Greener Gaming Products: Considering Environmental Impacts When Assessing Gambling-Related Harms

Greener Gaming Products: Considering Environmental Impacts When Assessing Gambling-Related Harms

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Abstract

The gaming (i.e., gambling) industry currently does not include environmental impacts in its assessment of new products. Advocates and researchers of problem gambling are actively changing their approach to understand all "gambling-related harms" but have yet to identify environmental impacts as an important human health risk. The existing field of research has argued that legal gambling should be viewed as a toxin from a public health perspective (Shaffer, LaBrie, & LaPlante, 2004). A public health perspective should include environmental impacts and the associated human health risks; however, this has not been the case for gaming in the US. We need to expand the gaming industry's assessment focus to include environmental impacts, which arguably affects more of the world's population than the 2.2% of problem gamblers in the United States (US) adult population (National Council on Problem Gambling, 2018).

This research looked at the environmental impacts of the most prevalent form of US gaming, Scratch-off tickets, compared to its likely future replacement, legal online electronic instant scratch-off tickets (E-Instants) to complement current social product assessment models. Lottery Scratch-off tickets are paper-based, pre-printed games with fixed odds typically sold in a retail location, while E-Instants are online versions sold via a mobile app or computer website. People in the US spent approximately $80 billion on state lotteries (Isidore, 2017) and $60 billion in combined commercial and Native American casinos (Marotta et al., 2017) in 2016. Out of that $80 billion in sales, Scratch-off tickets made up 61% of sales and was the primary growth driver in the US.

My main research question was: What are the significant environmental impacts of Scratch-off tickets and E-Instants? I hypothesized that one Scratch-off ticket game (five million tickets printed for a US lottery) had more substantial environmental impacts than an equivalent amount of E-Instant ticket sales.

To test this hypothesis, I conducted two separate attributional environmental life cycle assessments (LCA) using the OpenLCA software, the Ecoinvent database, USEEIO, and publicly available information on US lottery sales and contracts. I conducted a Monte Carlo simulation and uncertainty analysis and scenario-based sensitivity analyses. The resulting attributional LCAs were used to perform LCIAs using the TRACI 2.1 model and normalized to the US national average.

Overall, E-Instants showed significantly fewer impacts. The most substantial contribution to Scratch-off impacts was transportation by the player to the retailer. When this transportation was eliminated from the Scratch-off model, E-Instants had fewer total impacts but was comparable to Scratch-offs. Lotteries currently selling Scratch-offs can decrease impacts by looking deeper at impacts in the retail environment, increasing pack sizes to reduce shipping impacts, and avoiding landfilling paper products by instead recycling or incinerating paper products. Lotteries currently selling E-Instants can work with vendors to reduce the impacts from the software, platform, and central system operations. They can also watch their time-to-wager and balance the environmental impacts with social impact considerations. More work is needed to critically assess environmental impacts along with the social impacts of the products.

Author's Biographical Sketch

Katie Margaret Carlson has a bachelor's degree from the University of Rhode Island, where she was a double major in political science and Italian. She also has a Master of Business Administration from Bryant University in Rhode Island. She has worked for 15 years in the public affairs and corporate social responsibility, both in government and private industry. For the last thirteen years, she has been in the gaming industry, supporting efforts to legalize and expand regulated gaming, and then mitigate gambling-related harms. She is the mother of four boys and the only female in the house apart from the cat.

Dedication

This thesis is dedicated to my four wild and beautiful children, Kurt Carlson, Troy Carlson, Levi Carlson, and Luke Carlson. I want to leave you a world more beautiful than it was given to me. Pay it forward.

Also, to my husband, Wayne Carlson, who suffered through mountains of laundry, kissed all the boo-boos and became our family CFO so I could concentrate on my studies – all without a single complaint. I love you more than you will ever know.

Acknowledgments

Thank you to my thesis director, Dr. Thomas Gloria, who patiently took weekly calls and gently guided me through the "science and art of life cycle assessment." Thank you to my research advisor, Dr. Mark Leighton, and Jen Palacio, for teaching me how to think like a researcher.

My sincere appreciation to Executive Director Sarah Taylor of the Hoosier Lottery; Angela Wiczek, Tracy McNutt, and others at IGT who encouraged me to be bold.

Table of Contents

List of Tables

List of Figures

Definition of Terms

BAU: Business as Usual. Refers to the baseline life cycle assessment model from which scenarios where developed for testing.

CAPEX: Capital Expenditures. An accounting term for the depreciation costs of using physical buildings or other physical assets.

COGS: Cost of Goods Sold. An accounting term for the cost of inputs into a product or service.

Ecoinvent: One of the most well-known databases for life cycle assessment practitioners. I used version 2.2 in this research.

E-Instant: Electronic Scratch-off ticket. Gambling that imitates the look and feel of a paper-based lottery product called a Scratch-off ticket.

EPA: Environmental Protection Agency.

Gaming: The industry term for gambling.

LCA: Environmental Life Cycle Analysis. A method to measure the cradle-to-grave environmental impacts of products.

NASPL: North American State and Provincial Lottery Association. The industry association for lotteries located in the United States and Canada.

OAT Sensitivity: "One-at-a-time" testing, where each input is increased or decreased by a certain threshold to see how much the system changes in an LCA model.

OpenLCA: Opensource software for LCA practitioners, produced by GreenDelta.

Scratch-off: Pre-printed tickets with fixed odds sold from a pack at a retail location

USEEIO: The United States Environmentally Extended Input-Output database, produced by the US Environmental Protection Agency for LCA.

Chapter I

Introduction

The gaming (i.e., gambling) industry currently doesn't include environmental impacts in its assessment of new products. The existing field of research has argued that legal gaming should be viewed as a toxin from a public health perspective (Shaffer et al., 2004). Traditionally, a public health perspective would include environmental impacts and the associated human health risks. However, this has not been the case for gaming in the United States (US).

Decision-makers at both the company and regulatory level focus resources on addressing problem gambling, which affects about 2.2% of the US population (National Council on Problem Gambling, 2018). As a result, environmental impacts across the supply chain that affect a broader range of stakeholders have not been addressed. While federal regulations require environmental impact assessments, states focus on casino buildings instead of product assessments.

In the past, environmental life cycle assessment has illuminated the environmental impacts of products shifting from paper-based to electronic-based, such as paper books to electronic books. The gaming industry is experiencing something similar with Scratch-off tickets and instant online games (i.e., E-Instants). There is a need to expand the gaming industry's assessment focus to include environmental impacts. The gaming industry has struggled to assess its impact on society consistently. Most research focuses on addiction, prevention, or the environmental effects of casino buildings. However, I have not found research that has addressed the overall impacts of gaming from an individual product perspective. Researchers, regulators, and the industry must consider the environmental impacts of gaming products in order to have a full perspective of gambling-related harms.

Research Significance & Objectives

This research focused on one common form of gaming, Scratch-off tickets, and one new type of gaming, online E-Instant tickets. These results contribute to a better understanding of the full spectrum of gambling-related harms, with the ultimate goal of reducing impacts on society.

My research objectives were:

- To contribute to the body of knowledge on product-specific environmental impacts, and to inform the gaming industry, researchers, and advocates.
- To assess the environmental impacts of the most prevalent form of gaming – Scratch-off tickets - and compare it to the product that will likely take its spot in the future – legalized state-sponsored online gaming in the form of E-Instant tickets.
- To enable gaming operators to invest in more effective mitigation strategies across a spectrum of environmental and social impacts. Measuring impacts is the first step to understanding how to mitigate negative impacts.
- To provide insight into how certain activities do or do not significantly affect environmental impacts (e.g., burning tickets vs. recycling, or allowing new forms of gaming).

Background

The US gaming industry has various parts: state-run lotteries, state-authorized gaming venues (e.g., casinos, horse racing), Native American gaming venues, suppliers, and game manufacturers. The products offered at each venue type vary immensely and are usually regulated at the state level with federal stipulations.

Why Lottery?

In the US, there are currently 44 states with lotteries (Figure 1) (with two more in the process of legalizing lotteries right now) sold in about 217,000 retail locations—making it the most prolific form of gaming (NASPL, 2016). In 2016, US sales were approximately $80 billion, while sales from commercial and Native American casinos combined were approximately $60 billion (Marotta et al., 2017) and limited to few states (Figure 2).

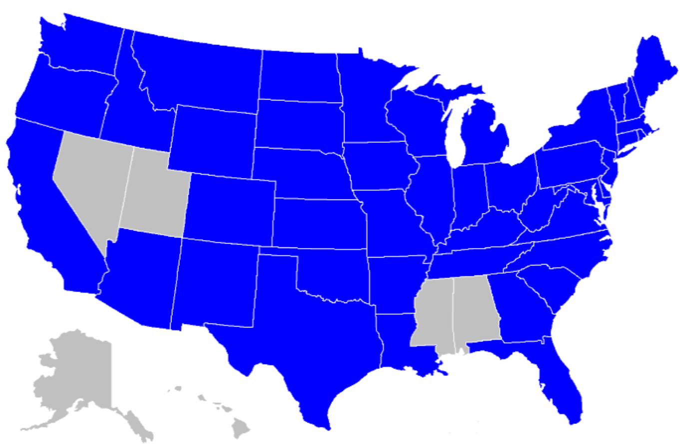

Figure 1. Map showing US lottery jurisdictions (in blue) (Marotta et al., 2017).

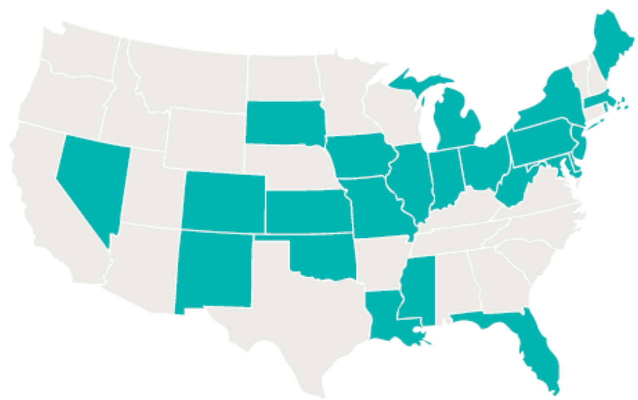

Figure 2. Map showing US commercial casino gaming jurisdictions (in turquoise) (Marotta et al., 2017).

The most significant driver of US lottery sales is the growth of Scratch-off tickets, which accounted for approximately 61% of sales in 2016 (Markle, La Fleur, & La Fleur, 2017). Research shows that Scratch-off tickets are more addictive than draw games (Griffiths & Wood, 2001). They also require an enormous amount of virgin, layered paper with specialized ink that makes them less attractive to recycle. Millions of Scratch-off tickets are shipped via truck to each state lottery's distribution center, where they are organized and transported to specific retail locations. Some states incinerate their unsold tickets as a security measure. There is currently no data on how many states incinerate instead of recycle or landfill their unsold Scratch-off tickets, or how many tickets are unsold each year. There is also no research on how the majority of consumers discard their tickets once sold. North America has three Scratch-off ticket printers that are capable of printing tickets to the security specifications and volume required of state-sponsored lotteries. Each printer may vary the chemical compounds used in their Scratch-off ticket printing to a certain degree so long as they do not violate security standards for lottery integrity.

The next generation of gamblers do not want traditional lottery offerings – they want online legal gaming. Online games are the next logical step in the modern offering for a new generation of gamblers who grew up with computers and the internet. Currently, the US lags behind the rest of the developed world, with only five jurisdictions where one could legally purchase state-sponsored online gaming. This number is currently in flux, due to changing federal regulations and interpretations.

