iGo Green: A Life Cycle Assessment of Apple's iPhone

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Abstract
Greenhouse gas (GHG) emissions continue to rise as a result of growth in population and industrialization. Manufacturing of new products with shortened life cycles, like the iPhone, are a significant source of GHG emissions. To identify and analyze potential environmental impacts of the iPhone, a life cycle assessment (LCA) was completed. A survey of iPhone users was conducted to gain a deeper understanding of consumer behavior. As part of this research it has been found that Apple's design of the iPhone used a strategy of planned obsolescence, resulting in a shorter life cycle, increased mining of rare earth minerals (REMs), higher rates of product turnover, and higher shipping costs and fuel usage. Surveyed iPhone users were largely unaware of Apple's iPhone recycling program.
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1 Introduction

For 650,000 years, greenhouse gases--carbon dioxide, methane, nitrous oxide and other manufactured gases--have remained below 300 parts per million (ppm), or mass of chemical per unit volume of water, in the Earth's atmosphere (NASA Global Climate Change, n.d.). Since 1950, however, greenhouse gases have risen significantly above the 300 ppm threshold, due partly to growth in manufacturing industries, and are considered a leading cause of climate change. Manufacturing now generates approximately 20% of worldwide greenhouse gas (GHG) emissions, making it the third largest contributor by category (Environmental Protection Agency, 2014). While growth in population and industrialization has led to an increase in manufacturing and GHG emissions, the production and consumption of products with shortened life cycles is also an important contributing factor to environmental damage.

Shortened product life cycles are partly a result of planned obsolescence, wherein "the production of goods [...] are less durable than would arise out of production by perfectly competitive industries" (Swan, 1972). As technology changes, companies modify older product models to include new features and market those new features to consumers. This economic behavior has become commonplace in the consumer electronics industry, particularly for smartphones. With over 150 million units produced and sold worldwide, the iPhone ranks as the most popular smartphone among consumers (Forbes, 2014). The iPhone serves as an excellent example of consumer electronics and durable goods that are designed and manufactured with planned obsolescence in mind. This study investigated links between Apple's iPhone and the production of GHG.

2 Methods

An Environmental Life Cycle Assessment (LCA) approach was used to conduct an analysis of the iPhone product life cycle. LCA is a technique that aims to identify and address the potential environmental impacts of a product throughout its life cycle. In its 2009 publication, *Guidelines for Social Life Cycle*

Assessment of Products, the United Nations Environment Program explained that "[LCA] is about going beyond the traditional focus on production sites and manufacturing processes so that the environmental, social, and economic impact of a product over its entire life cycle, including the consumption and end of use phase, is taken into account."

An LCA of Apple's iPhone was completed using product and company reports to compare and contrast all iPhone generations up to the iPhone 5s, as well as existing literature and industry news. Changes in product design, features, and manufacturing were considered in the analysis. In addition, a survey of iPhone users was distributed through online social networks to gain a deeper understanding of consumer behavior as it pertains to the iPhone product life cycle. The survey was not targeted to a specific age group or gender. iPhone users were surveyed in regards to why they replaced or disposed of their phone, what actions were taken when replacing or disposing of their phone, and if they were aware of, or participated in, Apple's Product Recycling Program.

3 Results & Discussion

The LCA completed for this study included five stages: raw material acquisition, design and production, packaging and distribution, use and maintenance, and disposal. Key findings from each stage are summarized below.

3.1 Extraction of Raw Materials

The extraction of raw materials, combined with the design/production stage, contributes 61% of the total GHG emissions for the creation of the iPhone (Apple Insider, 2013). Extraction of raw materials for the iPhone and other consumer electronics is mostly limited to minerals and rare earth metals (REM). Mineral and REM extraction is completed through various types of mining and is often an inefficient process, involving the creation of chemical slurries in which only a fraction (approximately 12%) of the material is considered usable. Moreover, the chemical slurry created in the process "can leach into groundwater, creating environmental hazards," (Greene, 2012). Large deposits of REMs are found in countries such as China and Mongolia, where the majority of Apple's 700 worldwide suppliers are located. In China, "which produces more than 90 percent of the world's supply of rare-earth minerals, environmental laws have historically been scant and enforcement lax" (Greene, 2012). REMs are also difficult to recycle later in the product life cycle. Marshall (2014) explains that REMs are contained in smartphones in very small amounts, yet "part of complex mixtures, which make the process too expensive to justify for these elements alone".

