INTEGRATING LIFE CYCLE ASSESSMENT
IN AT&T'S PRODUCT ECO-RATING SYSTEM

by

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Contents

EXECUTIVE SUMMARY

AT&T Inc. is an American communications holding company whose subsidiaries and affiliates are providers of AT&T services, including wireless services. In connection with its Citizenship & Sustainability (C&S) efforts, AT&T requires that wireless devices carrying its brand be rated based on a number of environmental factors. These factors are assessed and devices are given an eco-rating of 1-5 stars. Now, AT&T is looking to incorporate life cycle assessment (LCA) into this product eco-rating system. This Master's Project serves as a reference guide to assist AT&T in the integration of LCA in their eco-ratings. It also serves as the foundation for a business strategy roadmap which leverages the incorporation of LCA in corporate sustainability initiatives. This enhances transparency, reliability and innovation – not only as it relates to the company itself, but in helping consumers and other organizations forge a more sustainable future in an ever-evolving world.

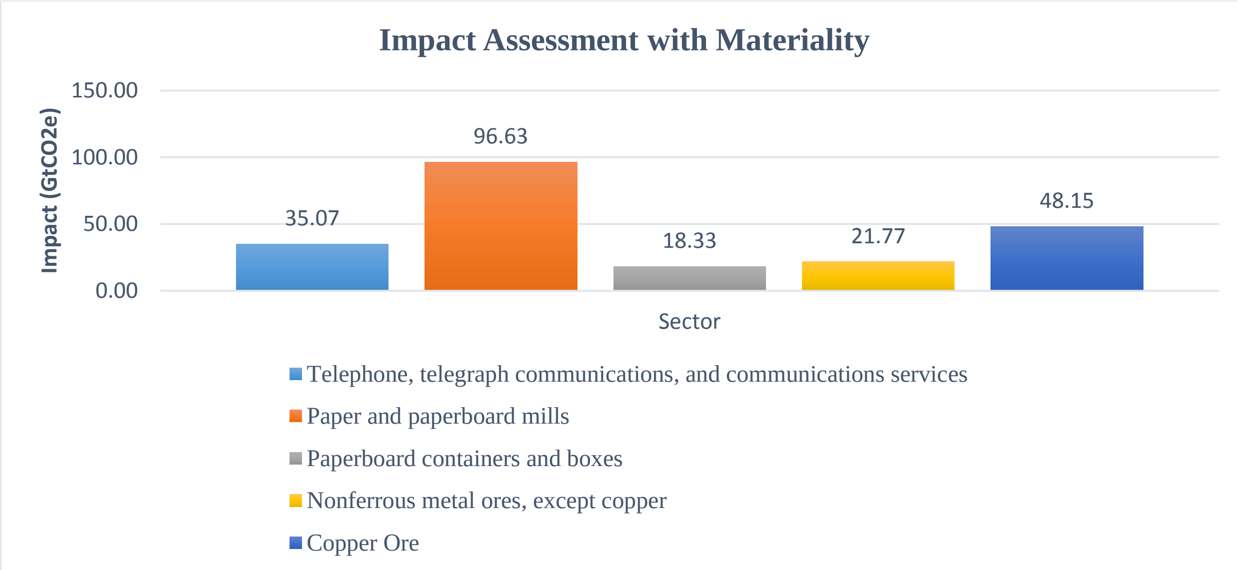
This report begins with an overview of sustainability initiatives at AT&T, followed by a breakdown of the company's product eco-rating system. Subsequent sections consist of an LCA overview and roadmap, an analysis of emerging trends in the industry with regards to life cycle and impact assessment, and recommendations for further development of AT&T's C&S efforts.

The LCA overview discusses the stages of a typical product life cycle: raw material extraction, manufacturing and assembly, transportation and distribution, consumer use, and end-of-life. Additional, less common, stages are sometimes included as well, such as packaging. This section then discusses methods for narrowing the scope of an LCA project, based on selected life cycle stages of importance. The general system boundary for a typical LCA falls into one of four scope categories: cradle-to-grave, cradle-to-cradle, cradle-to-gate, and gate-to-gate. Another possibility is a more detailed partial LCA with a narrower scope comprised of only a select few of these categories.

Further detail is provided on LCA frameworks in the section on ISO 14000 environmental standards. This section discusses the four components of a typical LCA: goal and scope definition, inventory analysis, impact assessment, and interpretation.

An environmental impact assessment is one of the most important components in conducting an effectual LCA. This section provides a sample impact assessment with respect to 13 impact categories: global warming potential, ozone depletion potential, human toxicity potential, freshwater aquatic ecotoxicity potential, acidification potential, eutrophication potential, ozone depletion potential, land use change, marine aquatic ecotoxicity potential, freshwater sediment ecotoxicity potential, and marine sediment ecotoxicity potential. Five sectors of the US economy were analyzed to determine their individual contributions to each of these categories. These sectors are: (1) telephone, telegraph communications, and communications services; (2) paper and paperboard mills; (3) paperboard containers and boxes; (4) nonferrous metal ores, except copper; and (5) copper ore.

Results are sub-divided into direct, intermediate, and final impacts, in order to evaluate where the environmental hotspots lie along the supply chain. Impact categories were ranked based on materiality, which were then used as dummy variables to create end-point scores. These scores (shown in the graph below) illustrate the results of this assessment in relative terms, which suggest that including the packaging stage in an LCA for a mobile device is extremely important, as the impacts of paper and paperboard milling (commonly used for packaging) are high relative to other parts of the product's life cycle.



Total (direct, intermediate and final) impacts by sector after correcting for materiality ranking. Results are relative. Data extracted from Economy Map.

According to a GeSI report on the role of information and communications technology (ICT) in driving a sustainable future, while ICT accounts for only 2.4% of the forecasted 2020 carbon footprint for the US, it has the potential to abate 16.5% of all greenhouse gas emissions – seven times its own footprint. GeSI has identified three main categories of environmental impacts in ICT – data centers, voice and data networks, and end-user devices – as well as a number of change levers that can be used to drive impact reduction. An analysis of these drivers (illustrated in a heat map) identifies the integration of renewables in power generation, and the optimization of logistics networks in manufacturing as the strongest change levers.

This report makes several key points and recommendations:

- Paperboard packaging is potentially one of the most impact-intense stages in the life cycle of a mobile device. Where possible, packaging should be included in the scope of an LCA.
- Environmental impact assessment is an important step in conducting an LCA. This should also be preceded by an internal stakeholder materiality assessment prior to defining the LCA's scope.
- ICT plays a key role in reducing impacts from greenhouse gas emissions, with the potential to abate more than seven times its own footprint. Renewables integration and logistics optimization can help drive this abatement.

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INTRODUCTION

Project Outline

The purpose of this project is to conduct an analysis of emerging trends in life cycle assessment (LCA) within the telecommunications industry, specifically as it relates to AT&T Inc. This project will serve as a reference guide for AT&T to incorporate elements of LCA in their corporate social responsibility (CSR) initiatives. More specifically, AT&T aims to integrate LCA in their product eco-ratings – a system that informs consumers of the environmental and social impacts of the products they purchase from AT&T by raising awareness on the environmental and social implications of the life cycles of those products. In connection with its Citizenship & Sustainability (C&S) efforts, AT&T developed a product eco-rating system for the original equipment manufacturers (OEMs) to assess whether their devices (cellphones, accessories, and tablets) satisfy a specific set of environmental and social criteria. Depending on which criteria are – or are not – met, the device is given a score which is associated with an eco-rating of 1-5 stars. This rating is displayed on AT&T's consumer website (http://www.att.com/ecospace) so that consumers can incorporate environmental and social considerations in their purchasing decisions.

Greenhouse gas (GHG) emissions are some of the greatest contributors to global climate change, highlighting the importance of regulation. The information and communications technology (ICT) sector has the potential to reduce a significant amount of greenhouse gas emissions through technological innovation. An industry analysis was performed to determine GHG abatement potential within ICT.

To further address emerging industry trends, this project also provides a high level overview of what some other companies in the industry are doing with respect to LCA. AT&T can use this information to gauge the state of LCA in the ICT industry and the general direction LCA in corporate sustainability is heading.

Legal Statement and Master's Project Scope

This Master's Project was written in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment at Duke University. Master of Environmental Management candidate Danielle Barrs is the author of this report. The student's advisor was Dr. Christopher Wedding. AT&T was pleased to assist the Duke University student in this work. However, AT&T is not the author of this report and does not make any claim, express or implied, or endorse any claims made by the authors of this report.

Brief History of AT&T

AT&T Inc. is an American communications holding company headquartered in Dallas, Texas. Its subsidiaries and affiliates are the providers of AT&T services, including wireless services – in the United States and internationally. AT&T is committed to corporate social and environmental responsibility and to reducing the environmental impacts of their products and services.

In 2011, AT&T released their first product eco-rating system – version 1.0. AT&T then collaborated with Business for Social Responsibility (BSR) to launch a second version of the original eco-rating system in 2015 – version 2.0. AT&T's Eco-Rating 2.0 has many of the same features and specifications as version 1.0, plus some additional components. The next section provides an overview of both eco-rating systems.

Sustainability at AT&T

Each year, AT&T publishes a sustainability update report to give consumers and stakeholder insight into the company's sustainability initiatives. Showcasing these accomplishments increases transparency and provides a foundation on which others in the industry can grow their own sustainability initiatives. AT&T asserts that helping markets and consumers develop sustainable practices is a big part of their mission, using technology to facilitate more effective environmental management[1]. Through water efficiency, energy conservation, smart grids, and many other program developments, AT&T uses technology and innovation to pave the way for sustainable development in ICT.

Another way AT&T drives sustainable development in the ICT industry is through collaboration. AT&T has worked with a number of organizations in the name of paying it forward. For instance, AT&T recently collaborated with the Environmental Defense Fund (EDF) to develop a water efficiency toolkit to help companies reduce their water consumption[2]. The toolkit is comprised of an Excel-based water management application (which includes a scorecard and efficiency calculator), a video series on cooling system efficiency, and downloadable sample water audit forms. AT&T has also developed a comprehensive energy management approach which focuses on company-wide energy efficiency initiatives, collaboration, and alternative energy solutions to improve service reliability[3]. AT&T uses key performance indicators such as energy intensity, solar and fuel cell capacity, and annualized energy savings from internal energy projects. Additionally, AT&T encourages the reuse and recycling of products through various device buyback and recycling programs. Customers can receive a promotion card worth the buyback value of their smartphones, tablet or netbook, just by turning in their old device. AT&T makes it easy and convenient by offering prepaid mailing labels for returning old items. Customers can also drop items off at any retail store.

With so many CSR program developments under AT&T's belt, it raises the question of where all these impacts are coming from. Exploring product LCA and engaging OEMs can give AT&T great insight into sources of environmental impacts, and help prioritize projects based on magnitude and abatement potential.

AT&T'S PRODUCT ECO-RATINGS

Overview

AT&T requires that wireless devices carrying its brand be rated by the Original Equipment Manufacturer (OEM) based on five environmental attributes: (1) Substances of Concern, (2) Environmentally Preferable Materials, (3) Energy Efficiency, (4) End of Life, and (5) Responsible Manufacturing. Each attribute is further broken down into individual criterion. The device receives one point for each criteria met. These are the criteria OEMs use to self-assess each product. The results of this self-assessment are given to AT&T for verification. Based on that assessment, each device will carry an AT&T eco-rating of 1-5 stars. This rating is displayed next to the associated product on AT&T's website.

