. and Rueschemeyer, D. eds. *Comparative historical analysis in the social sciences*. Cambridge University Press, pp. 208–240.

Traiman, S. 1999. Sites + Sounds. *Billboard* 111(*28*).

Traiman, S. 2001. Sites + Sounds. *Billboard* 113(*4*).

Trainer, T. 2001. The “de-materialisation” myth. *Technology in Society* 23(*4*), p.pp. 505–514.

Truffer, B., Murphy, J.T. and Raven, R. 2015. The geography of sustainability transitions: Contours of an emerging theme. *Environmental Innovation and Societal Transitions* 17, p.pp. 63–72.

Tseng, M.-L., Tan, K.-H., Lim, M., Lin, R.-J. and Geng, Y. 2013. Benchmarking eco-efficiency in green supply chain practices in uncertainty. *Production Planning & Control*, p.pp. 1–12.

Tukker, A. *et al.* 2008. Fostering change to sustainable consumption and production: an evidence based view. *Journal of Cleaner Production* 16(*11*), p.pp. 1218–1225.

Tukker, A. 2006. Special issue on priorities for environmental product policy. *Journal of Industrial Ecology* 10(*3*).

Tukker, A., Cohen, M.J., Hubacek, K. and Mont, O. 2010. The Impacts of Household Consumption and Options for Change. *Journal of Industrial Ecology* 14(*1*), p.pp. 13–30.

Tukker, A. and Tischner, U. 2006. *New business for old Europe. Product services, sustainability and competitiveness*. Sheffield: Greenleaf Publishing Ltd.

Türk, V., Alakeson, V., Kuhndt, M. and Ritthoff, M. 2003. The environmental and social impacts of digital music A case study with EMI. *Digital Europe*, p.pp. 1–71.

UNDESA 1992. *Agenda 21*. New York: United Nations.

UNDESA 2002. *Plan of implementation of the World Summit on Sustainable Development*. New York: United Nations.

UNEP 2011. Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication. A Synthesis for Policy Makers. . Available at: http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_synthesis_en.pdf [Accessed: 2 February 2012].

Van Buskirk, E. 2008. Negotiations Leak: Could Variable iTunes Pricing Be on the Table? [Online]. Available at: http://web.archive.org/web/20080520061609/http://blog.wired.com/music/2008/05/apple-squares-o.html [Accessed: 29 June 2015].

Vidich, A.J. and Lyman, S.M. 2000. Qualitative Methods: Their history in sociology and anthropology. In: Denzin, N. K. and Lincoln, Y. S. eds. *Handbook of Qualitative Research*. 2nd ed. London: SAGE.

van der Voet, E., van Oers, L. and Nikolic, I. 2004. Dematerialization: Not Just a Matter of Weight. *Journal of Industrial Ecology* 8(*4*), p.pp. 121–137.

Walrave, B. and Raven, R. 2016. Modelling the dynamics of technological innovation systems. *Research Policy* 45(*9*), p.pp. 1833–1844.

Walsh, C. 2006. UMG Sets Sights On MySpace, YouTube. *Billboard* 118(*38*).

Wang, Y., Sun, M., Wang, R. and Lou, F. 2015. Promoting regional sustainability by eco-province construction in China: A critical assessment. *Ecological Indicators* 51, p.pp. 127–138.

WBCSD 2005. *Eco-efficiency: learning module*. Five Winds International.

Weaver, P.M. and Rotmans, J. 2006. Integrated sustainability assessment: what is it, why do it and how? *International Journal of Innovation and Sustainable Development* 1(*4*), p.p. 284.

Weber, C.L., Koomey, J.G. and Matthews, H.S. 2010. The Energy and Climate Change Implications of Different Music Delivery Methods. *Journal of Industrial Ecology* 14(*5*), p.pp. 754–769.