Appropriateness of LCA

More environmental assessments need to be done in gaming outside of casino construction. Gaming products likely have substantial environmental impacts, and the way we procure, produce, use, and dispose of these products affects the degree of impact. LCA looks at the total impacts of the entire product system instead of just looking at one dimension, like greenhouse gas emissions. Having a better understanding of the total supply chain can identify hot spots of impact. We manage what we measure; therefore, understanding where the most significant impacts sit will allow vendors, regulators, and consumers to make better choices in production, distribution, and destruction of gaming products.

Unlike other industries, gaming has focused more on the social impacts of its products than its environmental impacts. Both problem gambling and gaming products have been studied in depth over the years from a psychological, ethical, policy, sociology, and economic perspective. These varied perspectives give rich insights into gambling-related harms but mostly focus on 2.2% of the US population that experience compulsive gambling. LCA will likely fill a significant gap related to additional human health and environmental risk that is not currently considered, and arguably affects a larger population on the planet.

I have not found peer-reviewed life cycle assessments on any gambling products. The research gap is quite substantial. However, there are environmental impact statements on casino buildings (Analytical Environmental Services, 2016) social impact assessments (ANIELSKI Management, 2008), and cost-benefit assessments on certain lottery products (Williams, 2000). The cost-benefit assessments are controversial as putting dollar amounts to social impacts is notoriously inaccurate, and estimates vary wildly (Walker, 2007).

Similar Products with LCA Assessments

Gaming is not the first industry to experience a dramatic shift from paper products to electronic products. Electronic books (e-books) fundamentally changed the traditional paper book business over the past 20 years. LCAs have been conducted to see what the impact e-books had on the paper book industry (Denis, Donadio, & Klein, 2015; Borggren, Moberg, & Finnveden, 2011; Moberg, Borggren, & Finnveden, 2011). These LCAs provide insights into the specific elements that require measurement in printed products that change to electronic products, such as printing process, transportation, usage, disposal, electronic readers, and electricity usage. These studies highlighted the product's sensitivity to user usage patterns. For example, those who shared books had significantly less impact than individually bought e-books.

Research Question, Hypothesis, and Specific Aims

My main research question was: What are the significant environmental impacts of Scratch-off tickets and E-Instants? I hypothesized that one Scratch-off ticket game (five million tickets printed for a US lottery) had more substantial environmental impacts than an equivalent amount of E-Instant ticket sales.

Specific Aims

To complete this research, I had to:

- Define the functional unit of both systems
- Map the system and boundary of an average Scratch-off ticket sold by an average US lottery
- Map the system and boundary of one E-Instant game offered by one US lottery
- Conduct two attributional LCAs using OpenLCA 1.7, the Ecoinvent 2.2 database, and USEEIO
- Interpret results to find the most significant impacts based on data quality, uncertainty, sensitivity analysis, and normalized results
- Highlight opportunities for reducing impacts

Chapter II

Methods

I used an environmental lifecycle assessment to explore my research question. LCA focuses on the physical quantities of materials used to produce products, from their initial extraction down to their final decomposition. This method uses ISO 14040 & 14044 for guidance in execution. LCA has a long history of helping establish baselines from which products and processes can improve. Since there is a research gap regarding environmental product assessments published for the gaming industry, LCA seemed like a natural choice for the first iteration and modeling.

LCA's start is primarily attributed to Coca Cola in the 1960s, who wanted a way to see if switching to plastic single-use bottles was better or worse for the environment (Jolliet, Saade-Sbeih, Shaked, Jolliet, & Crettaz, 2016). It gained in popularity in the 1990s, and ISO 14040 was issued in 1997 to standardize practices, especially around LCAs that make comparative assertions.

Attributional Life Cycle Assessment

This research used an attributional LCA approach for two reasons; Harvard does not teach consequential LCA, and it doesn't supply students with the database necessary to accomplish consequential LCAs. Ecoinvent 2.2, the database available to me, is inadequate to do a consequential LCA. Attributional LCA is an older method that looks at the direct impacts of a product or system as opposed to a consequential LCA that considers the indirect impacts as well (Gaudreault, Samson, & Stuart, 2010).

Functional Unit

I had to define a functional unit to identify what I was measuring, then set up parameters and boundaries. Technically speaking, the functional unit is the "quantified performance of a product system for use as a reference unit" (ISO 14044 (2006).

The functional unit for this assessment was one game purchased by one state lottery wagered at $5 and sold over two years. The functional unit was very straight forward for Scratch-off tickets since all tickets are pre-printed at a set wager amount at set quantities. For this study, I defined the "game" as one play style and prize structure at the wager amount. This was especially important for E-Instants since they are still rare in the US, and public information on sales, average wager, etc. are not publicly available. Lottery games sold over the internet may differ from printed Scratch-offs by having multiple customer facings that appear like different games (e.g., keno vs. quickdraw), but on the back end has the same play style and prize structure. The playstyle and prize structures are the backbones of the game. Playstyles and prize structures are like Campbell's tomato soup; the company may sell one batch under the Campbell brand and simultaneously under another generic grocery store brand; if you only looked at the product sold under the brand name label, you'd miss the other impacts from the entire production of the product.

Scratch-off System and Boundaries

Figure 3 shows the Scratch-off ticket development process. Items outside of the boxed area were outside the scope of this assessment. Resource extraction was not in scope; neither was the creation of the inputs before being shipped to the printer. Also excluded were impacts from using paper money or electronic fees. There was no information available in the Ecoinvent or USEEIO that could adequately account for the use of physical money vs. electronic transactions. After looking at various papers, I decided that the likelihood of there being an impact greater than 1% was unlikely and eliminated it from the assessment. Alternative transportation of the consumer to the retailer was not considered because data was not available in Ecoinvent or USEEIO. Scenarios with zero customer travel were considered as well to account for this. The central system was partially accounted for in the assessment because it is used for much more than one game and is reflected in the model as a percentage of sales. The industry currently compensates most central system vendors in the US as a percentage of sales.

E-Instants System Boundaries

Figure 4 shows the boundaries of the E-Instant model. This model is very new, and there is not as much information available. I assume that there is a capacity at which both the platform and central system may need additional servers. However, that information was not publicly available. It would be interesting to understand if a certain amount of E-Instant sales require additional servers, as that factor may significantly affect the outcome of the model. Electronic money usage was also not considered for either model. There was no information in Ecoinvent or USEEIO that was specific to tablet usage. However, the likelihood that it would have a significant impact on the results is low because the current information from lotteries is that most players are using mobile phones. The transport of customers for larger prizes was not considered in either model. Many lotteries require prizes over certain thresholds to be redeemed in person at a specific location with additional security checks. In the E-Instant model, there was zero customer transportation considered because there were no trips required to a retailer. However, there may be requirements from lotteries for larger prizes. Estimating the distances customers travel for large prizes wasn't straight forward since there could be many variations, and large prizes are relatively rare compared to the number of tickets sold.

Assumptions and Financial Models

I used OpenLCA v 1.7 software to conduct both LCAs with datasets from Ecoinvent 2.2 and the United States Environmentally Extended Input-Output Model (USEEIO). USEEIO requires financial information, and therefore, I created financial modeling with assumptions. Ecoinvent 2.2 did not have complete information from which to pull for both the products tested, so I substituted USEEIO for those items that Ecoinvent 2.2 did not contain. I used averages whenever possible because the purpose of this study wasn't to be precise but to give the industry a better understanding of the overall impact of these products. My assumptions were necessary for building the financial model in the input/output USEEIO database.

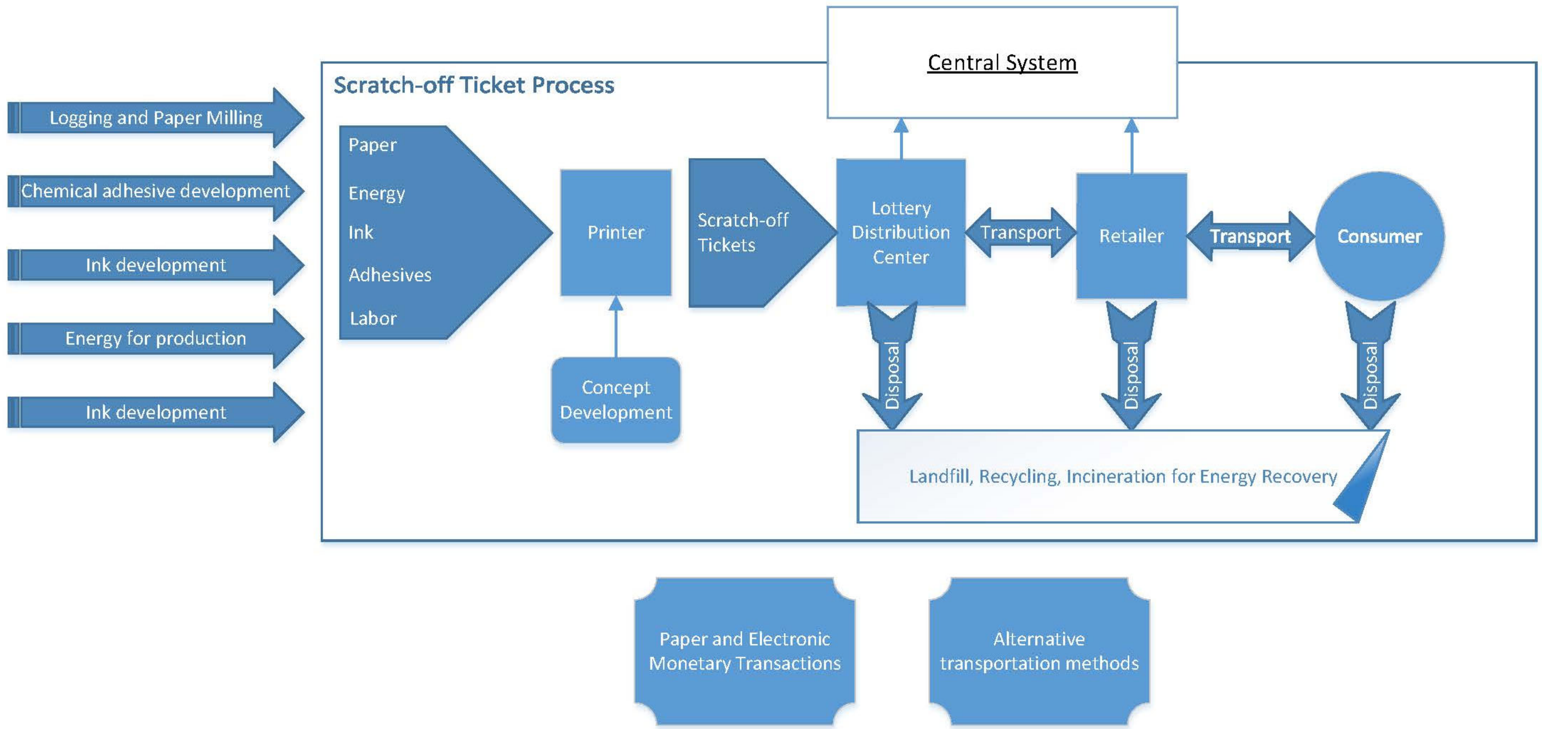

Figure 3. Scratch-off ticket process and boundaries.