3.2 Design & Production

Design and Production includes all of the processes that turn raw materials into a finished product. Apple has attempted to reduce the environmental impact of recent iPhone models by minimizing hazardous chemical components used in manufacturing processes. The iPhone 4, 4s and 5 are Brominated flame retardants (BFR)-free, Polyvinyl chloride (PVC)-free, and include an arsenic-free display glass, a mercury-free LED backlit display, a system battery made of lithium-ion polymer and external surfaces free of Nickel plating. In addition, those models include batteries free of lead, cadmium, and mercury, which previous models did not include (Healthy Stuff - Ecology Center, 2012). While Apple has made progress in reducing the use of some environmentally costly materials in the design and production of iPhones, many of those benefits are counteracted by the short life cycle of each model. Apple has released a new iPhone model every 1-2 years (Apple Product Environmental Reports (2008-2013). Newer design features, like batteries that are not user-replaceable, also prompt consumers to replace, rather than repair, their iPhones (Forbes, 2013).

3.3 Packaging & Distribution

Packaging and Distribution produces approximately 5% of total GHG emissions in the iPhone life cycle. Apple has made efforts to improve their packaging materials with each new generation of iPhone. Since 2007, packaging materials have been reduced by 26%, creating 60% more space for iPhone 5s

shipments (Apple, 2014). Apple chooses to transport iPhones by air rather than sea to shorten delivery schedules, despite the higher fuel costs associated with air transportation. iPhones are transported using Fed Ex's Boeing 777 planes, in which a 15 hour trip from China costs "about $242,000, with fuel accounting for more than half the expense" (Satariano, 2013).

3.4 Use & Maintenance

Use and Maintenance accounts for 30% of the total GHG emissions in the iPhone life cycle. iPhone users, when surveyed, indicated a tendency to cycle through multiple iPhone models over time and replace their current version because a newer model was available. Of 88 iPhone users surveyed, 65% of respondents indicated they owned an average of 1-3 iPhones before settling on their current iPhone. When respondents were asked why they disposed of their previous iPhone, 63% (of 30 respondents) cited the release of a newer model as the reason for their choice.

3.5 Disposal

Disposal is the final stage of the LCA and can be performed in three methods. Landfills and incineration facilities are commonly used disposal methods for consumer electronics. From the 20-50 million tons of global electronic waste, 70% is outsourced to China to be dumped (Bodeen, 2007). iPhones can be recycled for parts and components to be reused in production stages. The last method, reuse, commonly known as refurbishing, has become more common in recent years. Apple operates a recycling program and uses a third party company, SIMS Recycling Solutions, to dismantle, reuse, and recycle iPhones. From the survey, of the 60 respondents who disposed of an iPhone, 42 were not aware of Apple's Recycling Program. In a follow-up question, only 31% of respondents indicated that they would participate in the recycling program if they were better informed. Survey respondents also reported that the most common way of discarding their iPhones was by selling the device. Recycling and discarding an iPhone through the garbage was cited as the least favored method. Apple's efforts to be environmentally friendly during the disposal phase account for 2% of overall GHG for the iPhone life cycle.

4 Conclusion

In the LCA of the iPhone product life cycle, the extraction and design/production stages account for the majority of GHG emissions. Apple releases a new model of the iPhone every 1-2 years. The iPhone is intentionally designed to have a shortened life cycle, which leads to increased mining of REMs and more fossil-fuel usage in production and transportation. iPhone users, when surveyed, reported that their decision to purchase a new iPhone was often prompted by the release of a new model. Survey respondents also indicated they may not be well informed about Apple's Recycling Program. Therefore, if Apple were to better promote their Recycling Program, air pollution and chemical infusion of land would be significantly lowered.

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