Weber, C.L., Koomey, J.G. and Matthews, H.S. 2009. *The Energy and Climate Change Implications of Different Music Delivery Methods (Final report to Microsoft Corporation and Intel Corporation)*.

von Weizsäcker, E.U. 1998. Dematerialisation. In: Vellinga, P., Berkhout, F., and Gupta, J. eds. *Managing a Material World*. Environment & Policy. Springer Netherlands, pp. 45–54.

von Weizsäcker, E.U., Lovins, L. and Lovins, A.B. 1997. *Factor four : doubling wealth-halving resource use ; the new report to the Club of Rome*. London: Earthscan.

Wells, P. and Nieuwenhuis, P. 2012. Transition failure: Understanding continuity in the automotive industry. *Technological Forecasting and Social Change* 79(*9*), p.pp. 1681–1692.

Wernick, I.K., Herman, R., Govind, S. and Ausubel, J.H. 1996. Materialization and Dematerialization: Measures and Trends. *Daedalus* 125(*3*), p.pp. 171–198.

Whitmarsh, L. 2012. How useful is the Multi-Level Perspective for transport and sustainability research? *Journal of Transport Geography* 24, p.pp. 483–487.

Wikström, P. 2010. *The Music Industry: Music in the Cloud*. Cambridge: Polity Press.

Wilde-Mathews, A. 2002. MusicNet, Pressplay Nearing License Deals With Music Firms. *Wall Street Journal*. Available at: http://www.wsj.com/articles/SB1034632657311611076 [Accessed: 4 June 2015].

Wolf, M.J. 1999. *The entertainment economy: how mega-media forces are transforming our lives*. New York: Three Rivers Press.

Wuppertal Institute for Climate, Environment and Energy 2014. Material intensity of materials, fuels, transport services, food. . Available at: http://wupperinst.org/uploads/tx_wupperinst/MIT_2014.pdf [Accessed: 19 February 2014].

Xing Technology Corporation 1993. XingSound MPEG Audio Player. . Available at: ftp://ftp.funet.fi/pub/sci/audio/mpeg-audioplayer/xing/mpgaudio.txt.

Yin, R.K. 2008. *Case Study Research: Design and Methods*. Fourth Edition. London: Sage Publications, Inc.

Yin, R.K. 2014. *Case study research : design and methods*. 5 edition.

Yong, C. 2005. Who Has the Patent On Stupidity. *HWM*.

Yu, Y., Chen, D., Zhu, B. and Hu, S. 2013. Eco-efficiency trends in China, 1978–2010: Decoupling environmental pressure from economic growth. *Ecological Indicators* 24, p.pp. 177–184.

Yuhas, A. 2014. Antitrust lawsuit against Apple: 10 years in the making, shot down in three hours [Online]. Available at: http://www.theguardian.com/technology/2014/dec/16/antitrust-lawsuit-apple-ipod-software-updates [Accessed: 27 June 2015].

Zhu, Z., Wang, K. and Zhang, B. 2014. Applying a network data envelopment analysis model to quantify the eco-efficiency of products: a case study of pesticides. *Journal of Cleaner Production* 69, p.pp. 67–73.

12 Technical Annex

MIPS for 1 million CDs data taken from Türk *et al.* 2003.

Table 30: MIPS input table for energy required to produce 1 million CDs

Calculation sheet Data refer to: 1 million CDs Energy														
				Abiotic Material		**Biotic Material**		**Earth movements**		**Water**		**Air**	
Name Substance/pre-product	Unit	Amount		MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
Electricity	kWh	159,484.00		1.58	251,984.72					63.83	10,179,863.72	0.43	67,780.70
Gas	m^3	5,340.00		1.22	6,514.80					0.50	2,670.00		
∑	Total amount	164,824.00			258499.52		0.00		0.00		10182533.72		67780.70

Table 31: MIPS input table for materials required to produce 1 million CDs

Calculation sheet
Data refer to: 1 million CDs Pre-products & semi-finished products