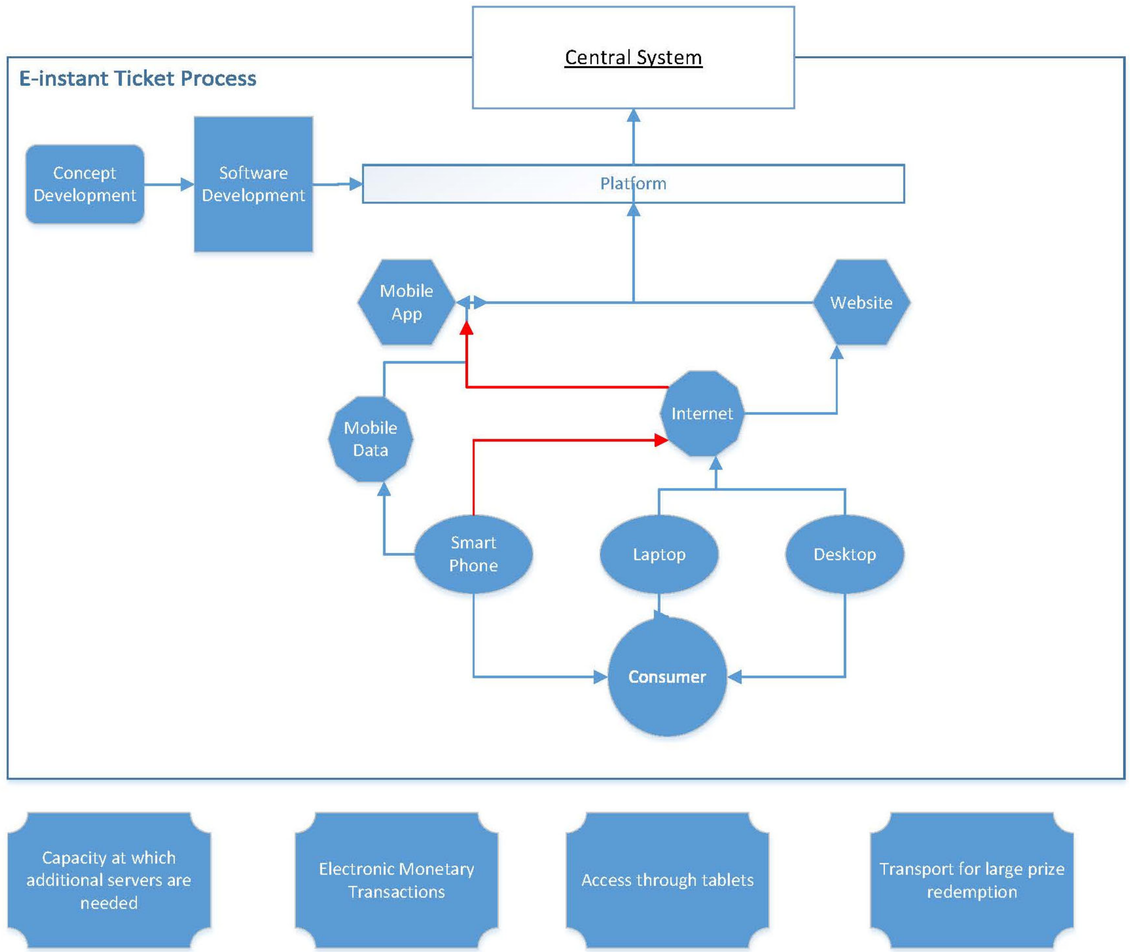

Figure 4. E-Instants process and boundaries.

Table 1 shows the assumptions and calculations that were constant for both LCA models. Most of the cost calculations were based on a percentage of sales, making them more relatable to other lotteries for comparison. I used the Hoosier Lottery because it is a mid-ranking US lottery in terms of total sales and sales per capita (Markle et al., 2017), making it a close proxy to an average US lottery. It should be noted that there are not currently any US lotteries with total E-Instant sales of twenty-million dollars, and indeed, no singular E-Instant games have generated that amount of sales. However, this was a hypothetical LCA for E-Instants to see what the comparable impacts would be should it someday achieve the same sales as Scratch-offs. Numbers from the Michigan Lottery

Table 1. Constant assumptions for both Scratch-off BAU and E-Instant BAU.

Financial Model and Assumptions	**Amount**	**Source**	**OpenLCA Input Flow**	**Category**	**Database**
Wager amount	$5	Assumed	Calculations needed for inputs below		
Total Wagers	4,000,000	Assumed			
Total Sales (wager amount times total wagers)	$20,000,000	Assumed			
Lottery Overhead 6.2% of sales ($20,000,000*6.2%)	$1,240,000	Hoosier Lottery CSR Report FY '18	Gambling establishments (except casino hotels) - US	Technosphere Flows/71: Arts, Entertainment, and Recreation/7132: Gambling Industries	USEEIO
Facilities Management: Data processing and hosting 1.06% of sales ($20,000,000*1.06%)	$212,000	Michigan Lottery FY ’18 Annual Report	Other computer-related services, including facilities management - US	Technosphere Flows/54: Professional, Scientific, and Technical Services/5415: Computer Systems Design and Related Services	USEEIO

were used because it is often referred to as one of the most successful E-Instant offerings in the US to date, and it offered transparent information on its annual report and website about sales and contracts. The Michigan Lottery was used to account for expenses associated with data processing and hosting (i.e., servers, backup servers, communication systems). Michigan's contract information was readily available on its website, and there is likely little difference in costs from vendor to vendor for this particular standard service.

Scratch-off financial model. I used publicly available information from a variety of sources and substituted with stated assumptions where necessary. I first had to decide how big the print run should be for the model game (Table 2). I chose a small print run of about five million tickets. [redacted] Print runs vary by state according to their population size and anticipated sales. For example, a small print run in New York is much bigger than a small print run in Indiana. I used information from La Fleurs publications (Markle et al., 2017) to confirm the popularity of the $5 tickets in North America, [redacted].

I assumed that one-fifth of all tickets printed would go unsold. Unsold tickets are not reported to La Fleurs publications, the leading lottery industry collector and distributor of information and statistics on lotteries, or any other industry publication at this time (Table 2). Tickets go unsold for a variety of reasons, including all top prizes selling before all tickets are sold, retailers returning partial packs of tickets, and weak consumer demand.

I decided that the retailer commission would be a good proxy for allocated costs and impacts associated with selling tickets via a licensed physical retailer and used the Hoosier Lottery's published information (Table 2).

I assumed the Scratch-off ticket printing contract compensated at 4% of sales based on my general knowledge of how the industry compensates its vendors. I broke down potential costs within the printing contract to get estimates for essential inputs of the system, specifically paper, adhesives, inks, shipping, and labor (Table 2).

I had to estimate the weight in metric tons of an average lottery ticket print run to input the information into Ecoinvent 2.2 (Table 3). Lottery tickets come in various dimensions and designs based on a variety of factors. Usually, the play area increases as the price of the game goes up, which means larger tickets. [redacted] The Hoosier Lottery's CSR Report states that there is an average of 40 Scratch-offs offered at any time, and therefore I calculated what the total weight of the printed tickets for one game would be [redacted]. I then divided the total estimated weight of the tickets by the total tickets offered. That provided an estimated average weight of one print run for one game in metric tons. From there, I subtracted unsold tickets.

To calculate disposal, I used the assumption that unsold tickets were disposed of through an incinerator for resource recovery (energy) as they are at the Hoosier Lottery (Table 3). I used the US average recycling rate and subtracted that from the total. I estimated that half of the remaining tickets would end up in landfills, and the other half incinerated. There is currently no information available on the rate at which individuals recycle their lottery tickets, so I assumed the US average.

Table 2. Scratch-off calculations and assumptions: financial model.

Financial Model and Assumptions	**Amount**	**Source**	**OpenLCA Input Flow**	**Category**	**Database**
Assumed ticket run of 5 million for $5 game	5,000,000	Assumed	Output (number of items) from Scratch-off model	NA	NA
Retailer 6.8% of sales ($20,000,000*6.8%)	$1,360,000	Hoosier Lottery CSR report FY '18	Other retail – US	Technosphere Flows/44-45: Retail Trade	USEEIO
Printing tickets 4% of sales ($20,000,000*4%)	$800,000	Assumed	NA		
Assumed printer profit margin of 25% (of the 4% of sales) ($800,000*25%)	$200,000	Assumed – used to calculate items below for inputs			
Total Costs: ($800,000 - $200,000)	$600,000	Calculation			
CAPEX 25% of total costs ($600,000*25%)	$150,000	Assumed			
COGS 25% of total costs ($600,000*25%)	$150,000	Assumed			
Paper ¼ of COGS ($150,000*25%)	$37,500	Assumed	Paper; at the manufacturer - US	Technosphere Flows/31-33: Manufacturing/3221: Pulp, Paper, and Paperboard Mills	USEEIO

Adhesives 1¼ of COGS ($150,000*25%)	$37,500	Assumed	Adhesives; at the manufacturer - US	Technosphere Flows/31-33: Manufacturing/3255: Paint, Coating, and Adhesive Manufacturing	USEEIO
Inks ¼ of COGS ($150,000*25%)	$37,500	Assumed	Ink and ink cartridges; at the manufacturer - US	Technosphere Flows/31-33: Manufacturing/3259: Other Chemical Product and Preparation Manufacturing	USEEIO
Shipping ¼ of COGS ($150,000*25%)	$37,500	Assumed	Truck transport – US	Technosphere Flows/48-49: Transportation and Warehousing	USEEIO
Printer Overhead 50% of total costs ($600,000*50%)	$300,000	Assumed	Printing support; at the manufacturer – US	Technosphere Flows/31-33: Manufacturing/3231: Printing and Related Support Activities	USEEIO

Incineration often offsets some energy from other sources. I used the online Covanta calculator to measure the kilowatt-hours generated from incineration and offset those emissions in the LCA model (Table 3).

Table 3. Scratch-off calculations and assumptions: printing and disposal.

Printing and Disposal Assumptions	Amount	Source	OpenLCA Input Flow	Category	Database
[redacted]	[redacted]	[redacted]	Calculations needed for inputs below		
40 games at any one time	40	Hoosier Lottery CSR Report FY '18			
Unsold Tickets (1/5 of all tickets printed)	20%	Assumed			
[redacted]	1500 metric tons	Calculation			
[redacted]	37.5 metric tons	Calculation	use, printer, laserjet, color, per kg printed paper – RER	electronics/ services	Ecoinvent 2.2
[redacted]	7.5 metric tons	Calculation	Calculations needed for inputs below		
[redacted]	30 metric tons	Calculation			
US Average Recycling = .35 (total tickets sold to consumers * recycling rate) (30 metric tons *0.35)	10.5 metric tons	Indy Star article	waste paper, mixed, from public collection, for further treatment – RER	paper & cardboard/pulps	Ecoinvent 2.2
Remaining tickets sold to consumers (30 metric tons – 10.5 metric tons)	19.5 metric tons	Calculation	Calculation needed for inputs below		
Assume half of remaining consumer tickets go to landfill (19.5 metric tons*50%)	9.75 metric tons	Calculation	disposal, paper, 11.2% water, to sanitary landfill – CH	waste management/sanitary landfill	Ecoinvent 2.2
Assume half of remaining consumer tickets and all unsold tickets to the incinerator (9.75 metric tons +7.5 metric tons)	17.25 metric tons	Calculation	disposal, paper, 11.2% water, to municipal incineration – CH	waste management/municipal incineration	Ecoinvent 2.2
kWh of energy produced from incineration (17.25 metric tons put into the online calculator)	9,350 kilowatt-hours	Covanta Calculator	electricity from waste, at municipal waste incineration plant – CH	waste management/municipal incineration	Ecoinvent 2.2

The EPA gave an average of 3.79 miles one-way for consumers to travel to their store of choice for purchasing groceries or other goods. I assumed that an individual would purchase two tickets on average during a trip (Table 4). Based on my knowledge of how consumers purchase tickets, I assumed the Scratch-off was an impulse buy for the majority of consumers, and that it would account for a percentage of the consumer's travel to a destination. I allocated 20% of the total transport to a retail location for lottery ticket purchasing as a proxy for consumer travel.

Table 4. Scratch-off calculations and assumptions: consumer travel for tickets.