Eco-Ratings 1.0

Eco-Rating 1.0 Scoring and Devices	
Scoring	**Number and Types of Devices Rated**
• 1 point per criterion • 15 criteria • 15 points total	• New devices and accessories to the AT&T's portfolio - approximately 45 handset devices and 10 accessories annually.

Eco-Rating 1.0 Number of Stars by Score	
Score	**Number of stars**
6-7	1
8-9	2
10-11	3
12-13	4
14-15	5

Eco-Rating 1.0 Attribute Categories and Criteria		
Attribute	**Criteria**	**Highest Possible Score**
Hazardous Substances	1. Restriction of lead, cadmium and mercury in battery 2. Restriction of Hazardous Substances (RoHS) compliance and restriction of BFR, PVC and chlorine compounds 3. Restriction of extractable nickel 4. Restriction of antimony trioxide/antimony compounds and beryllium compounds	4/4
Environmentally Preferable Materials	1. Meets AT&T environmentally preferable packaging criteria 2. Percentage of postconsumer waste plastic in housing 3. Recycled metal contents and percentage	3/3
Energy Efficiency	1. GSMA/OMTP Universal Charging Solution and meets no-load consumption threshold 2. Energy-efficiency features: full charge notification or power-based monitoring/management of applications	2/2
End of Life	1. Battery removability and device disassembly by recycler 2. Device materials recyclability rate 3. Provision of recycling information and promotion on device	3/3
Responsible Manufacturing	1. ISO 14001 (Environmental Management) or EU's Eco-Management & Audit Scheme (EMAS) 2. Device materials recyclability rate 3. Public reporting of greenhouse gas (GHG) emission reduction targets and performance toward targets	3/3
Total eco-score		**15/15**

Eco-Ratings 2.0

Eco-Rating 2.0 Scoring and Devices	
Scoring	**Number and Types of Devices Rated**
• 1 point per criterion • 20 criteria • 20 points total	• New devices and accessories to the AT&T's portfolio - approximately 45 handset devices; 10 accessories; and 5 tablets annually.

Eco-Rating 2.0 Number of Stars by Score	
Score	**Number of stars**
8-9	1
10-12	2
13-15	3
16-18	4
19-20	5

Eco-Rating 2.0 Attribute Categories and Criteria		
Attribute	**Criteria**	**Highest Possible Score**
Substances of Concern	1. Collection of data on device materials. 2. Restriction of antimony trioxide and beryllium compounds. 3. Restriction of extractable nickel. 4. Restriction of PVC, phthalates, and chlorinated and brominated fire retardants.	4/4
Environmentally Preferable Materials	1. Lifecycle assessment. 2. Recycled plastic in housing. 3. Device contains recycled metals.	3/3
Energy Efficiency	1. Device charger complies with California Energy Commission (CEC) standards.	1/1
End of Life and Recycling	1. Battery is readily removable and device is easily disassembled by recycler. 2. Device contains recyclable materials equal to or greater than 65% of its mass.	2/2
Environmentally and Socially Responsible Manufacturing	1. Global Reporting Initiative (GRI) sustainability report 2. Conflict minerals disclosure. 3. Stand-alone human rights policy or statement. 4. Policy, management systems and public performance reporting for labor, occupational safety and environment at assembly and/or supplier facilities.	10/10
Total eco-score		**20/20**

OVERVIEW OF LIFE CYCLE ASSESSMENT

Product Life Cycle

Life Cycle Assessment (LCA) is a tool used to identify and evaluate environmental impacts of products and services. A complete LCA should consider all stages of a product's life cycle, but specifics will differ depending on the agreed-upon scope. The typical product life cycle consists of at least five stages: (1) Extraction, (2) Manufacturing, (3) Distribution, (4) Use, and (5) End-of-Life (*figure 1*). In some instances, especially within the consumer products industry, companies will include packaging and/or retail as a 6th stage (*figures 2-3*). In fewer instances, a design stage is also included.

Figure 1: Stages of a basic LCA.

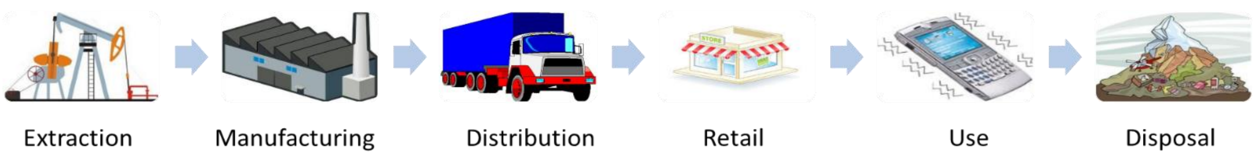

Figure 2: Variation of the basic LCA with Retail stage added.

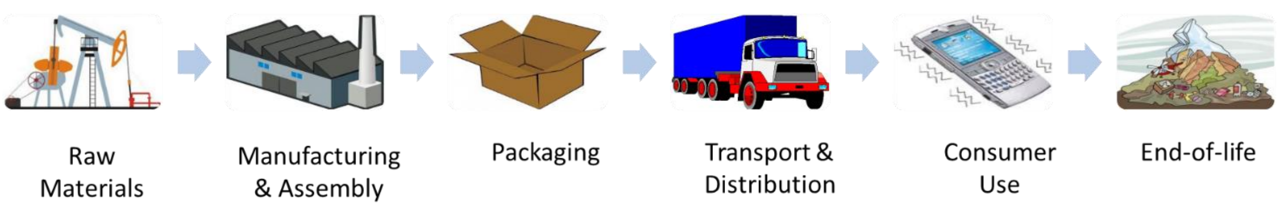

Figure 3: Variation of the basic LCA with Packaging stage added.

Extraction

Extraction refers to the withdrawal of raw materials from their source. For example, approximately 40% of the material used in the production of printed circuit boards (PCBs) for mobile phones and laptops contain metals such as copper[4]. The mining of copper ore (and other raw material components) would therefore be the first stage in the life cycle of a mobile phone. This stage in the product life cycle directly impacts the depletion of natural resources.

Manufacturing & Assembly
Manufacturing is the process of forging raw materials into components of the final product for assembly and shipping. One way to mitigate environmental impacts at this stage is to use sulfur dioxide scrubbers on factory smoke stacks to help purify the air. Sulfur dioxide (SO_2) is a gas released mostly by coal-fired power plants, which can cause acid rain and ground-level ozone (smog)[5]. The SO_2 captured in the scrubber can be mixed with limestone to create calcium sulfate (also known as synthetic gypsum), a recyclable product that can be used to make drywall and cement.[6] In 2010, UL Environment released a standard for gypsum boards and panels, called ULE 100, along with interim sustainability requirements (ISRs).[7]

Distribution
The distribution stage consists of the transportation of manufactured products from the factory to the intermediate holding facility, which could be a warehouse, retail store, or purchaser. This stage consists of an evaluation of both the mode of transportation and distance to retail. Converting to a more fuel-efficient fleet or creating more efficient shipping routes (or closer facilities) is the best way to mitigate environmental impacts within this stage. Bulk shipping is generally more environmentally-friendly than "just-in-time" shipping.

Retail
The retail stage is comprised of impacts associated with retail stores in which products are stored and sold. Converting lighting from fluorescents to LEDs is a popular way of mitigating environmental impacts at this stage. Product displays also utilize a lot of lighting. Adding motion sensors so that displays only light up as customers pass by is one way to decrease energy use from retail store displays. Converting paper and paperboard signage to digital signage is a more creative and increasingly popular way to mitigate the environmental impact of retail.

Use
The use stage consists of actual consumer use of the product. Impacts derived from consumer use of mobile phones to talk, text, and browse the internet – and all associated telecommunications – are components of the use stage.

End-of-Life
The end-of-life (post-consumer use) phase can take two different paths. The first is disposal – throwing the product in the trash that ends up in a landfill. Products that follow this path have what is known as "cradle-to-grave" life cycles. The second path is reuse and/or recycling. Products that follow the second path have what is known as "cradle-to-cradle" life cycles.

System Boundary
The scope – or system boundary – of an LCA depicts what will – and will not – be in included in the assessment. The scope of a project may vary depending on geographic location or timeframe, but are most often differentiated based on which stages of the product's life cycle are being assessed.

Cradle-to-grave
Cradle-to-grave LCAs assess a product's life cycle from raw material extraction to post-consumer use, where "post-consumer use" typically means the product is sent to a landfill for incineration (*figure 4*). It is sometimes referred to as a B2C (business-to-consumer) process. A cradle-to-grave product life cycle is an "open loop" system.

Cradle-to-cradle

Cradle-to-cradle LCAs are similar to cradle-to-grave LCAs, as they also assess a product's life cycle from raw material extraction to post-consumer use (*figure 5*). But in cradle-to-cradle LCAs, "post-consumer use" is typically either recycling or reuse of the product, often with the help of take-back programs.

Cradle-to-gate

Cradle-to-gate LCAs assess a product's life cycle from raw material extraction to the distribution phase and is considered a partial LCA (*figure 4*). The use and disposal phases are omitted. This is sometimes referred to as a B2B (business-to-business) process.

Gate-to-gate

Gate-to-gate LCAs look at a single stage in a product's life cycle (e.g., transport and distribution). This partial LCA can later be incorporated into a more extensive LCA.

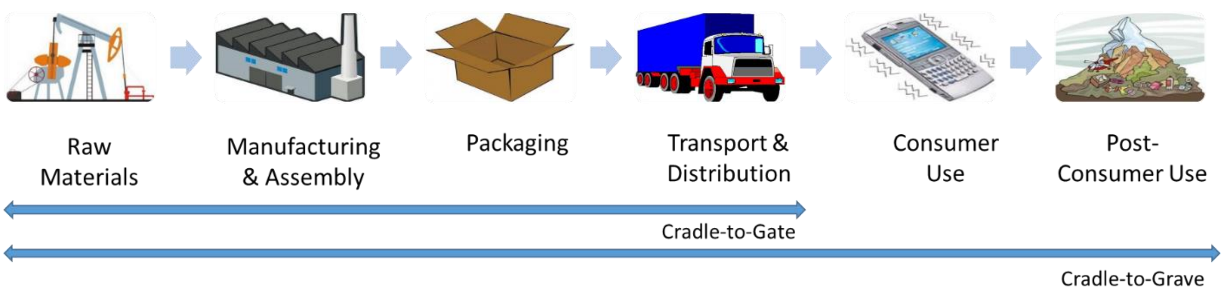

Figure 4: A typical product life cycle showing cradle-to-gate and cradle-to-grave scope boundaries. Drawn by Danielle Barrs.