Name				**Abiotic Material**		**Biotic Material**		**Earth movements**		**Water**		**Air**	
Substance/pre-product	Unit	Amount	Percentage of product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
Polycabonate (PC)	kg	17300	15.22	6.94	120,062.00					212.19	3,670,887.00	4.70	81,310.00
Aluminium	kg	10	0.01	37.00	370.00					1047.00	10,470.00	10.87	108.70
UV-Lacquer (acrylate)	kg	10	0.01		0.00						0.00		0.00
Ink	kg	20	0.02		0.00						0.00		0.00
Foil (PE)	kg	1000	0.88		0.00						0.00		0.00
Polystyrene (PS) (jewel boxes)	kg	67400	59.31	2.51	169,174.00					164.04	11,056,296.00	2.80	188,720.00
Paper (booklet & inlay)	kg	23200	20.42	9.17	212,744.00	2.57	59624.00			302.99	7,029,368.00	1.28	29,696.00
Carboard (Boxes for 25 CDs)	kg	4700	4.14	1.86	8,742.00	0.75	3525.00			93.56	439,732.00	0.33	1,551.00
					0.00						0.00		0.00
					0.00						0.00		0.00
∑	Total amount	113,640.00			510722.00		63149.00		0.00		22196283.00		301277.00

Table 32: MIPS input table for materials required to produce 1 million CD cases, artwork and booklets.

Calculation sheet Data refer to: 1 million CDs other process inputs													
				Abiotic Material		**Biotic Material**		**Earth movements**		**Water**		**Air**	
Name Substance/pre-product	Unit	Amount	total percentage	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
Tap water	m^3	331.2	0.29	0.01	3.31					1.30	430.56	0.00	0.00
Methanol	litre	41.6	0.04	1.67	69.47					4.46	185.54	3.87	160.99
Acetone	litre	35.3	0.03	3.19	112.61					18.72	660.82	1.89	66.72
Screen wash (ink remover)	litre	60	0.05		0.00						0.00		0.00
NaHO	litre	187.5	0.16	2.76	517.50					90.31	16,933.13	1.06	198.75
HCl	litre	33.3	0.03	3.03	100.90					40.66	1,353.98	0.38	12.65
H_3PO_4	Kg	16.7	0.01		0.00						0.00	1.28	21.38
Nickel	Kg	53.4	0.05	141.29	7,544.89	0.75	40.05			233.34	12,460.36	40.83	2,180.32
Nickelsulfamate	Kg	14.1	0.01		0.00						0.00		0.00
Glass	Kg	0.75	0.00	2.95	2.21					11.65	8.74	0.74	0.56
∑					8350.89		40.05		0.00		32033.11		2641.37
	Total Amount:	773.85											
	Total for 1000000 CDs	113,640.00											
Total				Abiotic	769221.52	Biotic	63149.00	Earth		Water	32378816.72	Air	369057.70
Per CD					0.77		0.06		0		32.38		0.37

Desktop PC MIPS tables.

PC Specifications:

Desktop: 3 GHz processor (or equivalent), built-in graphics card, 512 MB RAM, 80 GB HDD

Laptop: Mobile 1.7 GHz processor (or its equivalent), good 3D graphics performance, 15”-screen, 512 MB RAM and 60 GB HDD

CRT Monitor: 17”

LCD Monitor: 17”, with a resolution of 1280*1024

These specifications and the BOM are for an average best-selling computer or display in 2005 data taken from Sahni *et al.* 2010 and Maga *et al.* 2013.

Table 33: MIPS input table for materials required to produce 1 desktop PC.

Calculation sheet
Data refer to: 1 Desktop PC
(2007)