Consumer Travel for Tickets	**Amount**	**Source**	**OpenLCA Input Flow**	**Category**	**Database**
Average miles traveled per consumer in the US one way to store	3.79 miles	EPA	Calculations needed for passenger transport input below		
Average km traveled per consumer round trip	12.2 kilometers	Google conversion miles to kilometers			
Number of tickets bought per trip per customer	2	Assumption			
Total travel in kilometers for all four million tickets assumed purchased by consumers (4,000,000/2) *12.2	24,400,000 (kilometers/person)	Calculation			
Assume 1/5 of trip allocated to lottery (24,000,000/5)	4,880,000 kilometers	Calculation	transport, passenger car – RER	transport systems/road	Ecoinvent 2.2

E-Instant financial model. I used the Michigan Lottery's vendor contract information for E-Instant development and platform hosting as a proxy for software impact (Table 5).

There was no information available on how long it takes the average consumer in the US to make an E-Instant wager from beginning to end. I assumed it would take 30 seconds on average for an established customer (not including registering to gamble) to place the wager, see the animation, and understand if he/she won a prize (Table 6). While Michigan allows various wagers at multiple price points for their E-Instant games ranging from 50¢ to $20 ("All Lottery Games | Michigan Lottery," n.d.), I assumed an average $5 wager, which translated to four million transactions (Table 6). Total seconds wagered was converted to days for input into Ecoinvent 2.2 (Table 6). I assumed equal wagering from mobile and computer, and I further assumed that half of all computers would be desktops, and half would be laptops (Table 6).

I calculated the allocated costs of using mobile devices for wagering and used that as an average proxy for the impacts of using mobile (Table 7). I also allocated costs for accessing mobile data from mobile phones (Table 7) and accessing the internet from computers and desktops and used those as inputs into USEEIO (Table 8).

Table 5. E-Instant calculations and assumptions: financial.

Financial Model and Assumptions	**Amount**	**Source**	**OpenLCA Input Flow**	**Category**	**Database**
E-Instant development and platform maintenance 18.4% of sales ($20,000,000*18.4%)	$3,680,000	Michigan Lottery FY '18 annual report	Software - US	Technosphere Flows/51: Information/5112: Software Publishers	USEEIO

Table 6. E-Instant calculations and assumptions: device usage.

Device Usage assumptions	**Amount**	**Source**	**OpenLCA Input Flow**	**Category**	**Database**
Amount of time spent on wagering in days (Assume 30 seconds to wager and complete the ticket) (4,000,000 tickets * 30 seconds)/ 86400 seconds in a day	1,389 days	Assumption			

Total mobile usage to wager in days (assume 50% of total wagers)	694 days	Assumption			
Total computer usage to wager in days (assume 50% of total wagers)	694 days	Assumption			
Desktop (half of computer usage)	347 days	Assumption	use, computer, desktop, mix, home use - RER	electronics/ services	Ecoinvent 2.2
Laptop (half of computer usage)	347 days	Assumption	use, computer, laptop, active mode - RER	electronics/ services	Ecoinvent 2.2

Table 7. E-Instant calculations and assumptions: phone and data wagering.

Smartphone usage costs	**Amount**	**Source**	**OpenLCA Input Flow**	**Category**	**Database**
Lifespan in days (2 years)	730 days	Assumption	Calculations needed for input below.		
Assume price in USD	$700	Assumption			
cost per day ($700/730 days)	$0.96 per day	Calculation			
cost of mobile phones (695days*$0.96)	$666	Calculation	Wireless communications; at the manufacturer - US	Technosphere Flows/31-33: Manufacturing/3342: Communications Equipment Manufacturing	USEEIO
Mobile data usage	**Amount**	**Source**	**OpenLCA Input Flow**	**Category**	**Database**
Gigabytes per month per person	4.8	Statista	Calculations needed for inputs below.		
cost per gigabyte	$12	Forbes article			
Total use of GB cost/month (4.8 gigabytes *$12)	$60	Calculation			
cost per day ($60/30 days per month)	$1.98	Calculation			
cost of mobile data for wagering ($1.98*694)	$1,378	Calculation	Wireless telecommunications - US	Technosphere Flows/51: Information/5172: Wireless Telecommunications Carriers (except Satellite)	USEEIO

Table 8. E-Instant calculations and assumptions: Wi-Fi usage.

Internet data usage	Amount	Source	OpenLCA Input Flow	Category	Database
Average internet cost $/month	60	USA Today article	Calculations needed for input below.		
The average cost per person per day in a household (assuming 2.5 people per household)	0.8	United Nations			
Cost of Wi-Fi wagering ($0.80*694)	$556	Calculation	Telecommunications - US	Technosphere Flows/51: Information/5171: Wired Telecommunications Carriers	USEEIO

Inputs and Flows

I had to find corresponding data in Ecoinvent and USEEIO to the calculations and assumptions in both models. The USEEIO sources contained wide amounts of information that included some of the items I was estimating. Ecoinvent 2.2 tended to be more specific, but often did not have US information and instead used data from Europe.

Data Quality and Uncertainty

In order to understand the impact categories and interpret their significance, I needed to have some idea of the data quality and the degree to which the models are uncertain. I used two sources to determine the uncertainty in the models; Pedigree Matrixes already provided in both USEEIO and Ecoinvent 2.2, and Monte Carlo Simulation. Pedigree Matrixes transform qualitative information as to how confident we are in the inputs into a quantitative score from 1-5, where one is very confident, and five is not at all confident (Jolliet et al., 2016). Monte Carlo Simulations take into account individual inputs and tell us how confident we can be in the resulting impact categories after running thousands of random simulations.

Sensitivity and Normalization

I used secondary datasets to calculate impacts and therefore made many assumptions in both the financial model for the USEEIO database inputs and the inputs for Ecoinvent. While those assumptions were qualified since I'm in the gaming industry, they still needed extensive sensitivity analyses to see if the models were prone to significant changes if the assumptions changed. I used two different scenario-based sensitivity methods in this research. First, I used a simple one-at-a-time (OAT) method, where each assumption had two corresponding sensitivity analyses with a 50% increase or decrease (Jolliet et al., 2016). Each input was changed and recorded and then put into a tornado graph to show the degree to which each input was sensitive in each impact category (see Figures 11-30).

Additionally, for items that had a cascading effect on the model, such as the percentage of mobile use in E-Instant wagers and the time to wager, the entire model was recalculated and compared to the business as usual (Bagchi & Lin, 1997).

TRACI 2.1 was used to conduct the LCIA since it is the most up-to-date method for US inputs (Ryberg, Vieira, Zgola, Bare, & Rosenbaum, 2014). There are ten potential impact categories in TRACI 2.1, and I discuss each below (Acero, Rodríguez, & Ciroth, 2015).

1. Acidification: measures the impact of nitrogen and sulfur on soil and water, which results in a reduced ph. level and affects biodiversity.

2. Ecotoxicity: measures chemicals (heavy metals) on land and in both fresh and saltwater that lead to a loss of biodiversity (species extinction).
3. Eutrophication: measures the buildup of chemical nutrients (nitrogen and phosphorus) in water, which affect ecosystems.
4. Global warming: measures the global warming potentials of greenhouse gasses and their effect on the total average global temperature.
5. Two human health impacts: measures the effects of chemicals that cause diseases related to cancer and those not related to cancer.
6. Ozone depletion: measures the amount of chemicals (chlorofluorocarbons) that deplete stratospheric ozone.
7. Photochemical ozone formation: measures the amount of ozone formation on the ground level, which is toxic to humans.
8. Respiratory effects: measures the formation of particulates from combustion and resource extraction, which affects human health.
9. Fossil fuel resource depletion: measures the amount of energy it takes to extract the fossil fuel resource, assuming that the more that is extracted, the less efficient the extraction method (Klinglmair, Sala, & Brandão, 2014).

I normalized the resulting data to the total impacts in the US. Normalization, in this context, tells us what share the product impact have compared to the total impacts of the US. Normalization gives us a frame of reference to understand the meaning of the impacts with context.

Chapter III

Results

The financial models and estimates were input to OpenLCA 1.7, and averages were used where possible from Ecoinvent 2.2, and USEEIO. The two baselines, or "business as usual" (BAU) systems, were analyzed using TRACI 2.1.

Data Quality and Uncertainty

Both Ecoinvent and USEEIO have pedigree tables that transform qualitative information on data quality into a quantitative score. Essentially, all of the human health impact areas have a high degree of uncertainty due to the sources in the databases. Uncertainty is important when looking at the results of the models.

An uncertainty analysis was done using four thousand randomly generated iterations in the Monte Carlo simulation in OpenLCA. Tables 9 and 10 show the probability of hitting these same results or higher. I included the impact categories that had a probability above 60% in the final interpretation of results. Scratch-off results also showed that the human health impact categories had high probabilities of the outcome being incorrect around 50% of the time.

Environmental Impact Category Results

The face-value results of the two BAU systems without additional analysis showed that Scratch-offs had higher impacts in all ten impact categories (Table 11). We can see from the BAU results that Scratch-offs were at least one order of magnitude larger than E-Instants in all the impact categories, except for respiratory effects, though it is still larger in that category as well. Customer transportation to retail locations

Table 9. E-Instant Monte Carlo analysis results from OpenLCA.

Impact category	Reference unit	Probability
Respiratory effects	kg PM2.5 eq	87.46%
Photochemical ozone formation	kg O3 eq	82.58%
Ozone Depletion	mt CFC-11 eq	81.26%
Acidification	kg SO2 eq	80.88%
Fossil fuel resource depletion	MJ surplus	75.63%
Global Warming	mt CO2 eq	72.54%
Eutrophication	kg N eq	66.19%
Human Health - carcinogenic	CTUh	57.36%
Ecotoxicity	CTUe	56.10%
Human Health - non-carcinogenic	CTUh	51.98%

Table 10. Scratch-off Monte Carlo analysis results from Open LCA.

Impact category	Reference unit	Probability
Respiratory effects	kg PM2.5 eq	79.05%
Eutrophication	kg N eq	75.73%
Acidification	kg SO2 eq	74.55%
Ecotoxicity	CTUe	72.44%
Ozone Depletion	kg CFC-11 eq	70.09%
Photochemical ozone formation	kg O3 eq	67.43%
Global Warming	kg CO2 eq	63.45%
Fossil fuel Resource depletion	MJ surplus	62.06%
Human Health - noncarcinogens	CTUh	55.92%
Human Health - carcinogens	CTUh	45.45%

contributed 45%-99% of the total impact in all impact categories of the BAU Scratch-off product system (Table 12). Software was the top contributor for E-Instants, which included the games, platform, and servers (Table 13). Therefore, additional scenarios were compared to see what impacts might look like with different assumptions.

Table 11. LCIA untransformed results from OpenLCA of BAU e-instants and BAU Scratch-offs.

LCIA Results

This table shows the LCIA results of the project variants. Each selected LCIA category is displayed in the rows and the project variants in the columns. The unit is the unit of the LCIA category as defined in the LCIA method.

Impact category	a. e-instants	d. Scratch-offs	Unit
Acidification	1.11529e+3	5.31905e+3	kg SO2 eq
Ecotoxicity	5.54696e+4	4.37755e+6	CTUe
Eutrophication	4.33806e+1	1.50261e+3	kg N eq
Global Warming	3.79743e+5	1.57877e+6	kg CO2 eq
Human Health - carcinogenics	3.61547e-4	5.81053e-2	CTUh
Human Health - non-carcinogenics	1.81574e-3	1.53879e-1	CTUh
Ozone Depletion	4.61510e-2	2.85492e-1	kg CFC-11 eq
Photochemical ozone formation	2.17631e+4	1.04113e+5	kg O3 eq
Resource depletion - fossil fuels	2.95000e+2	1.64016e+6	MJ surplus
Respiratory effects	2.26104e+2	6.23072e+2	kg PM2.5 eq

Table 12. BAU Scratch-off input contribution tree from OpenLCA.