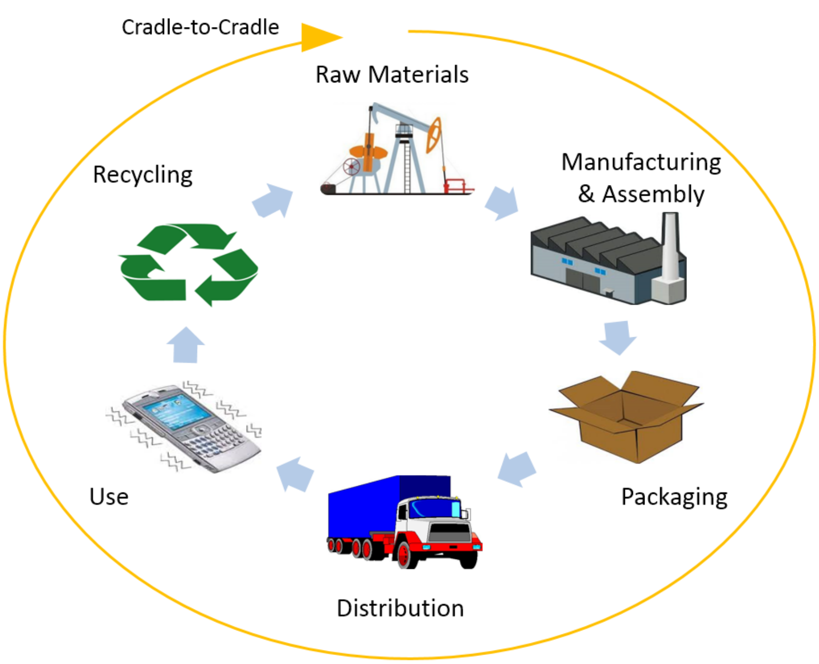

Figure 5: A typical closed-loop product life cycle showing the cradle-to-cradle scope boundary. Drawn by Danielle Barrs.

ENVIRONMENTAL STANDARDS

Environmental standards guide the impact of human activities on the natural environment. They depict a set of conditions that must be adhered to for those standards to be met. Standards vary among differing environmental activities, agencies, and organizations. ISO 14001 (part of the ISO 14000 series) is the world's most popular standard for environmental management, which helps companies and organizations worldwide reduce impacts and costs without compromising on performance or service[8].

ISO 14000

The International Organization for Standardization (ISO) follows a consensus-based approach for developing market-led standards initiated by industry demand. These standards are sometimes used as the basis for environmental regulations, and thus provide an opportunity for AT&T to meet both current and future relevant regulations, without compromising their own quality of products and services. ISO 14000 series is a family of standards that covers Environmental Management, which is then subdivided into more specific topics. For the purposes of this project, the two most relevant series are: *ISO 14040:2006 Life Cycle Assessment Principles and Framework*; and *ISO 14044:2006 Life Cycle Assessment Requirements and Guidelines*. According to ISO, the four phases of a complete LCA framework are (1) Goal & Scope Definition, (2) Inventory Analysis, (3) Impact Assessment, and (4) Interpretation[9].

(1) Goal and scope definition

The first phase of conducting an LCA is defining the goal and scope. The goal definition should include the overall purpose, the intended application, and the intended audience. The scope definition should include (a) the functional unit, (b) the system boundary, (c) allocation procedures, (d) impact categories, (e) assumptions and limitations, and (f) the format of the report.

Overall purpose

The purpose of conducting an LCA usually falls under one of three categories: (1) information gathering, (2) product or service evaluation, or (3) product or service comparison.

Functional unit

The functional units serves as a reference point, allowing a wide range of inputs and outputs of variable units to be compared by normalizing all measurements to a common unit, increasing comparability and accuracy. For example, both CO_2 and methane can be measured in CO_2 equivalents (CO_2e). As the universal reference gas under the Intergovernmental Panel on Climate Change (IPCC), CO2e is allocated a global warming potential (GWP) of 1. Methane, with 21 times the potency, has a GWP of 21. Thus, 1kg of methane has the same GWP as 21kg of CO_2, and can be normalized to 21kg of CO2e (with CO2e as the functional unit).[10]

System boundary

Creating a system boundary maps out which unit processes will and will not be included in the scope. For example, an open-looped product system may not include recycling processes, where the system boundary consists only of material extraction to disposal product life cycle stages. The boundary can also be set in terms of geographic area or time frame.

Impact categories

Defining the scope includes selecting impact categories for characterizing data. Impacts are defined as the consequences of system inputs and outputs on ecological health, human health, and resource depletion. Further detail on impact categories are discussed in later sections.

Limitations

Uncertainty is a limiting factor in many analyses, and LCA is no different. Defining system boundaries and gathering data are other difficulties. Furthermore, LCA does not account for non-environmental considerations such as product quality and cost.

(2) Inventory analysis

The life cycle inventory analysis (LCI) is a compilation of the inputs and outputs of the collected data.

3) Impact assessment

The life cycle impact assessment (LCIA) phase assesses the impact each output has on human and environmental health, as indicated by their contribution to pre-determined impact categories. During this phase, each component of the life cycle inventory is assigned to an impact category. Detailed information is provided on the significance and relevance of impacts. The LCIA should include impact categories, selected category indicators, individual LCI impact category assignments, and indicator results.[11]

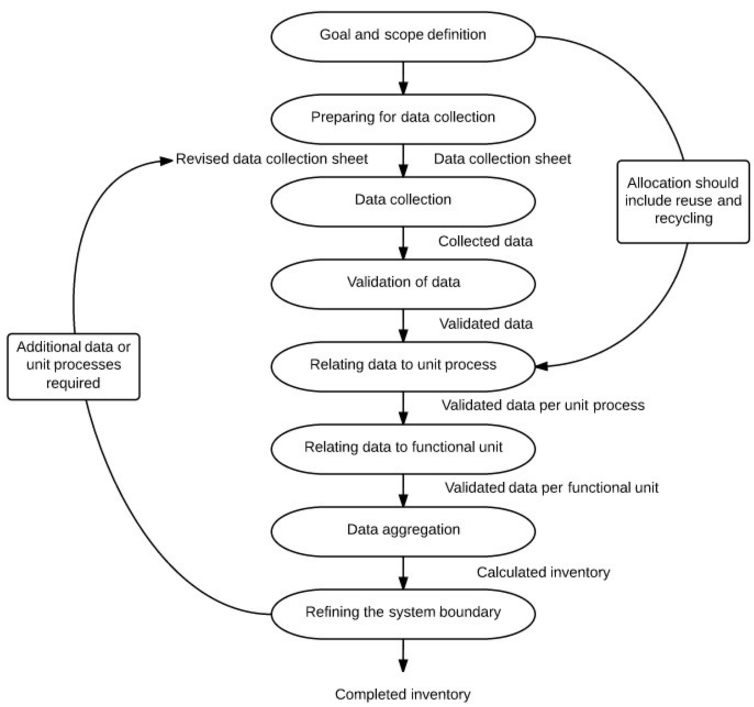

Figure 6: Simplified procedure for inventory analysis. Source: ISO 14044:2006.

(4) Interpretation

The interpretation consists of conclusions and subsequent recommendations. Each of the other three phases (goal and scope definition, inventory analysis, and impact assessment) should be interpreted separately, then aggregated to form over-arching inclusive conclusions. For each phase, identify significant issues; evaluate completeness, sensitivity, consistency, and limitations; and form conclusions and recommendations taking limitations into consideration.

ENVIRONMENTAL IMPACT ASSESSMENT

Impact Categories

According to the Environmental Protection Agency (EPA), the most commonly used life cycle impact categories are Global Warming Potential, Ozone Depletion Potential, Human Toxicity Potential, Freshwater Aquatic Ecotoxicity Potential, Marine Sediment Ecotoxicity Potential, Photochemical Oxidation Potential, Acidification Potential, Eutrophication Potential, Abiotic Depletion Potential, Land Use Change, and Ionizing Radiation.[12]

Impact Categories		
Impact Category	**Description**	**Units**
Global Warming Potential (GWP)	Potential to affect indicators of climate change such as polar melt, deforestation, and changes in wind and ocean patterns.	kg of CO_2e
Ozone Depletion Potential	Degradation of the stratospheric ozone layer caused by the release of certain pollutants, many of which have been banned by the 1987 Montreal Protocol. Thinning of the ozone layer increases the amount of UV radiation reaching the Earth's surface, which has significant human and environmental health implications.	kg of CFC-11e
Human Toxicity Potential	Effect of the release of certain chemical on human health. May also be considered in a toxics release inventory (TRI).	kg dichlorobenzene (DCB) eq.
Freshwater Aquatic Ecotoxicity Potential	Effect of the release of certain chemicals on freshwater ecosystems.	kg dichlorobenzene (DCB) eq.
Marine Sediment Ecotoxicity Potential	Effect of the release of certain chemicals on toxicity of marine sediment.	kg dichlorobenzene (DCB) eq.
Photochemical Oxidation Potential	Ground level ozone formation, also known as 'photochemical smog'. Usually caused by the reaction of sunlight on certain pollutants – such as volatile organic compounds (VOCs) and other emissions – in the atmosphere.	Non-methane Volatile Organic Compound (NMVOC) eq.
Acidification Potential	Decreasing the pH of a system, thus making it more acidic. Can result in acid rain.	SO_2e
Eutrophication Potential	High levels of algal growth caused by an over-abundance of nutrients, which can result in a hypoxic "dead zone".	Phosphate or nitrogen equivalents
Abiotic Depletion Potential	Effect on the depletion of abiotic (non-living) natural resources (e.g. crude oil). PETs (e.g. plastic water bottles) have high ADP since the primary raw material in plastic is petroleum.	kg antimony eq.
Land Use Change	Amount of land used or transformed for a given activity.	Total amount of land occupied (m^2 per year) or transformed (m^2)
Ionizing Radiation	Contribution to radiation of electromagnetic energy (common in X-rays).	kg of U-235e

Table 1: Environmental impact categories, descriptions and units. Source: U.S. Environmental Protection Agency. "Life Cycle Assessment: Principles and Practice". Scientific Applications International Corporation. May 2006. EPA/600/R-06/060. http://nepis.epa.gov/Exe/ZyPDF.cgi/P1000L86.PDF?Dockey=P1000L86.PDF

Types of Impacts

In addition to impact categories, impacts can also be divided into different types – direct and indirect. Indirect impacts can be sub-divided into intermediate and final impacts.

Direct impacts

Direct impacts are those that result directly from the industry's activity. A focus on direct impacts is sometimes referred to as the production- or supply- oriented perspective. For example, in the telecommunications industry, direct impacts would be those caused by customers actually using the device (talking, texting, and surfing the web). These types of impacts are best addressed through top-down regulation or technology innovation. Regulation and improved technology will have a direct and relatively immediate effect on the activity to which they are applied.

Intermediate impacts

Intermediate impacts are the cumulative direct and indirect (upstream) impacts of each sector. In the telecommunications industry, upstream impacts include metals and other materials that are used to make mobile phones and accessories. These types of impacts are best addressed by engaging AT&T's supply chain. A complete assessment of intermediate impacts would include an evaluation of all materials that go into making a typical mobile phone and product packaging – including metals, plastics, glass, and paper products. These materials "pass through" the telecommunications sector – as well as other industries – on their way down the supply chain. Intermediate impacts are best regulated through sustainable supply chain management and operational efficiency improvements. AT&T can use impact assessment and life cycle analysis to effectively manage product supply chains. These types of impacts should be AT&T's main focus as they are what AT&T has the most influence over.