Name				**Abiotic Material**		**Biotic Material**		**Earth movements**		**Water**		**Air**	
Substance/pre-product	Unit	Amount		MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
LDPE	kg	0.25		2.49	0.61					122.20	30.06	1.62	0.40
ABS	kg	0.38		3.97	1.51					206.89	78.77	3.75	1.43
PA 6	kg	0.14		5.51	0.76					921.03	126.81	4.61	0.63
PC	kg	0.26		6.94	1.83					212.19	56.07	4.70	1.24
Epoxy	kg	0.10		13.73	1.34					289.88	28.38	5.50	0.54
Flex PUR	kg	0.00			0.00						0.00		0.00
St sheet galv.	kg	6.31		9.32	58.83					81.86	516.72	0.77	4.86
St tube/profile	kg	0.11		9.32	0.99					81.86	8.72	0.77	0.08
Cast iron	kg	0.48		12.00	5.79					91.00	43.91	1.90	0.92
Ferrite	kg	0.00			0.00						0.00		0.00
Stainless 18/8 coil	kg	0.01		14.43	0.14					205.13	1.95	2.83	0.03
Al sheet/extrusion	kg	0.31		37.00	11.64					1047.70	329.53	10.87	3.42
Al diecast	kg	0.02		8.11	0.12					234.13	3.51	2.93	0.04
Cu winding wire	kg	0.26		179.07	46.02					236.39	60.75	1.16	0.30
Cu wire	kg	0.33		179.07	59.72					236.39	78.84	1.16	0.39
Cu tube/sheet	kg	0.07		179.07	11.91					236.39	15.72	1.16	0.08
powder coating	kg	0.00		-	-					-	-	-	-
big caps and coils	kg	0.48											
Al	kg	0.16		37.00	5.92					1047.70	167.63	10.87	1.74

Cu	kg	0.16		348.47	55.76					367.16	58.75	1.60	0.26
Fe	kg	0.16		12.00	1.92					91.00	14.56	1.90	0.30
slots/extension ports	kg	0.31		179.07	55.76					236.39	73.28	1.16	0.36
IC's avg., 5%Si, Au	kg	0.07		-	-					-	-	-	-
IC's avg., 1% Si	kg	0.10		-	-					-	-	-	-
SMD/LED's avg.	kg	0.19		-	-					-	-	-	-
PWB 1/2 lay 3.75KG/m^2	kg	0.08		-	-					-	-	-	-
PWB 6 lay 4.5kg/m^2	kg	0.16		-	-					-	-	-	-
solder $SnAg4Cu_{0.5}$	kg	0.05		-	-					-	-	-	-
Cardboard	kg	2.29		1.86	4.25	0.75	1.71			93.56	213.92	0.33	0.75
	Total amount	12.75											
Electricity	kWh	0.61		3.15	1.92	0.04	0.02			57.64	35.11	0.51	0.31
∑					324.62		1.74		0.00		1834.17		16.25

Table 34: MIPS input table for materials required to produce 1 laptop PC.

Calculation sheet Data refer to: 1 Laptop (2007)														
				Abiotic Material		**Biotic Material**		**Earth movements**		**Water**		**Air**	
Name Substance/pre-product	Unit	Amount		MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
LDPE	kg	0.04		2.49	0.11					122.20	5.25	1.62	0.07
PP	kg	0.00		4.24	0.02					205.48	0.82	3.37	0.01
PS	kg	0.00		2.51	0.01					164.04	0.43	2.80	0.01
EPS	kg	0.05		2.50	0.13					137.68	6.93	2.47	0.12
PVC	kg	0.02		3.47	0.08					305.29	7.11	1.70	0.04
ABS	kg	0.14		3.97	0.56					206.89	29.34	3.75	0.53
PA 6	kg	0.28		5.51	1.55					921.03	258.39	4.61	1.29
PC	kg	0.27		6.94	1.85					212.19	56.68	4.70	1.26
PMMA	kg	0.04		9.53	0.35					167.36	6.08	2.90	0.11
Epoxy	kg	0.00		13.73	0.04					289.88	0.77	5.50	0.01
steel sheet galvanized	kg	0.49		9.32	4.56					81.86	40.05	0.77	0.38
Al sheet/extrusion	kg	0.04		37.00	1.40					1047.70	39.71	10.87	0.41
CU wire	kg	0.06		179.07	10.74					236.39	14.18	1.16	0.07
CU tube/sheet	kg	0.02		179.07	2.72					236.39	3.59	1.16	0.02
$MgZn_5$	kg	0.12		21.76	2.65					305.12	37.12	8.28	1.01
Powder Coating	kg	0.00		-	-					-	-	-	-
big caps and coils	kg	0.50											
Al	kg	0.17		37.00	6.18					1047.70	174.97	10.87	1.82
Cu	kg	0.17		348.47	58.19					367.16	61.32	1.60	0.27