Impact category: Global Warming

Contribution	Process	Amount	Unit
100.00%	Scratch-off (average $5)B...	1.57877E6	kg C...
56.18%	transport, passenger car -...	8.86973E5	kg C...
17.59%	Other retail - US	2.77642E5	kg C...
05.35%	Printing support; at manufa...	8.45344E4	kg C...
05.00%	Gambling establishments (...	7.89877E4	kg C...
03.70%	Truck transport - US	5.83596E4	kg C...
03.14%	Paper; at manufacturer - US	4.96328E4	kg C...
02.11%	Adhesives; at manufacturer...	3.33459E4	kg C...
01.86%	Other computer related ser...	2.94291E4	kg C...
01.76%	Ink and ink cartridges; at m...	2.77286E4	kg C...
01.62%	disposal, paper, 11.2% wat...	2.56022E4	kg C...
00.83%	disposal, paper, 11.2% wat...	1.31308E4	kg C...
00.80%	use, printer, laser jet, colou...	1.26879E4	kg C...
00.05%	waste paper, mixed, from p...	713.04201	kg C...
00.00%	electricity from waste, at m...	0.00000	kg C...

Table 13. BAU E-Instant input contribution tree from OpenLCA.

Flow: dimethyl formamide - Emission to air/unspecified

Impact category: Global Warming

Contribution	Process	Amount	Unit
100.00%	e-instant $5 scenario 1	3.79743E5	kg CO2 eq
71.25%	Software - US	2.70583E5	kg CO2 eq
20.80%	Gambling establishments (except casino hotels) - US	7.89877E4	kg CO2 eq
07.75%	Other computer related services, including facilities management - US	2.94291E4	kg CO2 eq
00.06%	use, computer, desktop, mix, home use - RER	230.82072	kg CO2 eq
00.06%	Wireless telecommunications - US	217.51539	kg CO2 eq
00.04%	use, computer, laptop, active mode - RER	148.29286	kg CO2 eq
00.03%	Wireless communications; at manufacturer - US	97.79156	kg CO2 eq
00.01%	Telecommunications - US	48.87548	kg CO2 eq

Sensitivity Analysis

Scenario testing was completed to understand the effects of different assumptions on product systems. I completed two different types of scenarios; Total system scenario changes where changing assumptions had a cascading effect, and I recalculated the entire system; OAT testing where each input was increased and decreased by +/-50%. Each assumption in each system was tested, resulting in nearly 20 scenarios for E-Instants, and approximately 40 scenarios for Scratch-off tickets.

Total System Results

First, I ran a scenario that set passenger travel (travel by customers to and from retail locations) to zero. When compared to E-Instants BAU, impacts were closer, but E-Instants still had less relative impacts (Figure 5). Additional scenarios were assuming 1/20th of a customer's trip allocation to Scratch-off purchase, and another 1/10th of a customer's trip allocated to Scratch-off purchases. Both scenarios resulted in higher impacts than BAU E-Instants.

Next, I ran scenarios to look at a decrease in the recycling rate to 10% as opposed to the BAU rate of 35%. The recycling rate seemed to have no relative effect compared to BAU Scratch-offs (Figure 6).

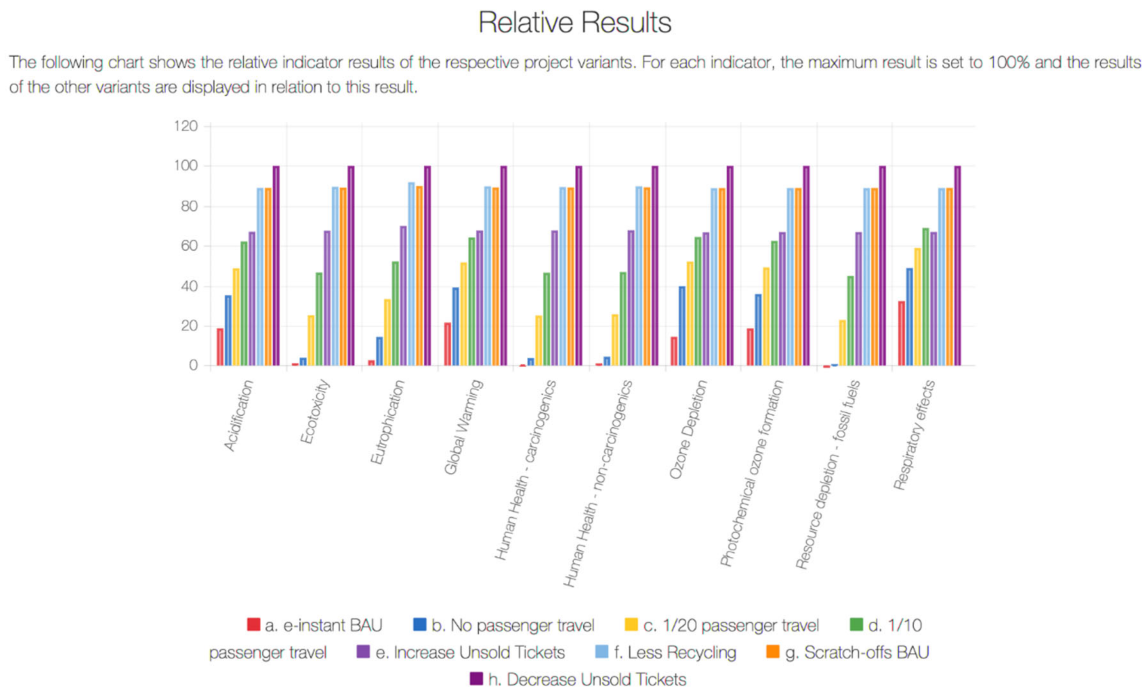

Figure 5. Relative scenarios from OpenLCA.

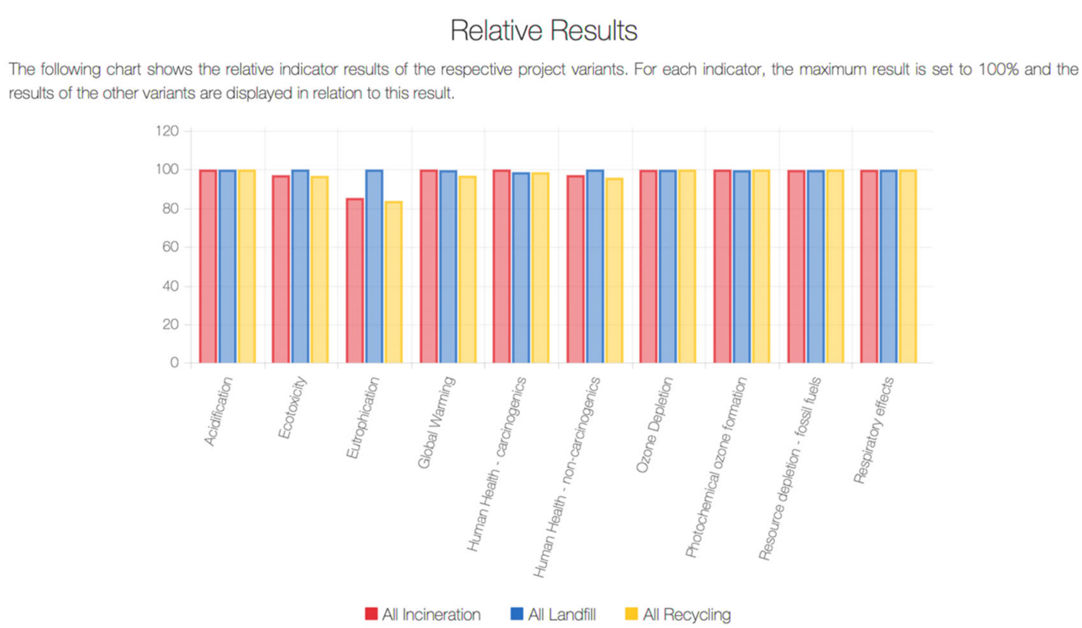

Figure 6. Relative scenarios of Scratch-off destruction method from OpenLCA.

Notably, when I decreased the rate of tickets that went unsold, the entire system had more relative impacts than the BAU Scratch-off system. Another test was run to see if the destruction method affected the results, and there were little to no effects on the total system by changing the destruction method of the tickets. The landfilled tickets were slightly worse, relatively speaking (Figure 6). Another test was run to see if there were any significant increases in impacts when there was no customer travel, but a decrease in unsold tickets. The results showed that each input had almost the same percentage of contribution when compared to "no customer travel Scratch-offs." I interpreted this to mean that the system was not sensitive to an increase or decrease in ticket sales.

Total system scenarios were run for the E-Instants looking at increased mobile wagering, decreased mobile data usage, and the time-to-wager. The scenario "more mobile wagering" increased the percentage of mobile wagers from 50% to 90% and allocated 100% of that to mobile data usage. The scenario "more mobile Wi-Fi" also assumed that 90% of wagers came from mobile devices but allocated 100% to Wi-Fi. I also changed the total time to wager from 30 seconds to 30 minutes. Figure 7 shows that the BAU scenario was not sensitive to mobile or Wi-Fi wagering but was sensitive to total time-to-wager.

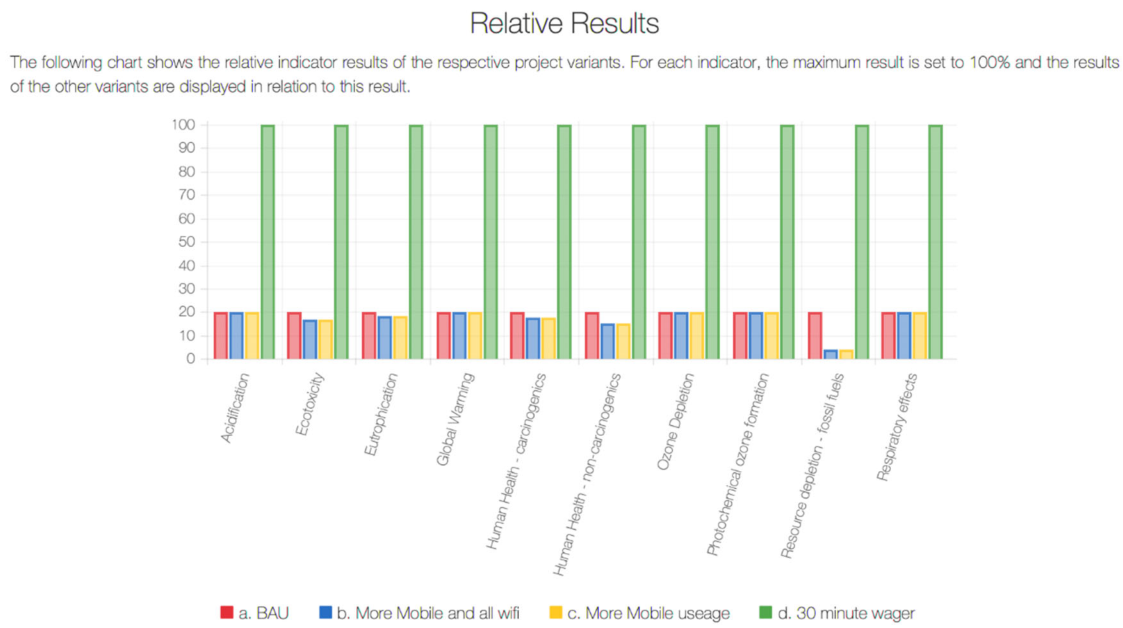

Figure 7. Relative scenarios of E-Instants from OpenLCA.

OAT Sensitivity Results

Tornado graphs were created by increasing and decreasing each input by 50%. The result is a range of change according to adjusting the inputs up or down, and I documented it as a percentage of the total contribution in each impact category. The tornado graphs show us how sensitive the model is to changing data. Sensitive data can show us where we need more accurate measurements and where hot spots exist (inputs that have significantly more or less impacts when changed up or down).