Final impacts

Final impacts are those that result from downstream activities, and is sometimes referred to as a demand-oriented perspective. These types of impacts are best addressed through market mechanisms, and are usually in the hands of the consumer.

SAMPLE IMPACT ASSESSMENT USING ECONOMY MAP

Overview

There are many different methods, tools, and programs that can be used to conduct an impact assessment. The following analysis was conducted using Economy Map, which illustrates the concept of impact weighting for the purposes of impact assessment. Economy Map – an open-access interactive online map of the US industrial economy – is used to evaluate human and environmental direct, intermediate, and final impacts of US industries and their sources. Financial data is sourced from the the Bureau of Economic Analysis (BEA) at the US Department of Commerce, and environmental data is sourced from the US Environmental Protection Agency[13]. The software gathers readily available government data and creates a visual model representing the results of this data using Comprehensive Environmental Data Archive (CEDA) databases. Since each sector is measured in different units (global warming potential is measured in kg of CO_2 equivalent; abiotic depletion potential is measured in kg of antimony equivalent), all sector impacts are normalized into percentages of the overall US economy. For example, direct impacts associated with the *telephone, telegraph communications, and communications services* sector contribute to 0.1% of all impacts on *global warming potential* of the US economy (*table 2)*. In other words, eliminating all direct impacts of this sector would decrease the total impact of the US economy on global warming by 0.1%.

Method

Tables 2-6 display the results of an impact assessment using Economy Map. The output of Economy Map is divided up into thirteen impact categories: (1) global warming, (2) abiotic depletion, (3), photochemical oxidization, (4) human toxicity, (5) freshwater aquatic ecotoxicity, (6) acidification, (7) eutrophication, (8) ozone depletion, (9) land use change, (10) marine aquatic ecotoxicity, (11) terrestrial ecotoxicity, (12) freshwater sediment ecotoxicity, and (13) marine sediment ecotoxicity. For this analysis, these categories were ranked qualitatively from 1 to 13 based on assumptions of materiality to AT&T and the company's stakeholders, where 13 is of greatest importance to AT&T's stakeholders and 1 is of least importance *(note: total impact scores and subsequent conclusions will vary depending on selected impact categories and their respective quantitative impact weight)*. The top three material impact categories were global warming potential, abiotic depletion potential, and photochemical oxidation potential.

Selected Categories and Sectors of Interest

Five industry sectors were selected based on relevance to mobile phone production. The selected industry categories were: (1) telephone, telegraph communications, and communications services; (2) paper and paperboard mills; (3) paperboard containers and boxes; (4) nonferrous metal ores, except copper; and (5) copper ore. *Telephone, telegraph communications, and communications services* was included to illustrate overall impacts of the telecommunications industry. As most cell phones come in paperboard packaging, *paper and paperboard mills* and *paperboard containers and boxes* sectors were included as well. Nonferrous metal ores and copper ore sectors were included as to represent components of mobile phone parts such as the circuit board and battery.

The cumulative mid-point mean average weight is obtained by taking the average of direct, intermediate, and final impact scores. The result is multiplied by the qualitative impact weight to get a category end-point weight. All end-point weights are tallied to get a total end-point weight, which can then be used in a comparative analysis with other sectors. The multiplication of a quantitative variable (mid-point average) by a qualitative dummy variable (sector materiality rank) renders the results of this analysis relative, rather than absolute. Final impact scores can therefore be compared in relative terms, but not taken as absolute values. Table 7 summarizes the total end-point weights for each of the selected sectors of the US economy.

Results

Results of the sample impact assessment using Economy Map are displayed in Tables 2-6. The sector's contribution to each impact category is divided into direct, intermediate, and final impacts. The cumulative mid-point mean of these impacts are multiplied by the pre-determined qualitative impact weight (materiality ranking) to get the end point score. The summation of all end point scores for each impact category is the sector's total (relative) score.

	Mid-point				End-point	
Impact Category	**Direct Impacts**	**Intermediate Impacts**	**Final Impacts**	**Cumulative Mid-Point Mean Average Weight**	**Qualitative Impact Weight**	**End Point Weight**
Global Warming Potential	0.1	0.6	0.7	0.47	13	6.07
Abiotic Depletion	0	0.3	0.6	0.30	12	3.60
Photochemical Oxidation Potential	0.1	0.7	0.8	0.53	11	5.87
Human Toxicity Potential	0	0.6	0.9	0.50	10	5.00
Freshwater Aquatic Ecotoxicity Potential	0	0.2	0.2	0.13	9	1.20
Acidification Potential	0	0.6	0.7	0.43	8	3.47
Eutrophication Potential	0.1	0.4	0.5	0.33	7	2.33
Ozone Depletion Potential	0	0.7	1	0.57	6	3.40
Land Use Change	0	0.1	0.1	0.07	5	0.33
Marine Aquatic Ecotoxicity Potential	0	0.6	0.8	0.47	4	1.87
Terrestrial Ecotoxicity Potential	0	0.2	0.3	0.17	3	0.50
Freshwater Sediment Ecotoxicity Potential	0	0.6	0.8	0.47	2	0.93
Marine Sediment Ecotoxicity Potential	0	0.6	0.9	0.50	1	0.50
Total	0.3	6.2	8.3			35.07

Table 2: Economic Input/Output Life Cycle and Weighting for Telephone, telegraph communications, and communications services. Source: Economy Map

	Mid-point				End-point	
Impact Category	**Direct Impacts**	**Intermediate Impacts**	**Final Impacts**	**Cumulative Mid-Point Mean Average Weight**	**Qualitative Impact Weight**	**End Point Weight**
Global Warming Potential	1	0.8	0.1	0.63	13	8.23
Abiotic Depletion	0	0.5	0	0.17	12	2.00
Photochemical Oxidation Potential	1.6	1.1	0.1	0.93	11	10.27
Human Toxicity Potential	7.4	3.6	0.3	3.77	10	37.67
Freshwater Aquatic Ecotoxicity Potential	0.8	0.6	0	0.47	9	4.20
Acidification Potential	2.3	1.5	0.1	1.30	8	10.40
Eutrophication Potential	1.1	0.7	0.1	0.63	7	4.43
Ozone Depletion Potential	0.2	0.7	0.1	0.33	6	2.00
Land Use Change	0	0.1	0	0.03	5	0.17
Marine Aquatic Ecotoxicity Potential	1.6	1.2	0.1	0.97	4	3.87
Terrestrial Ecotoxicity Potential	1.9	1.1	0.1	1.03	3	3.10
Freshwater Sediment Ecotoxicity Potential	2.6	1.7	0.1	1.47	2	2.93
Marine Sediment Ecotoxicity Potential	14.5	7	0.6	7.37	1	7.37
Total	35	20.6	1.7			96.63

Table 3: Economic Input/Output Life Cycle Evaluation and Weighting for Paper and paperboard mills. Source: Economy Map

	Mid-point				End-point	
Impact Category	**Direct Impacts**	**Intermediate Impacts**	**Final Impacts**	**Cumulative Mid-Point Mean Average Weight**	**Qualitative Impact Weight**	**End Point Weight**
Global Warming Potential	0.3	0.4	0	0.23	13	3.03
Abiotic Depletion	0	0.2	0	0.07	12	0.80
Photochemical Oxidation Potential	0.4	0.6	0	0.33	11	3.67
Human Toxicity Potential	0	1.1	0.1	0.40	10	4.00
Freshwater Aquatic Ecotoxicity Potential	0	0.2	0	0.07	9	0.60
Acidification Potential	0.1	0.6	0	0.23	8	1.87
Eutrophication Potential	0.2	0.3	0	0.17	7	1.17
Ozone Depletion Potential	0.2	0.4	0	0.20	6	1.20
Land Use Change	0	0	0	0.00	5	0.00
Marine Aquatic Ecotoxicity Potential	0	0.4	0	0.13	4	0.53
Terrestrial Ecotoxicity Potential	0	0.3	0	0.10	3	0.30
Freshwater Sediment Ecotoxicity Potential	0	0.6	0	0.20	2	0.40
Marine Sediment Ecotoxicity Potential	0.1	2.1	0.1	0.77	1	0.77
Total	1.3	7.2	0.2			18.33

Table 4: Economic Input/Output Life Cycle Evaluation and Weighting for Paperboard containers and boxes. Source: Economy Map

	Mid-point				End-point	
Impact Category	**Direct Impacts**	**Intermediate Impacts**	**Final Impacts**	**Cumulative Mid-Point Mean Average Weight**	**Qualitative Impact Weight**	**End Point Weight**
Global Warming Potential	0	0	0	0.00	13	0.00
Abiotic Depletion	0	0	0	0.00	12	0.00
Photochemical Oxidation Potential	0	0	0	0.00	11	0.00
Human Toxicity Potential	3.4	1.2	0.7	1.77	10	17.67
Freshwater Aquatic Ecotoxicity Potential	0.4	0.1	0.1	0.20	9	1.80
Acidification Potential	0	0	0	0.00	8	0.00
Eutrophication Potential	0	0	0	0.00	7	0.00
Ozone Depletion Potential	0	0	0	0.00	6	0.00
Land Use Change	0	0	0	0.00	5	0.00
Marine Aquatic Ecotoxicity Potential	0.2	0.1	0.1	0.13	4	0.53
Terrestrial Ecotoxicity Potential	0.8	0.3	0.2	0.43	3	1.30
Freshwater Sediment Ecotoxicity Potential	0.4	0.2	0.1	0.23	2	0.47
Marine Sediment Ecotoxicity Potential	0	0	0	0.00	1	0.00
Total	5.2	1.9	1.2			21.77

Table 5: Economic Input/Output Life Cycle Evaluation and Weighting for Nonferrous Metal Ores, Except Copper. Source: Economy Map

	Mid-point				End-point	
Impact Category	**Direct Impacts**	**Intermediate Impacts**	**Final Impacts**	**Cumulative Mid-Point Mean Average Weight**	**Qualitative Impact Weight**	**End Point Weight**
Global Warming Potential	0	0.1	N/A	0.05	13	0.65
Abiotic Depletion	0	0.1	N/A	0.05	12	0.60
Photochemical Oxidation Potential	0	0.1	N/A	0.05	11	0.55
Human Toxicity Potential	4.8	1.7	N/A	3.25	10	32.50
Freshwater Aquatic Ecotoxicity Potential	0.9	0.3	N/A	0.60	9	5.40
Acidification Potential	0	0.1	N/A	0.05	8	0.40
Eutrophication Potential	0	0	N/A	0.00	7	0.00
Ozone Depletion Potential	0	0.1	N/A	0.05	6	0.30
Land Use Change	0	0	N/A	0.00	5	0.00
Marine Aquatic Ecotoxicity Potential	0.6	0.3	N/A	0.45	4	1.80
Terrestrial Ecotoxicity Potential	2	0.7	N/A	1.35	3	4.05
Freshwater Sediment Ecotoxicity Potential	1.3	0.6	N/A	0.95	2	1.90
Marine Sediment Ecotoxicity Potential	0	0	N/A	0.00	1	0.00
Total	9.6	4.1	N/A			48.15

Table 6: Economic Input/Output Life Cycle Evaluation and Weighting for Copper Ore. Source: Economy Map

	Telephone, telegraph communications, and communications services	**Paper and paperboard mills**	**Paperboard containers and boxes**	**Nonferrous metal ores, except copper**	**Copper Ore**
Total End Point Weight	35.07	96.63	18.33	21.77	48.15

Table 7: Total end point weight of selected industry sectors.