Fe	kg	0.17		12.00	2.00					91.00	15.20	1.90	0.32
slots/extension ports	kg	0.13		179.07	55.76					236.39	31.42	1.16	0.15
IC's avg., 5%Si, Au	kg	0.05		-	-					-	-	-	-
IC's avg., 1% Si	kg	0.03		-	-					-	-	-	-
SMD/LED's avg.	kg	0.05		-	-					-	-	-	-
PWB 1/2 lay 3.75KG/m^2	kg	0.00		-	-					-	-	-	-
PWB 6 lay 4.5kg/m^2	kg	0.08		-	-					-	-	-	-
glass for LCD	kg	0.36		2.95						11.65	0.74		
glass for lamps	kg	0.00		2.95						11.65	0.74		
solder $SnAg4Cu_{0.5}$	kg	0.01		-	-					-	-	-	-
Cardboard	kg	0.92		1.86	1.71	0.75				93.56	86.17	0.33	0.30
	Total amount	3.72											
Electricity	kWh	0.33		3.15	1.05	0.04	0.01			57.64	19.23	0.51	0.17
∑					151.66		0.01		0.00		896.23		8.37

Table 35: MIPS input table for materials required to produce 1 17 inch LCD Monitor.

Calculation sheet
Data refer to: 17inch LCD Monitor
(2007)

Name				**Abiotic Material**		**Biotic Material**		**Earth movements**		**Water**		**Air**	
Substance/pre-product	Unit	Amount		MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
LDPE	kg	0.16		2.49	0.41					122.20	20.04	1.62	0.27
EPS	kg	0.28		2.50	0.70					137.68	38.37	2.47	0.69
PVC	kg	0.04		3.47	0.15					305.29	13.07	1.70	0.07
ABS	kg	0.68		3.97	2.70					206.89	140.50	3.75	2.55
PA 6	kg	0.42		5.51	2.33					921.03	388.88	4.61	1.95
PC	kg	0.38		6.94	2.67					212.19	81.64	4.70	1.81
PMMA	kg	0.15		9.53	1.46					167.36	25.58	2.90	0.44
E-glass Fibre	kg	0.12		6.22	0.74					94.49	11.32	2.09	0.25
Aramid fibre	kg	0.01		37.03	0.24					940.39	6.11	19.57	0.13
steel sheet galvanized	kg	1.85		9.32	17.28					81.86	151.77	0.77	1.43
Al sheet/extrusion	kg	0.04		37.00	1.44					1047.70	40.86	10.87	0.42
CU wire	kg	0.19		179.07	33.95					236.39	44.82	1.16	0.22
Powder Coating	kg	0.00		-	-					-	-	-	-
big caps and coils	kg	0.04											
Al	kg	0.01		37.00	0.51					1047.70	14.44	10.87	0.15
Cu	kg	0.01		348.47	4.80					367.16	5.06	1.60	0.02
Fe	kg	0.01		12.00	0.17					91.00	1.25	1.90	0.03
slots/extension ports	kg	0.04		179.07	6.55					236.39	8.64	1.16	0.04
IC's avg., 5%Si, Au	kg	0.01		-	-					-	-	-	-

IC's avg., 1% Si	kg	0.02		-	-					-	-	-	-
SMD/LED's avg.	kg	0.01		-	-					-	-	-	-
PWB 1/2 lay 3.75KG/m^2	kg	0.03		-	-					-	-	-	-
PWB 6 lay 4.5kg/m^2	kg	0.02		-	-					-	-	-	-
glass for LCD	kg	0.00		2.95	0.00					11.65	0.00	0.74	0.00
glass for lamps	kg	0.03		2.95	0.08					11.65	0.30	0.74	0.02
Cast iron	kg	1.17		12.00	13.98					91.00	106.02	1.90	2.21
solder $SnAg4Cu_{0.5}$	kg	0.01		-	-					-	-	-	-
Office paper	kg	0.05		9.17	0.50	2.56	0.14			302.99	16.51	1.28	0.07
Cardboard	kg	0.65		1.86	1.21	0.75	0.49			93.56	60.81	0.33	0.21
	Total amount	6.41											
Electricity	kWh	0.27		3.15	0.84	0.04	0.01			57.64	15.42	0.51	0.14
∑					92.70		0.64		0.00		1191.42		13.12

Table 36: MIPS input table for materials required to produce 1 iPhone 5 (Apple 2012).