Tables 14 and 15 show which inputs were the most sensitive to each impact category. Each input had a cut-off of 1.5% change to be included as sensitive. I marked each sensitive input with a red "+" sign. Then, I listed each impact category from highest to lowest probability (see Tables 9 and 10 for probabilities). As stated previously, probabilities below 60% were not included in the final results. For Scratch-offs, the eliminated impact categories were carcinogens (Figure 16) and noncarcinogens (Figure 17). For E-Instants, the eliminated impact categories were ecotoxicity (Figure 25), carcinogens (Figure 26), and noncarcinogens (Figure 27).

The Scratch-off results show that the inputs for retail, lottery overhead, and printing overhead are the most sensitive (Table 14). All three of these inputs were a percentage of sales based on assumptions. The inputs with the lowest sensitivity were not put on the chart and were incineration and recycling. We can also see that the impact categories of ecotoxicity (Figure 11) and fossil fuel resource depletion (Figure 15) had very little sensitivity.

Table 14. Summary of Scratch-off OAT sensitivity tornados.

Impact Category from high to low probability	OAT Input Sensitivity (+/- 50%)									
	Retail	Printer	Shipping	Lottery Overhead	Printing Overhead	Paper	Adhesives	FM	Ink	Land fill
Respiratory effects (Figure 8)	+		+	+	+	+	+	+		
Eutrophication (Figure 9)		+								+
Acidification (Figure 10)	+		+	+	+	+				
Ecotoxicity (Figure 11)		+								
Ozone Depletion (Figure 12)	+	+		+	+	+	+		+	
Photochemical ozone formation (Figure 13)	+		+	+	+	+				
Global Warming (Figure 14)	+		+	+	+	+	+			
Fossil fuel resource depletion (Figure 15)										

The E-Instant results show that lottery overhead, software, and facilities management were the most sensitive inputs (Table 15). Once again, all the most sensitive inputs were percentages of sales. Laptop and desktop usage were sensitive in only two categories: fossil fuel resource depletion (Figure 22) and eutrophication (Figure 24). Three inputs were robust in all impact categories – mobile data, smartphone, and the internet, and were not included in Table 15.

Table 15. Summary of E-Instant OAT sensitivity tornados.

Impact Category from high to low probability	OAT Input Sensitivity (+/- 50%)				
	Lottery Overhead	Software	Facilities management	Desktop	Laptop
Respiratory effects (Figure 18)	+	+	+		
Photochemical ozone formation (Figure 19)	+	+	+		
Ozone depletion (Figure 20)	+	+	+		
Acidification (Figure 21)	+	+	+		
Fossil fuel resource depletion (Figure 22)				+	+
Global warming (Figure 23)	+	+	+		
Eutrophication (Figure 24)	+	+	+	+	+

While the summary tables above (Table 14 and 15) give an overall picture of the sensitivity, we can see from the tornado charts below how sensitive each input is by impact category (Figures 9-27).

Scratch-off tornado graphs. Certain impact categories had more robust inputs than others. The impact category with the most robust inputs was fossil fuel resource depletion (Figure 15), which had all robust inputs. A close second was ecotoxicity (Figure 11), which had one sensitive input, printer at 1.63%. Eutrophication (Figure 9) was sensitive to landfill and printer inputs at 4.77% each. The landfill input was only sensitive in eutrophication. Ozone depletion (Figure 12) was the only impact category to show the input ink as being sensitive at only 2.29% variation. The input facilities management was only sensitive in the respiratory effects impact category (Figure 8) at 1.7% variation.

Acidification (Figure 10), photochemical ozone formation (Figure 13), and global warming (Figure 14) had the same impacts showing as sensitive. Additionally, all three had retail being the most sensitive input.

E-Instant tornado graphs. Fossil fuel resource depletion (Figure 22) showed only two inputs as having measurable impacts, and both were very sensitive. The desktop and laptop inputs each had a range of sensitivity of about 25%. Eutrophication (Figure 24) had five sensitive inputs out of eight, the most of any of the E-Instant impact categories. Software had about a 25% variation, lottery overhead had about a 15% range, and facilities management had about a 5% variation. Ozone depletion had the input software at about a 22% variation and lottery overhead around a 25% variation.

All the other impact categories for e-instants showed the same three inputs as sensitive, with the other five inputs being robust. Respiratory effects (Figure 18), photochemical ozone formation (Figure 19), acidification (Figure 21), and global warming (Figure 23) all showed the input facilities management as having a much lower sensitivity. They all also showed the input software being the most sensitive and lottery Overhead a close second.

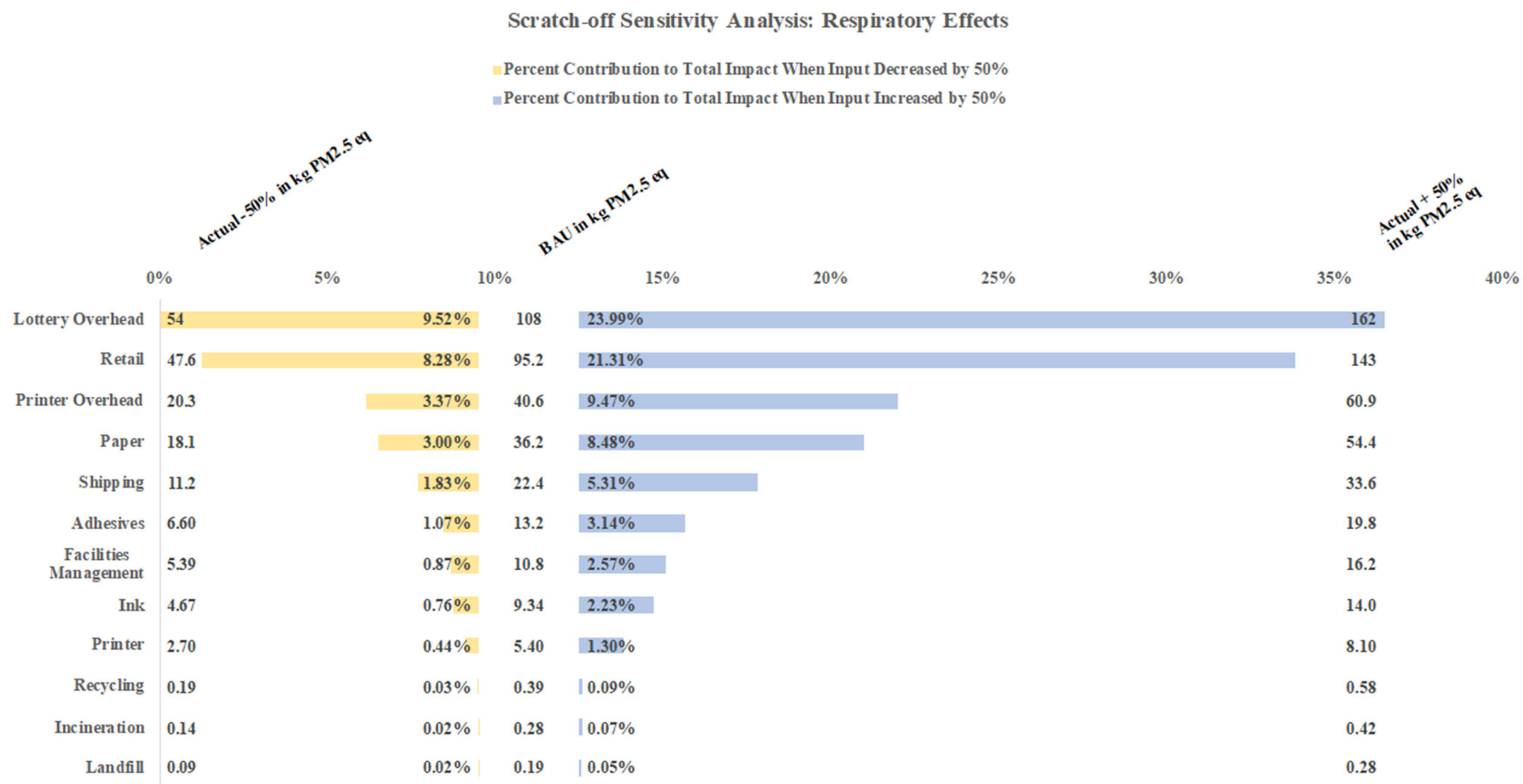

Figure 8. Scratch-off ticket sensitivity analysis: respiratory effects.

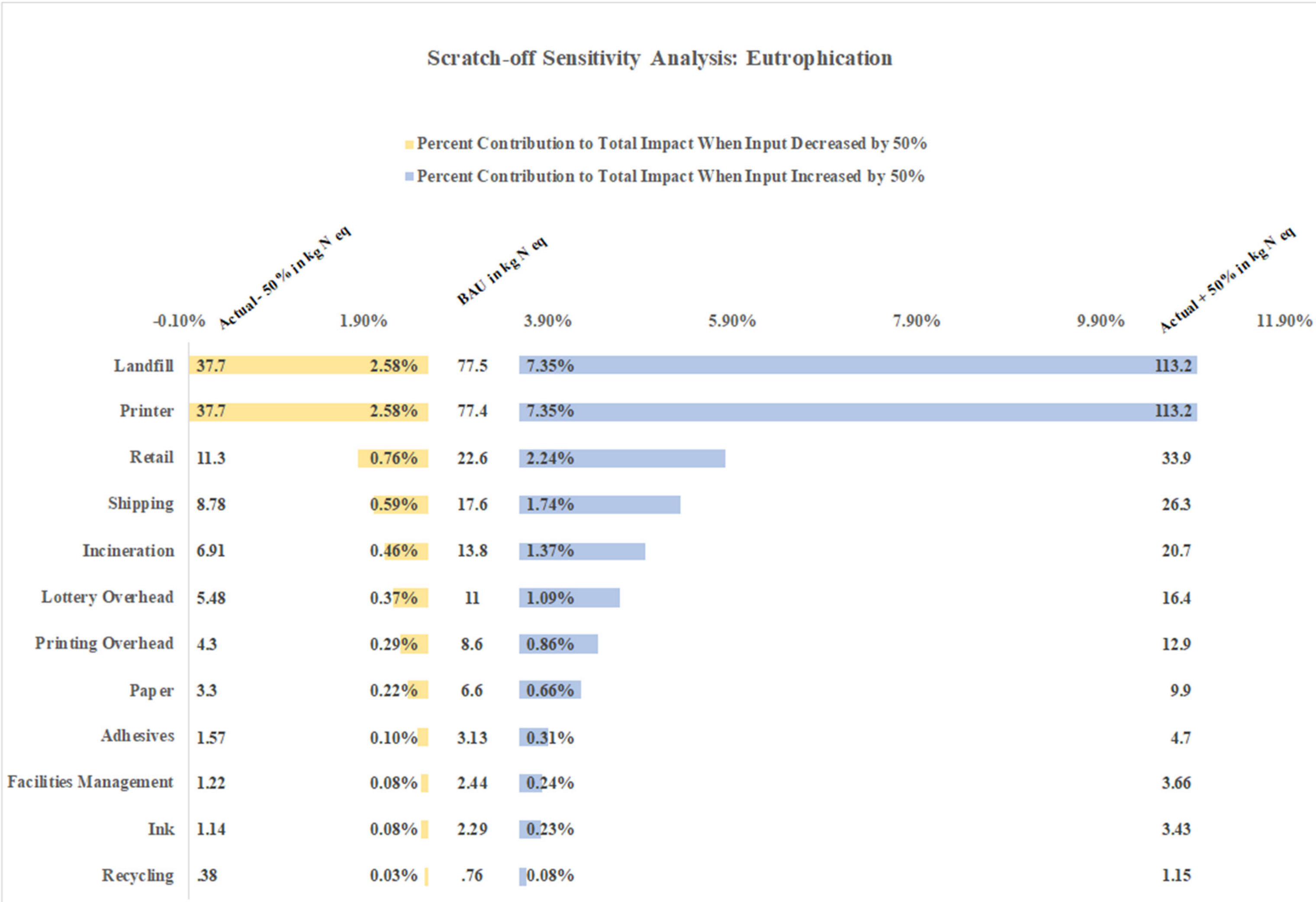

Figure 9. Scratch-off ticket sensitivity analysis: eutrophication.