Analysis

Each result in the direct, intermediate, and final impacts columns should be read as follows:

Table 2 - Economic Input/Output Life Cycle and Weighting for Telephone, telegraph communications, and communications services:

Direct impacts from the telephone, telegraph communications and communications services sector are responsible for 0.1% of all impacts the US economy has on global warming potential, 0% of all impacts the US economy has on abiotic depletion potential, and 0.1% of all impacts the US economy has on photochemical oxidation. Intermediate impacts from the *telephone, telegraph communications and communications services* sector are responsible for 0.6% of all impacts the US economy has on global warming potential, 0.3% of all impacts the US economy has on abiotic depletion potential, and 0.7% of all impacts the US economy has on photochemical oxidation potential. Final impacts from the *telephone, telegraph communications and communications services* sector are responsible for 0.7% of all impacts the US economy has on photochemical oxidation potential, 0.6% of all impacts the US economy has on photochemical oxidation potential, and 0.8% of all impacts the US economy has on photochemical oxidation potential.

Table 3 - Economic Input/Output Life Cycle Evaluation and Weighting for Paper and paperboard mills:

Direct impacts from the *paper and paperboard milling* sector are responsible for 1% of all impacts the US economy has on global warming potential, 0% of all impacts the US economy has on abiotic depletion potential, and 1.6% of all impacts the US economy has on photochemical oxidation potential. Intermediate impacts from the *paper and paperboard milling* sector are responsible for 0.8% of all impacts the US economy has on global warming potential, 0.5% of all impacts the US economy has on abiotic depletion potential, and 1.1% of all impacts the US economy has on photochemical oxidation potential. Final impacts from the *paper and paperboard milling* sector are responsible for 0.1% of all impacts the US economy has on photochemical oxidation potential, 0% of all impacts the US economy has on photochemical oxidation potential, and 0.1% of all impacts the US economy has on photochemical oxidation potential.

Table 4 - Economic Input/Output Life Cycle Evaluation and Weighting for Paperboard containers and boxes:

Direct impacts from the *paperboard containers and boxes* sector are responsible for 0.3% of all impacts the US economy has on global warming potential, 0% of all impacts the US economy has on abiotic depletion potential, and 0.4% of all impacts the US economy has on photochemical oxidation potential. Intermediate impacts from the *paperboard containers and boxes* sector are responsible for 0.4% of all impacts the US economy has on global warming potential, 0.2% of all impacts the US economy has on abiotic depletion potential, and 0.6% of all impacts the US economy has on photochemical oxidation potential. Final impacts from the *paperboard containers and boxes* sector are responsible for 0% of all impacts the US economy has on photochemical oxidation potential, 0% of all impacts the US economy has on photochemical oxidation potential, and 0% of all impacts the US economy has on photochemical oxidation potential.

Table 5 - Economic Input/Output Life Cycle Evaluation and Weighting for Nonferrous Metal Ores, Except Copper:

Direct, intermediate, nor final impacts from the *nonferrous metal ores (except copper)* sector are responsible for a significant amount of all impacts the US economy has on global warming potential, abiotic depletion potential, or photochemical oxidation potential. The sector is, however, responsible for direct, intermediate, and final impacts on human toxicity potential (3.4%, 1.2%, and 0.7%, respectively).

Table 6 - Economic Input/Output Life Cycle Evaluation and Weighting for Copper Ore:

Direct impacts from the *copper ore* sector do not have a significant impact on global warming potential, abiotic depletion potential, nor photochemical oxidation potential. Intermediate impacts from this sector, however, are responsible for 0.1% of all impacts the US economy has on global warming potential, 0.1% of all impacts the US economy has on abiotic depletion potential, and 0.1% of all impacts the US economy has on photochemical oxidation potential.

Information for final impacts from the *copper ore* sector on all impact categories is not available in Economy Map. This sector is therefore treated as if there are no associated impacts. Overall results were also analyzed using total scores for all impact types and categories, which provides a better understanding of environmental hotspots sectors (*figure 7*). When conducting an LCA, it is important to note where these sectors lie in the life cycle of the device. For example, the copper ore industry is part of the raw material extraction phase, which is outside AT&T's recommended scope. However, telecommunications services are part of the consumer use phase, which *is* within AT&T's recommended scope.

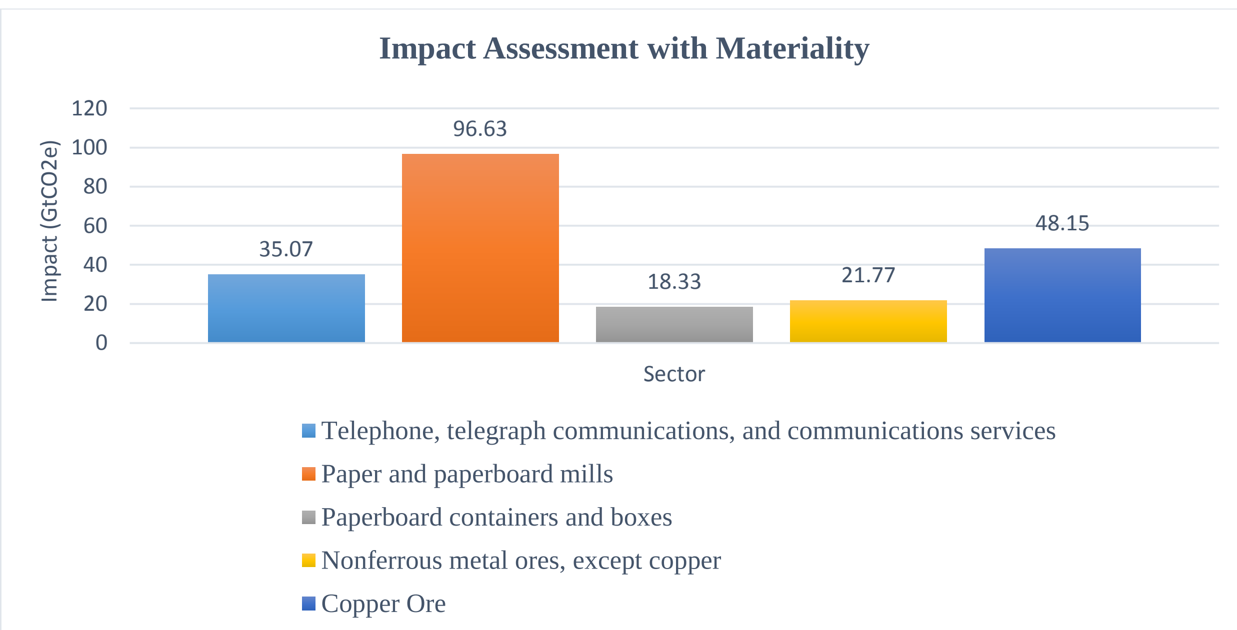

Figure 7: Total (direct, intermediate and final) impacts by sector after correcting for materiality ranking. Results are relative. Data extracted from Economy Map.

Impact assessment results can also be analyzed on the basis of materiality. For example, in this analysis global warming potential (GWP) was selected as the impact category carrying the most material (qualitative) weight. Out of the selected sectors, the *telephone, telegraph communications and communications services* and *paper and paperboard milling* sectors have the highest cumulative mid-point mean average weight. If the material weight of GWP holds true for AT&T's stakeholders, addressing these two sectors becomes a priority. Conducting a proper materiality assessment is essential prior to the impact assessment stage of the LCA framework, because difference in materiality rankings will affect overall impact scores in each impact category, which in turn will affect prioritization.

Finally, this analysis can be read as a comparison between similar categories. For example, based on the total end point weights for each category, *paper and paperboard mills* carry the most weight (*note: total end point weight will vary depending on quantitative impact weight*). If these qualitative impact category weights hold true, AT&T should consider focusing on paper and paperboard (packaging). However, it is also important to note, not only that paper and paperboard mills carry the most weight in this analysis, but also that paper and paperboard mills have a greater overall impact score than paperboard containers and boxes (96.63 and 18.33, respectively). Addressing upstream paperboard manufacturing should thus take precedence over paperboard container and box use and post-consumer use. In response to an analysis with these results, relaying these concerns to AT&T's packaging manufacturers would take precedence over addressing post-consumer use retail packaging. Put simply – cut down on paperboard manufacturing at the source. Similarly, within the umbrella category of nonferrous metal ores, copper has a greater overall impact score than non-copper nonferrous metal ores (48.15 and 21.77, respectively). Thus, in addressing impacts caused by the production of circuit boards and batteries, minimizing the use of copper should be a priority for manufacturers over other nonferrous metal ores.

Discussion

Direct impacts are best addressed through policy and regulations that incentivized technology innovation, and are thus most useful for policymakers. Intermediate impacts are best addressed through supply chain engagement, and therefore offer the best opportunity for businesses like AT&T to mitigate impacts associated with their products. Out of the five sectors analyzed, paper and paperboard mills has the highest intermediate impact score, therefore the highest potential to influence other sectors through effective supply chain management. Final impacts are best addressed through alternative purchasing decisions, and are therefore of greatest interest to consumers.

Telecommunications services, paper and paperboard mills, paperboard containers and boxes, nonferrous metal ores except copper, and copper ores industry sectors were chosen for the analysis based on their presumed materiality to AT&T. However, during this analysis, it became evident that other US industry sectors were shown to have a great enough impact to merit further consideration. These sectors are: crude petroleum and natural gas, electric services, motor vehicles and passenger car bodies, and retail trade.

Table 8 shows the intermediate impacts (those most easily addressed through supply chain management) for these additional industry sectors on the top three material impact categories chosen for the original Economy Map impact assessment (global warming potential, abiotic depletion potential, and photochemical oxidation potential). The focus is on intermediate impacts because these can be addressed through sustainable supply chain management, which can more easily be implemented by AT&T than direct or final impacts. Impact scores are listed as a ratio of their contribution to the total contribution of the US economy to the given impact category (shown as percentages).

Additional Material Impact Categories and Associated Intermediate Impact Scores	
US Economy Sector	**Intermediate Impact Score (% of US economy)**
Global Warming Potential	
Crude petroleum and natural gas	3.3
Electric services (utilities)	14.0
Motor vehicles and passenger car bodies	2.5
Retail Trade	2.0
Abiotic Depletion Potential	
Crude petroleum and natural gas	22.7
Electric services (utilities)	8.5
Motor vehicles and passenger car bodies	1.3
Retail Trade	1.3
Photochemical Oxidation Potential	
Crude petroleum and natural gas	2.7
Electric services (utilities)	9.6
Motor vehicles and passenger car bodies	2.8
Retail Trade	2.0

Table 8: Top 3 most material impact categories (Global Warming Potential, Abiotic Depletion Potential, and Photochemical Oxidation Potential) and associated intermediate impact score (as a percentage of the US economy for that impact type) for select sectors of interest not included in original analysis (crude petroleum and natural gas, electric services, motor vehicles and passenger car bodies, and retail trade). Data extracted from Economy Map.