Calculation sheet

Data refer to: 1 iPhone 5 (2013) Final product attributes only - does not consider treatment of materials to produce phone.

Name Substance/pre-product	Unit	Amount		**Abiotic Material** MI-Factor kg/unit	kg/unit Main product	**Biotic Material** MI-Factor kg/unit	kg/unit Main product	**Earth movement** MI-Factor kg/unit	kg/unit Main product	**Water** MI-Factor kg/unit	kg/unit Main product	**Air** MI-Factor kg/unit	kg/unit Main product
PC	kg	0.01		6.94	0.03					212.19	1.06	4.70	0.02
Aluminium	kg	0.02		37.00	0.78					1047.70	22.00	10.87	0.23
Stainless steel	kg	0.02		14.43	0.26					205.13	3.69	2.83	0.05
Glass	kg	0.02		2.95	0.05					11.65	0.21	0.74	0.01
big caps and coils	kg	0.01											
Al	kg	0.00		37.00	0.15					1047.70	4.19	10.87	0.04
Cu	kg	0.00		348.47	0.46					367.16	0.49	1.60	0.00
Fe	kg	0.00		12.00	0.01					91.00	0.04	1.90	0.00
Display	kg	0.10		-	0.47		0.00		0.00		6.68		0.06
Lithium-ion battery	kg	0.03		-	-					-	-	-	-
HighImpact PS	kg	0.02		2.78	0.07					175.26	4.21	3.15	0.08
Plastics	kg	0.00		2.51	0.01					164.04	0.66	2.80	0.01
Cardboard/paper	kg	0.12		1.86	0.22	0.75	0.09			93.56	10.85	0.33	0.04
	Total amount	0.34											
Electricity	kWh	35.00		3.15	110.25	0.04	1.40			57.64	2,017.40	0.51	17.99
∑					111.95		1.49		0.00		2048.42		18.28

Table 37: MIPS input table for materials required to produce 1 iPod (Apple 2013).

Calculation sheet

Data refer to: 1 iPod Classic (2013) Final product attributes only - does not consider treatment of materials to produce phone.

Name Substance/pre-product	Unit	Amount		**Abiotic Material** MI-Factor kg/unit	kg/unit Main product	**Biotic Material** MI-Factor kg/unit	kg/unit Main product	**Earth movements** MI-Factor kg/unit	kg/unit Main product	**Water** MI-Factor kg/unit	kg/unit Main product	**Air** MI-Factor kg/unit	kg/unit Main product
PC	kg	0.01		6.94	0.03					212.19	1.06	4.70	0.02
Aluminium	kg	0.02		37.00	0.67					1047.70	18.86	10.87	0.20
Stainless steel	kg	0.03		14.43	0.43					205.13	6.15	2.83	0.08
big caps and coils	kg	0.01											
Al	kg	0.00		37.00	0.12					1047.70	3.49	10.87	0.04
Cu	kg	0.00		348.47	0.39					367.16	0.41	1.60	0.00
Fe	kg	0.00		12.00	0.00					91.00	0.03	1.90	0.00
Display	kg			-	0.32		0.00		0.00		4.51		0.04
Lithium-ion battery	kg	0.03		-	-					-	-	-	-
polystyrene	kg	0.02		2.78	0.04					175.26	2.63	3.15	0.05
Plastics	kg	0.01		2.51	0.02					164.04	1.23	2.80	0.02
Cardboard (shipping)	kg	0.09		1.86	0.16	0.75	0.06			93.56	7.95	0.33	0.03
Cardboard/paper	kg	0.12		1.86	0.22	0.75	0.09			93.56	11.23	0.33	0.04
	Total amount	0.31											
Electricity	kWh	3.00		3.15	9.45	0.04	0.12			57.64	172.92	0.51	1.54
∑					11.16		0.27		0.00		210.56		1.84