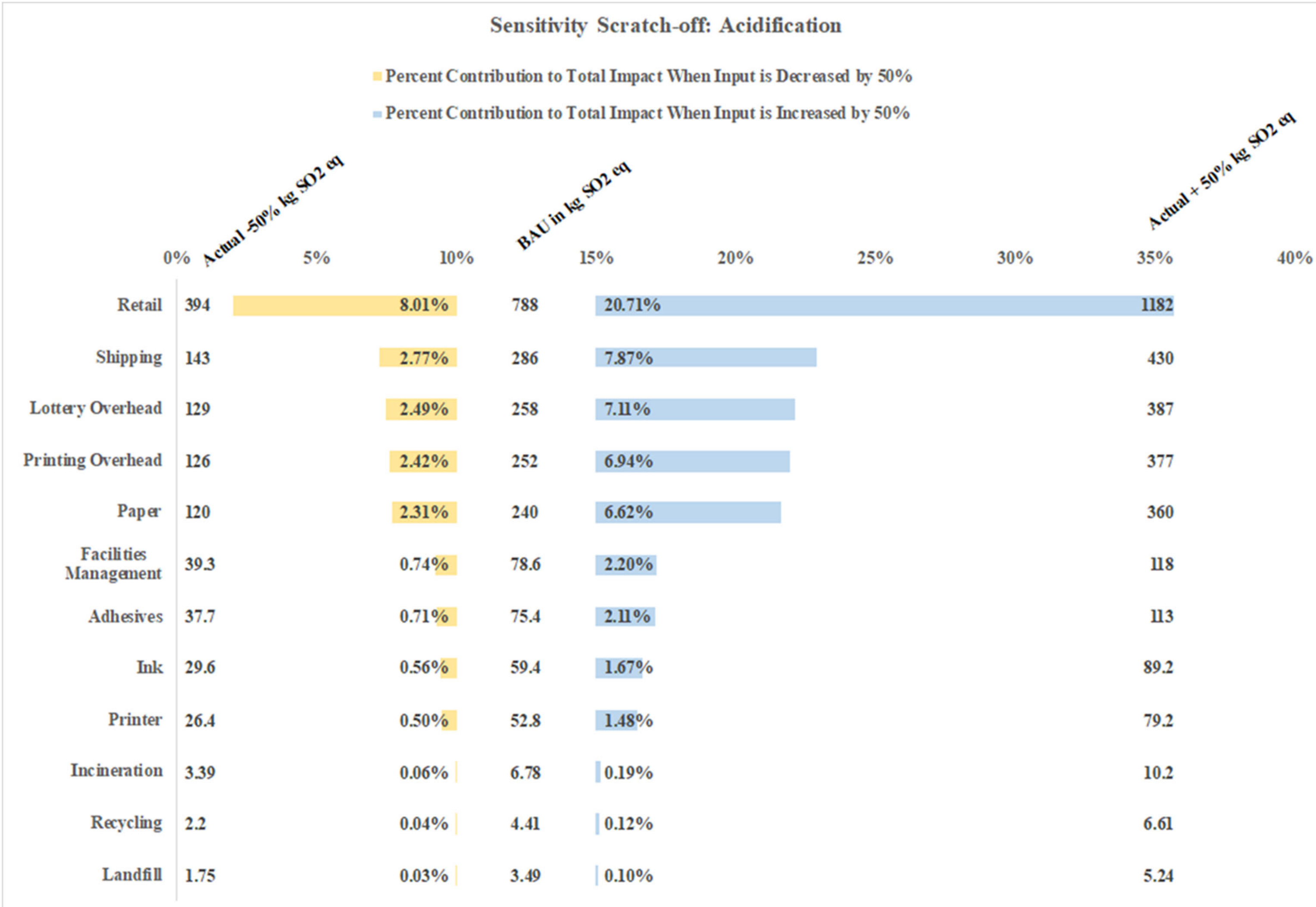

Figure 10. Scratch-off ticket sensitivity analysis: acidification.

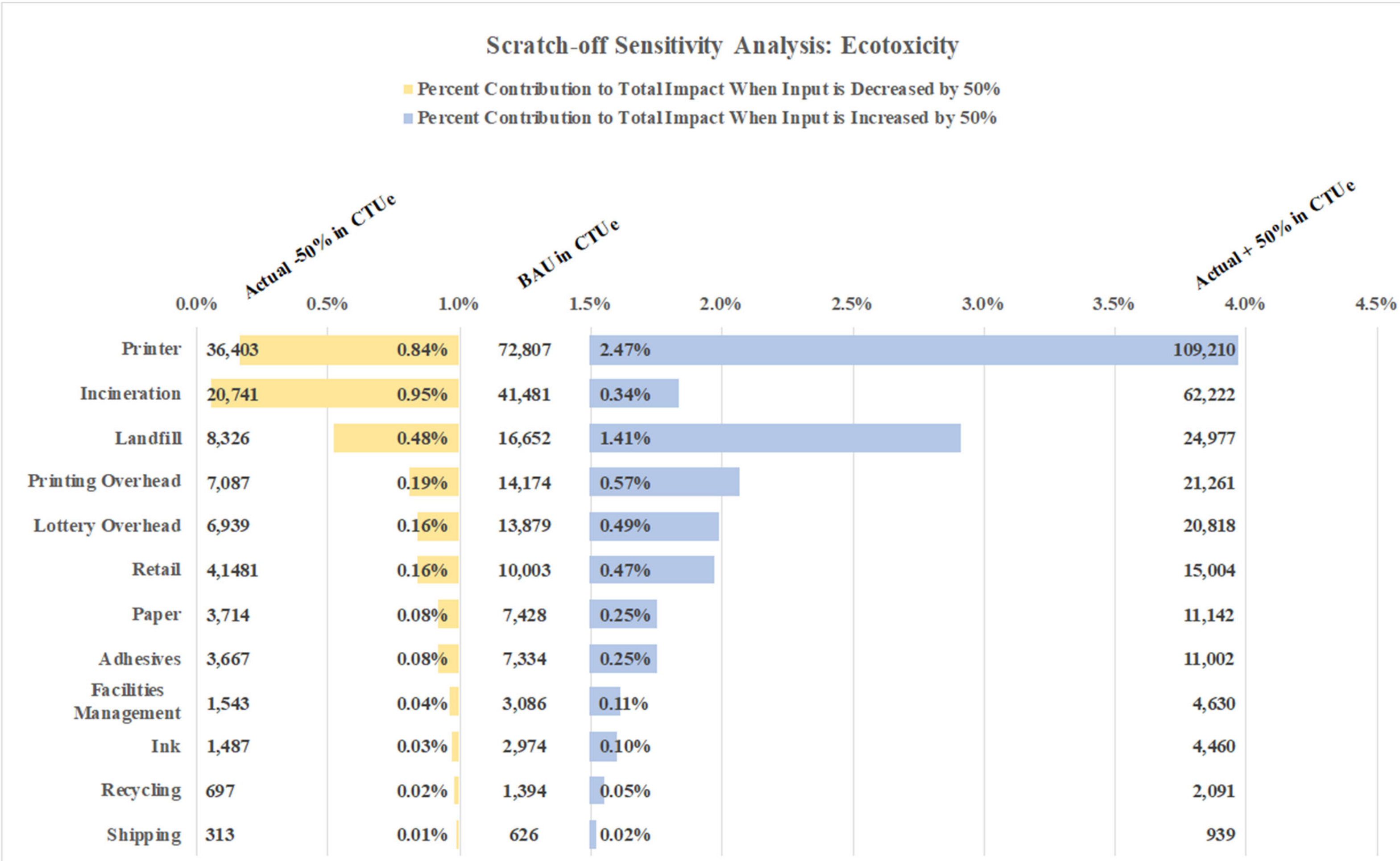

Figure 11. Scratch-off ticket sensitivity analysis: ecotoxicity.

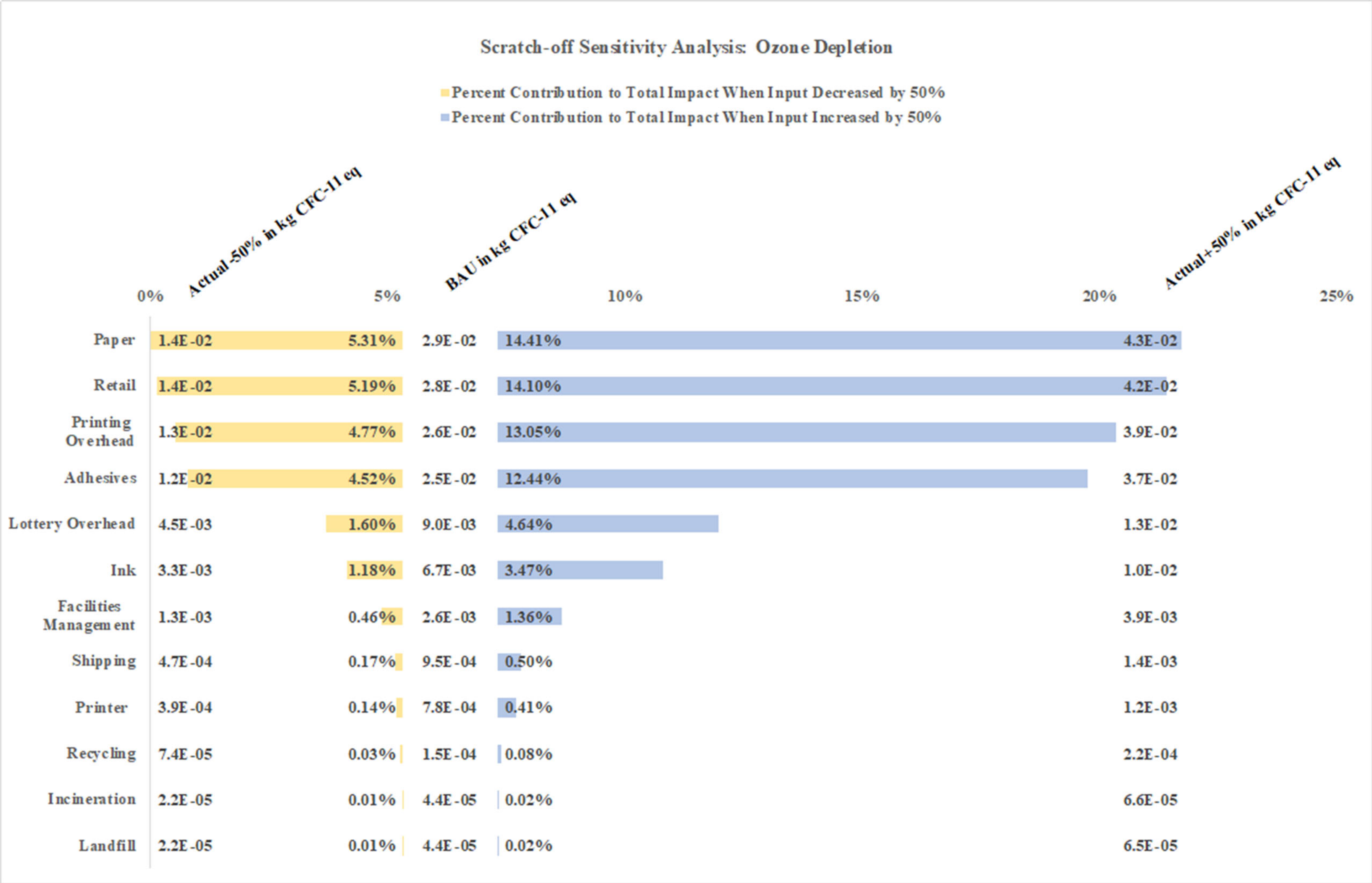

Figure 12. Scratch-off ticket sensitivity analysis: ozone depletion.