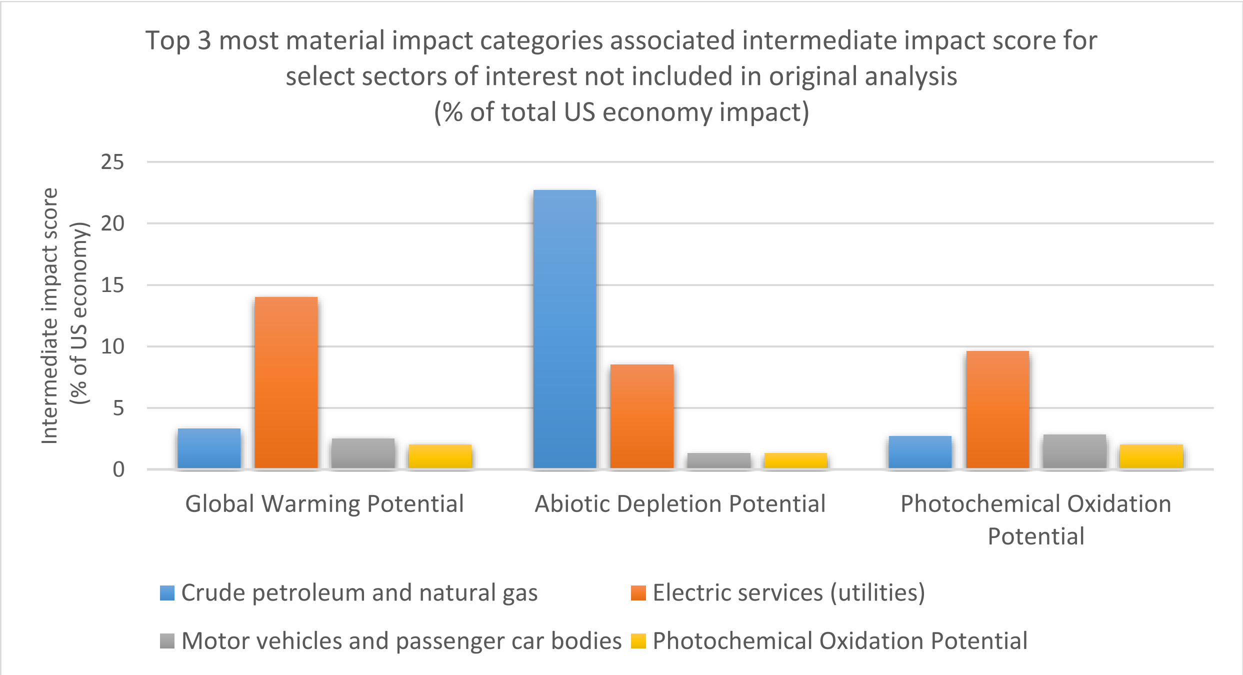

Figure 8: Top 3 most material impact categories (Global Warming Potential, Abiotic Depletion Potential, and Photochemical Oxidation Potential) and associated intermediate impact score (as a percentage of total US economy impacts on each impact category) for select sectors of interest not included in original analysis. Sectors are: crude petroleum and natural gas, electric services, motor vehicles and passenger car bodies, and retail trade). Source: Economy Map.

Out of the highest ranked material impact categories chosen for the original Economy Map impact assessment, both global warming potential and photochemical oxidation potential were most affected by intermediate impacts in the electric services sector, and abiotic depletion potential was most affected by intermediate impacts in the crude petroleum and natural gas sector. Although these sectors are not the focus of this project (nor should they be the main focus for the integration of LCA in AT&T's CSR initiatives), it illustrates the relative difference between impacts for sectors relevant for a telecommunications holding company, and those sectors actually causing the majority of intermediate impacts in the US economy. Consider that the range for intermediate impacts of the five original impact assessment sectors on global warming potential, abiotic depletion potential, and photochemical oxidation potential is 0%-1.1% – a fraction of the intermediate impacts of the select additional sectors. Table 9 shows these select additional sectors and examples of how to mitigate their impacts.

Select Additional US Economy Sectors and Mitigation Techniques	
US Economy Sector	**Examples of How to Address Impacts**
Crude petroleum and natural gas	Mitigating the use of petroleum-based product components, such as plastic.
Electric services (utilities)	Changing all plant and warehouse light bulbs to LED bulbs.
Motor vehicles and passenger car bodies	Converting part – or all – of transport and shipping fleets to electric vehicles (EVs) or hybrids.
Retail Trade	Changing store light bulbs to LED bulbs. Using occupancy (or motion) sensors during closing hours so display cases only light up when pedestrians pass by store windows.

Table 9: US economy sectors of interest not included in original analysis, and how to address associated impacts.

INDUSTRY ANALYSIS: GREENHOUSE GASES IN INFORMATION & COMMUNICATIONS TECHNOLOGY

Overview

As ranked by materiality through stakeholder engagement and consumer preference, the most important impact category from the sample impact assessment in previous sections was global warming potential (GWP). GWP measures the heat-trapping properties of a gas, and reflects how long the gas persists in the atmosphere and how much energy it absorbs[14]. Climate change is considered one of the greatest threats to human and natural systems, highlighting the extreme importance in forming a comprehensive global response to mitigate its effects by practicing effective emissions mitigation and risk management techniques. The faster these emissions can be reduced, the lower the risks posed by climate change[15].

Each stage in a product's life cycle has a set of inputs and outputs. Inputs are often in the form of raw materials or energy, while outputs are usually measured by their contribution to environmental degradation. For example, both aluminum and energy are circuit board inputs. Aluminum is a raw material that is used to manufacture circuit boards. The machinery that powers assembly of raw materials into product components (and eventually the final product) requires a certain amount of energy to run. Outputs for this stage are the by-products of manufacturing and assembly processes for each component of a mobile device.

GHGs that are emitted into the air as a result of these processes are outputs of circuit board production. When released into the air, these gases trap radiated energy, making them major contributors to global climate change. GHGs include carbon dioxide (CO_2), methane, nitrous oxide, and fluorinated gases, among others[16].

According to the International Energy Agency (IEA), business-as-usual will bring annual global GHG emissions to 55 $GtCO_2e$ (gigatons of carbon dioxide equivalent) by 2020, 1.3 Gt of which will come from ICT. The silver lining is that ICT also has the potential to abate 9.1 $GtCO_2e$ – seven times its own footprint.[17]

Impacts of ICT

Within the ICT sector, GeSI has identified three major categories for environmental impacts: (1) data centers, (2) voice & data networks, and (3) end-user devices. The data center category encompasses internal equipment and functions such as servers, storage systems, and cooling systems – and is the fastest growing category of ICT emissions. Voice and data networks are subdivided into wired and wireless categories. Wired – or *fixed* – networks include home access networks, enterprise networks, and data transport networks. Wireless network mobile data and voice traffic estimates for 2020 speculate that total traffic may grow by as much as 70 times compared to a 2011 baseline. Data per user is also expected to rise with the increasing popularity of streaming music and videos. Telecommunications companies are addressing this with 4G LTE networks and the expansion of wireless network capacities, and countering it with base station power amplifiers and redistribution of unused existing network capacity. Some companies have taken this a step further by integrating solar energy to power cell towers and base stations. End-user devices include TVs, printers, tablets, smartphones, and mobile phones.[18]

Within the ICT industry, GeSI predicts that data center processes (servers, storage systems, and cooling systems) will release 0.29 GtCO2e (23% of the ICT footprint) in 2020; voice and data networks will contribute 0.16 GtCO2e (23% of the ICT footprint) and 0.14 GtCO2e (23.8% of the ICT footprint) from wireless and wired sources, respectively; and end-user devices will contribute 0.67 GtCO2e (53.2% of the ICT footprint) to 2020 GHG emissions (figure 12). These numbers translate to 0.55% (data centers), 0.72% (voice and data networks), and 1.6% (end-user devices) of total 2020 GHG emissions. In 2014, AT&T reported a global total of 8,103,246 Scope 2 metric tonnes of CO2e – 682,011 of which came from data centers[19]. Powering AT&T's data centers with 100% renewable energy could reduce the company's Scope 2 emissions by 8.4%. This is equivalent to taking 143,581 passenger vehicles off the road[20].

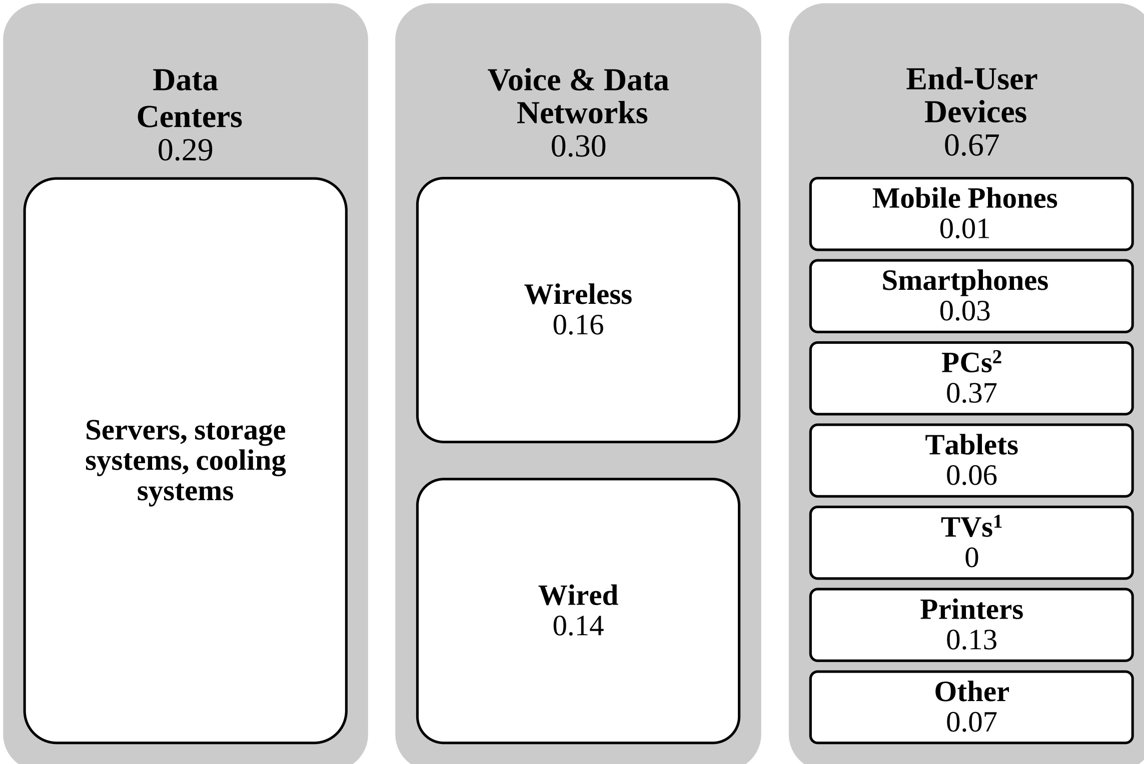

Figure 9: Estimated 2020 ICT impacts by category with associated impacts in GtCO2e (total = 1.3 GtCO2e). Only TV usage emissions related to IPTV included. Source: adapted from GeSI SMARTer 2020. Drawn by Danielle Barrs.

ICT's Abatement Potential

GeSI identifies four change levers that will drive GHG abatement in ICT: (1) digitalization and dematerialization, (2) data collection and communication, (3) system integration, and (4) process, activity and functional optimization. Of these drivers, *process, activity & functional optimization* is identified as having the greatest abatement potential, which addresses efficiency improvements by reducing transmission and distribution losses, using centralized data centers, and optimizing building design. *System integration* comes in second, which consists of more efficient resource use through virtualization of power plants, building management systems, and integration of renewables. *Data collection* is third, which encompasses the provision of real-time data and analysis for better and more efficient decision making, including demand management, building auditing, and performance benchmarking. Finally, *digitalization and dematerialization* eliminates emission-intensive processes and/or integrates material reuse and recycling. This includes increasing videoconferencing, telecommuting, and e-commerce. [21]

The study then divides each of the change levers (abatement drivers) into six end-use sectors: (1) power, (2), transportation, (3), manufacturing, (4) service and consumer, (5) agriculture and land use, and (6) buildings. Total manufacturing emissions across all four change lever categories have the greatest impact of the six end-use sectors – adding up to 17.4 $GtCO_2e$ – but estimated abatement potential is only 1.3 $GtCO_2e$ (figure 15).[22]

Abatement drivers	Sectors						
	Power	**Transportation**	**Manufacturing**	**Service & consumer**	**Agriculture & land use**	**Buildings**	**Total**
Digitalization & dematerialization	0	Video-conferencing	0	E-commerce	0	0	
	0	Tele-commuting	0	E-paper	0	0	
	0	0	0	Online media	0	0	
Sector total							0.5
Data collection & communication	Demand management	Eco-driving	0	Public safety & disaster management	Soil monitoring & Weather forecasting	0	
	Time of day pricing	Real-time traffic alerts	0	Smart water	Smart water	0	
	0	Intermodal transport app	0	0	Livestock management	0	
	0	Asset sharing & crowd sourcing	0	0	0	0	
Sector total							2.3
System integration	Integration of renewables	Integration of EVs	0	0	0	Renewables integration	
	Virtual power plant	Intelligent traffic management	0	0	0	Building management systems	
	Integration of off-grid renewables & storage	Fleet management & telematics	0	0	0	0	
Sector total							2.3
Process, activity & functional optimization	Power load balancing	Truck route optimization	Variable-speed motor system optimization	Minimizing packaging	Smart farming	Building design	
	Power grid optimization	Logistics network optimization	Logistics network optimization	Inventory reduction	0	Voltage optimization	
Sector total							4.1
Grand total	2	1.9	1.3	0.7	1.6	1.6	9.1

Figure 10: Heat map of ICT abatement potential by sector and driver from greatest (dark green) to least (red) amount of abatement potential (GtCO2e). Total ICT abatement potential is 9.1 GtCO2e. Only TV usage emissions related to IPTV included. Source: GeSI SMARTer 2020. Drawn by Danielle Barrs.

Analysis

GHG abatement potential associated with each driver and relevant end-user sectors have been compiled into a heat map (*figure 10*). Each of the four change drivers (process, activity and functional optimization, system integration, data collection, and digitalization and dematerialization) is sub-divided into six end-use sectors (power, transportation, manufacturing, service and consumer, agriculture and land use, and buildings). Only relevant end-use sectors (those with significant impact) are included for each driver category. The result is a heat map that color-codes change drivers from greatest to least abatement potential (dark green to red, respectively).

Drivers with the greatest impact are *integration of renewables* (power sector), *optimization of logistics networks* (manufacturing), *soil monitoring/weather forecasting* (agriculture and land use), and *livestock management* (agriculture and land use). However, agriculture is not relevant to AT&T's scope, so impacts associated with this sector should be negated. Moving to the next greatest abatement potential drivers, optimization of logistics networks (transportation sector), optimization of variable-speed motor systems (manufacturing), and integration of renewables (buildings) also have high environmental impacts. Of these drivers, integration of renewables (power sector), optimization of logistics networks (manufacturing and transportation), and optimization of variable-speed motor systems (manufacturing) are the most relevant to AT&T. Other sub-levers to consider are videoconferencing and telecommuting (transportation sector), minimization of packaging (service and consumer), and reduction in inventory (service and consumer), since AT&T may have more influence in driving change within these activities. For example, focusing on the development of highly-functional, well-designed, and easy-to-use videoconferencing applications on laptops, tablets, and mobile phones, can help mitigate end-user impacts associated with consumer use of these devices. Furthermore, distributing these devices to manufacturers, transportation and logistics employees, and other AT&T personnel can help mitigate indirect impacts within the supply chain and increase efficiency.

Conclusion

While ICT accounts for only 2.4% of forecasted carbon emissions over the next decade, it has the potential to reduce the impacts of both ICT and other sectors of the US economy by a combined total of more than seven times its own carbon footprint. If AT&T leveraged this ICT abatement potential to address Scope 2 emissions from its US data centers, the company could defer more than 680 thousand metric tonnes of carbon equivalent. This translates to pulling more than 143 thousand cars off the road. Powering these data centers with renewable energy can accomplish this. In addition to the integration of renewables in power generation, streamlining logistics networks in the manufacturing stage to increase efficiency has the potential to be a another strong driver in the reduction of carbon emissions.

APPENDICES

Appendix A- Duke Student Biography

Danielle Barrs is a second year Master of Environmental Management Candidate with a concentration in Environmental Economics and Policy and a focus in Energy. She is also pursuing a certificate in Sustainable Systems Analysis, which has allowed her to develop life cycle and environmental impact assessment skills while advising corporations on real industry projects. Her interests lie in sustainability business development strategy, specializing in sustainable supply chain management, operational efficiency, and management consulting. Danielle obtained her B.A. in Environmental Studies and Sustainability from Arizona State University, graduating Cumma Sum Laude as the Dean's Medalist for the School of Earth and Space Exploration. Before Duke, Danielle worked in environmental health and safety, healthcare, nonprofits, and event planning. She hopes to combine the knowledge on sustainability best practices and triple bottom line business solutions she learned at Duke to help bridge the gap between sustainability and business.

Appendix B- Select Economy Map Outputs

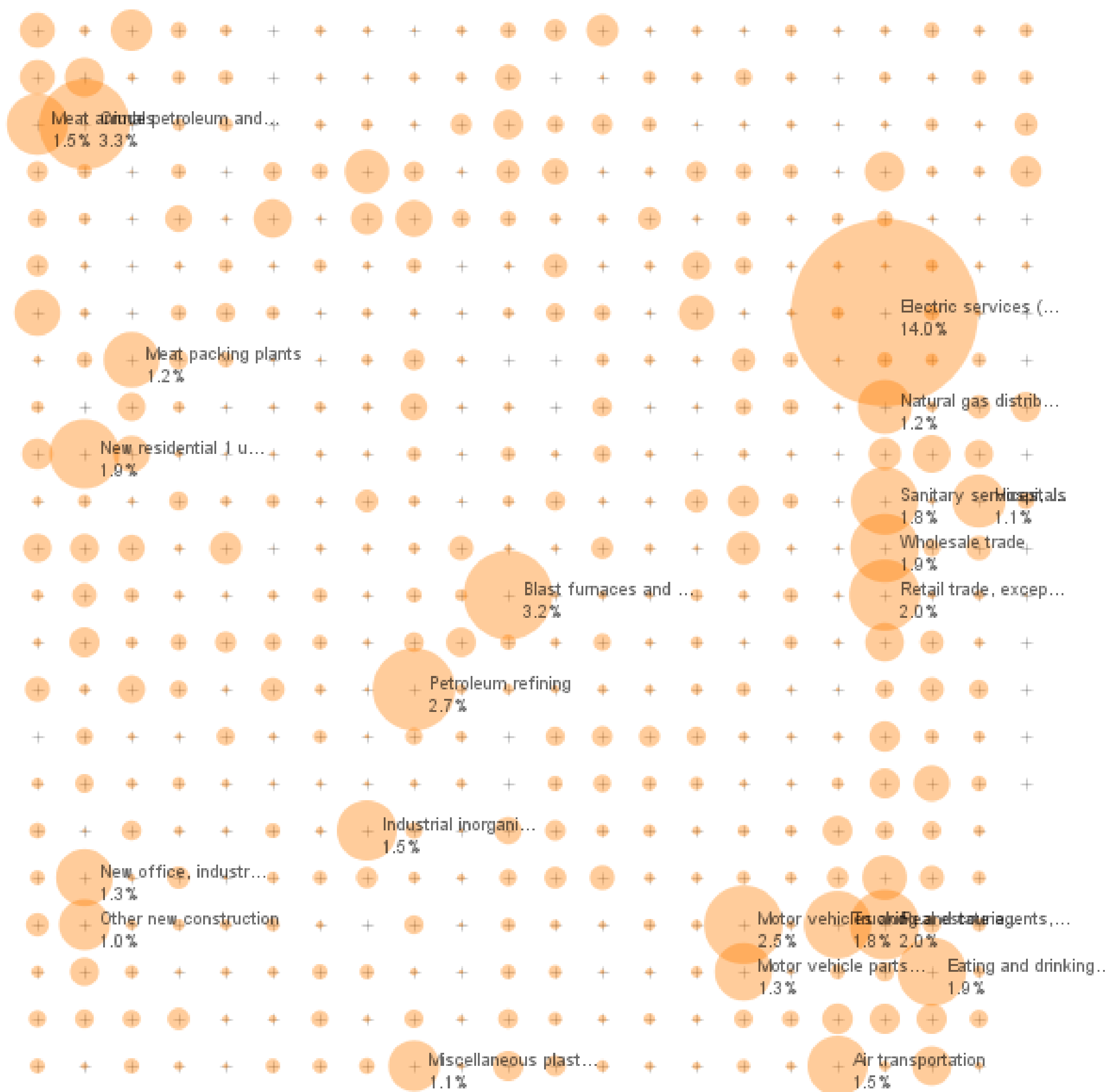

Figure 11: Global warming potential impact category Economy Map output for intermediate impacts. Data was extracted was these results to perform a sample impact assessment and subsequent analysis. Source: Economy Map.

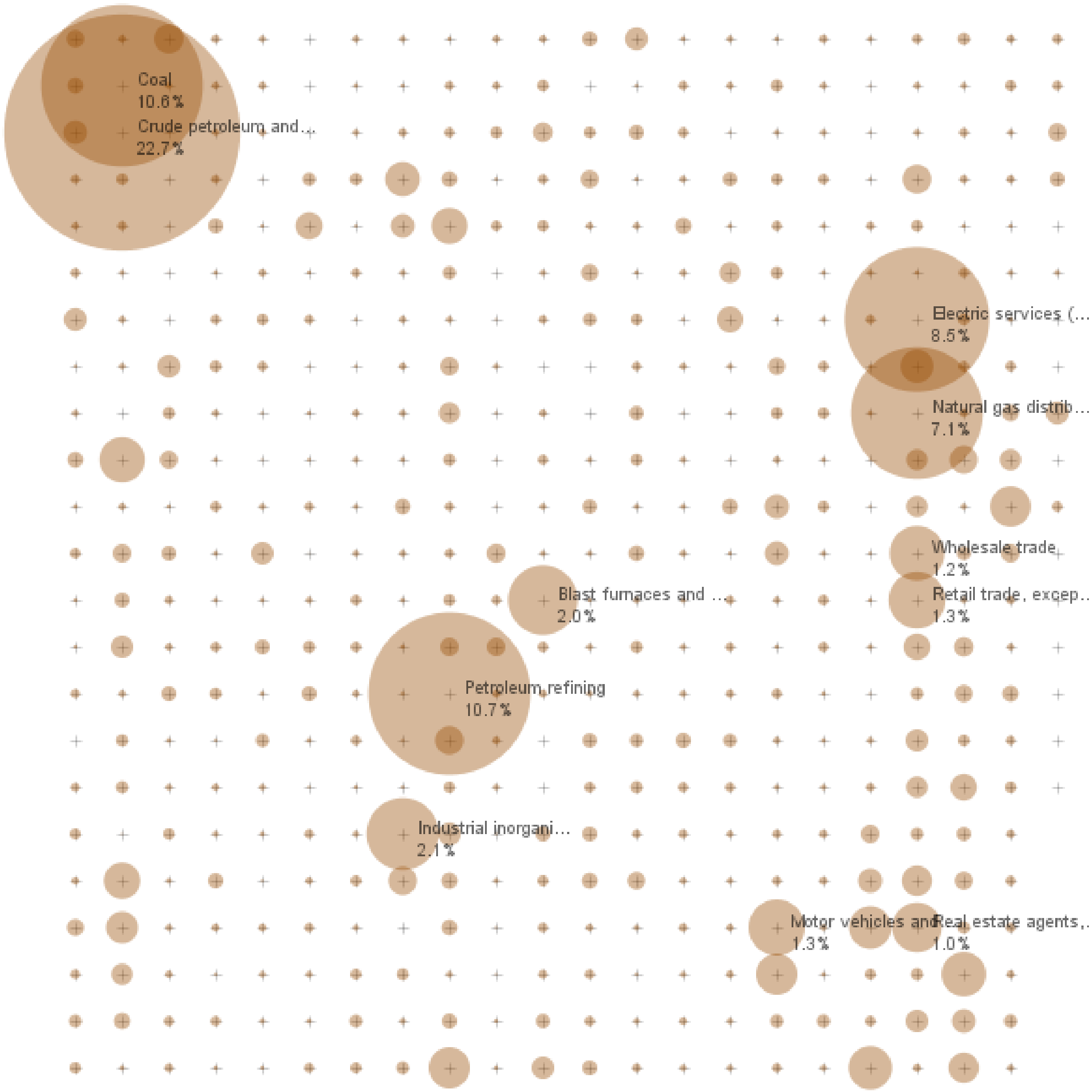

Figure 12: Abiotic depletion potential impact category Economy Map output for intermediate impacts. Data was extracted was these results to perform a sample impact assessment and subsequent analysis. Source: Economy Map.

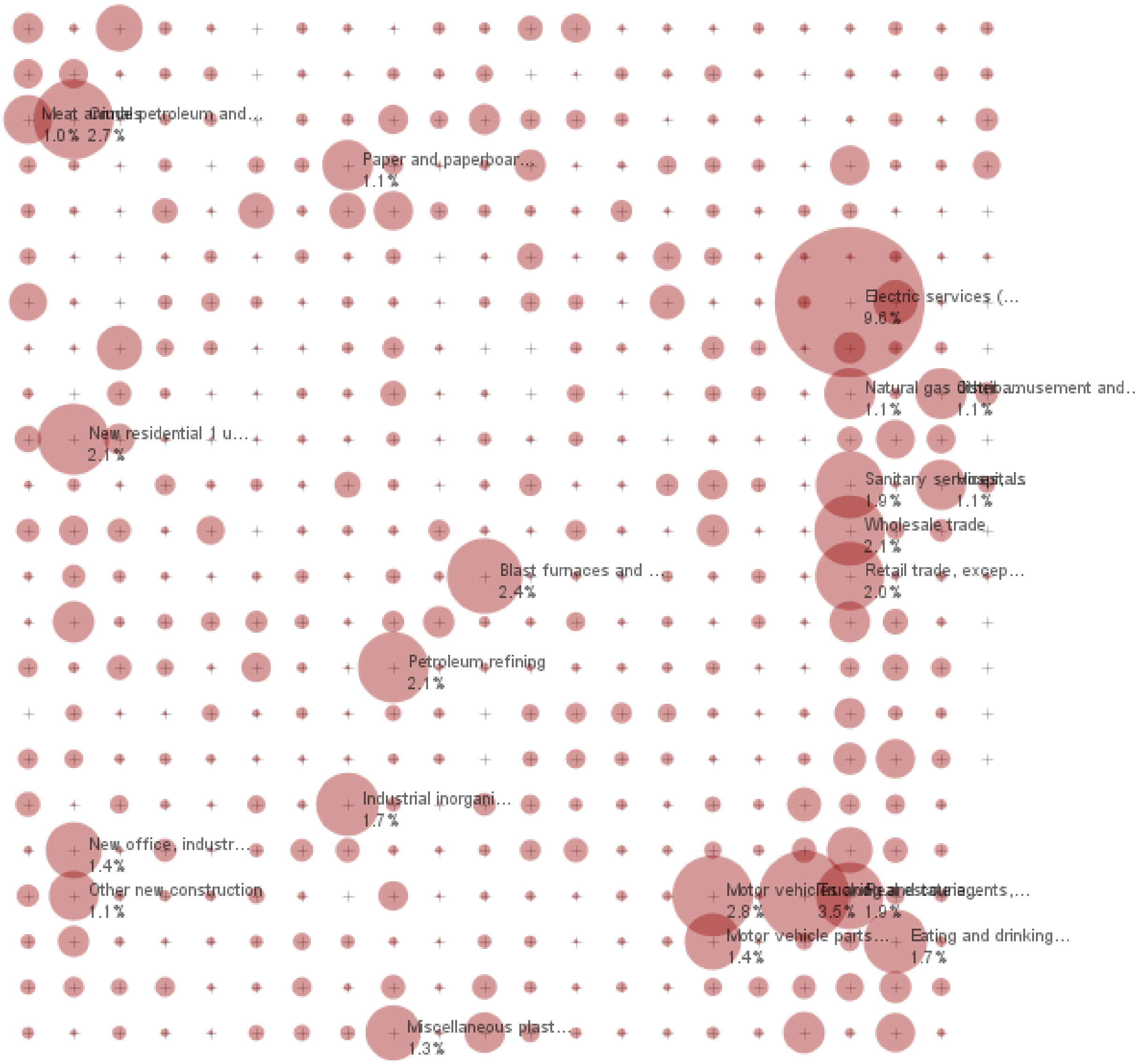

Figure 13: Photochemical oxidation potential impact category Economy Map output for intermediate impacts. Data was extracted was these results to perform a sample impact assessment and subsequent analysis. Source: Economy Map.

Appendix C- Life Cycle of a Typical Mobile Phone

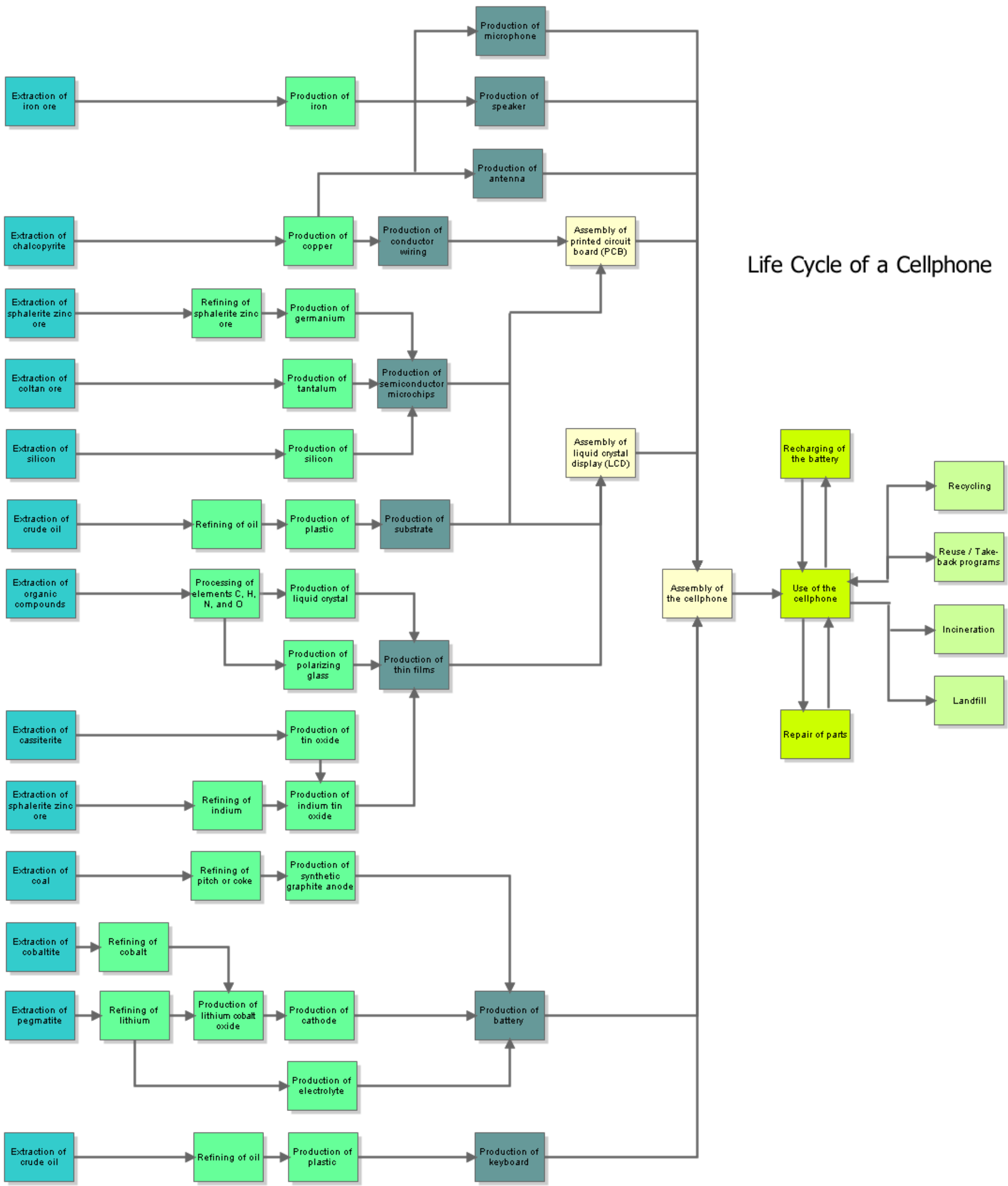

Figure 14: Life Cycle of a Typical Cell Phone. Source: University of Idaho. "Industrial Approaches to Sustainability".
http://www.webpages.uidaho.edu/sustainability/chapters/ch05/ch05-p02.asp

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