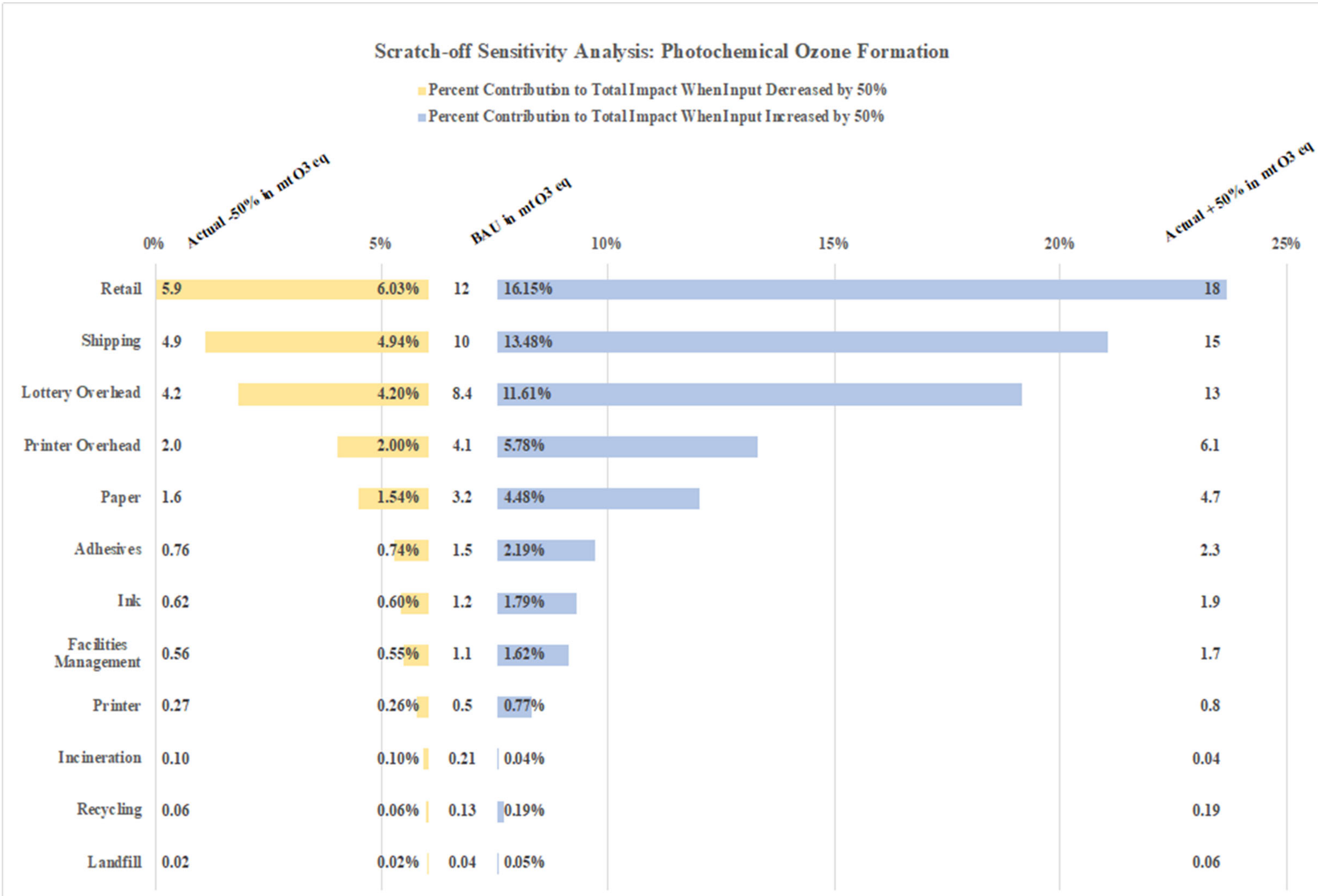

Figure 13. Scratch-off ticket sensitivity analysis: photochemical ozone formation.

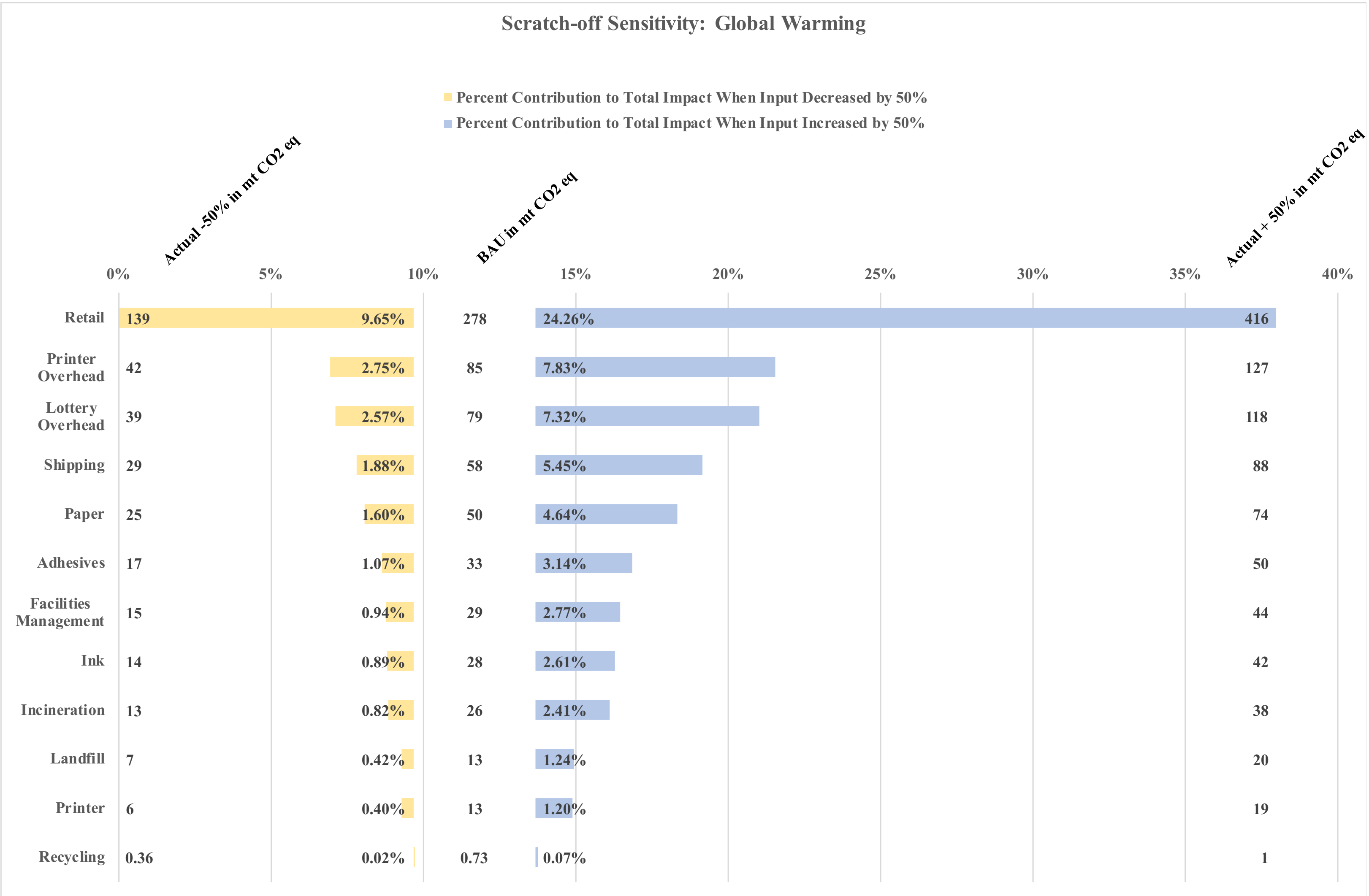

Figure 14. Scratch-off ticket sensitivity analysis: global warming.

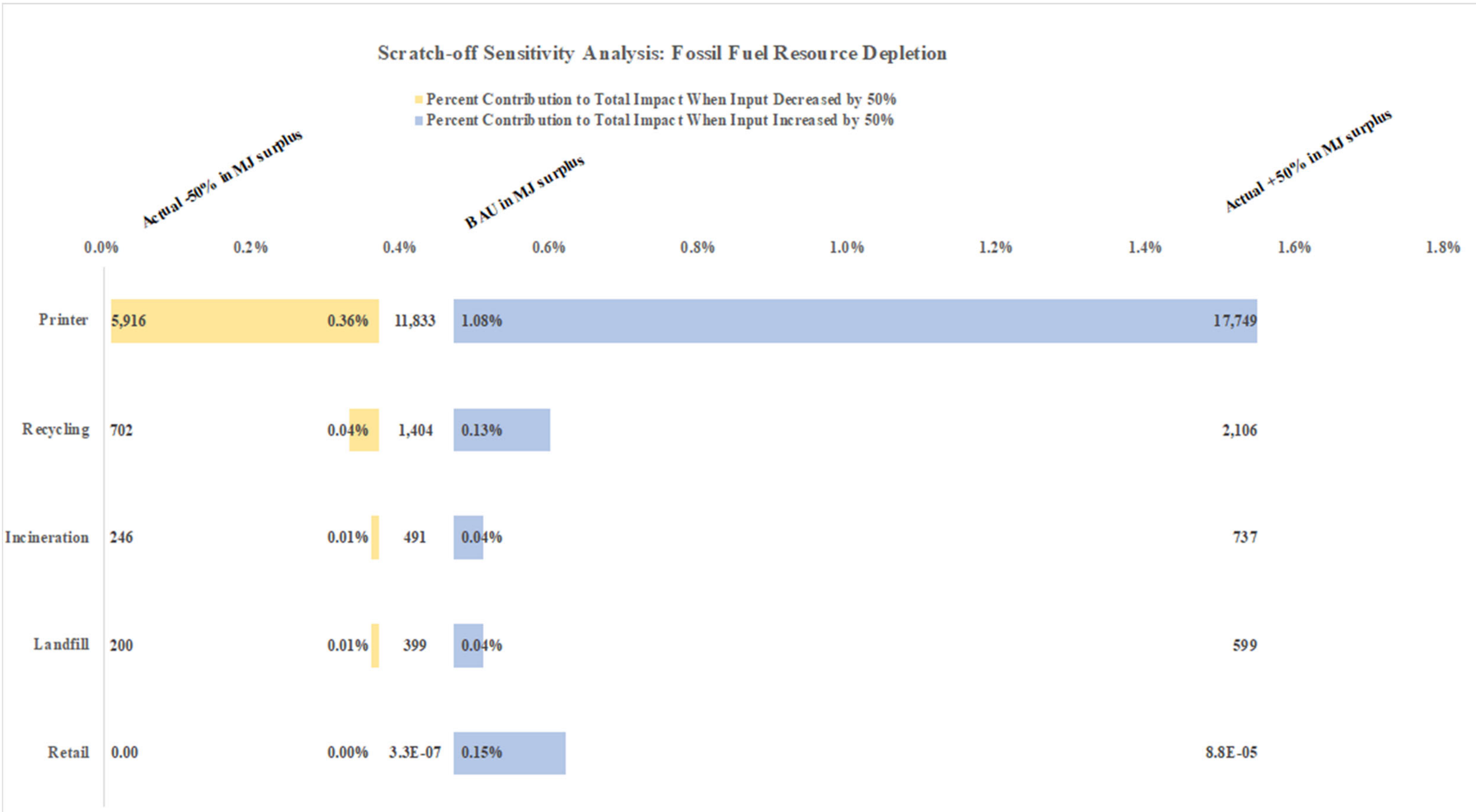

Figure 15. Scratch-off ticket sensitivity analysis: fossil fuel resource depletion.

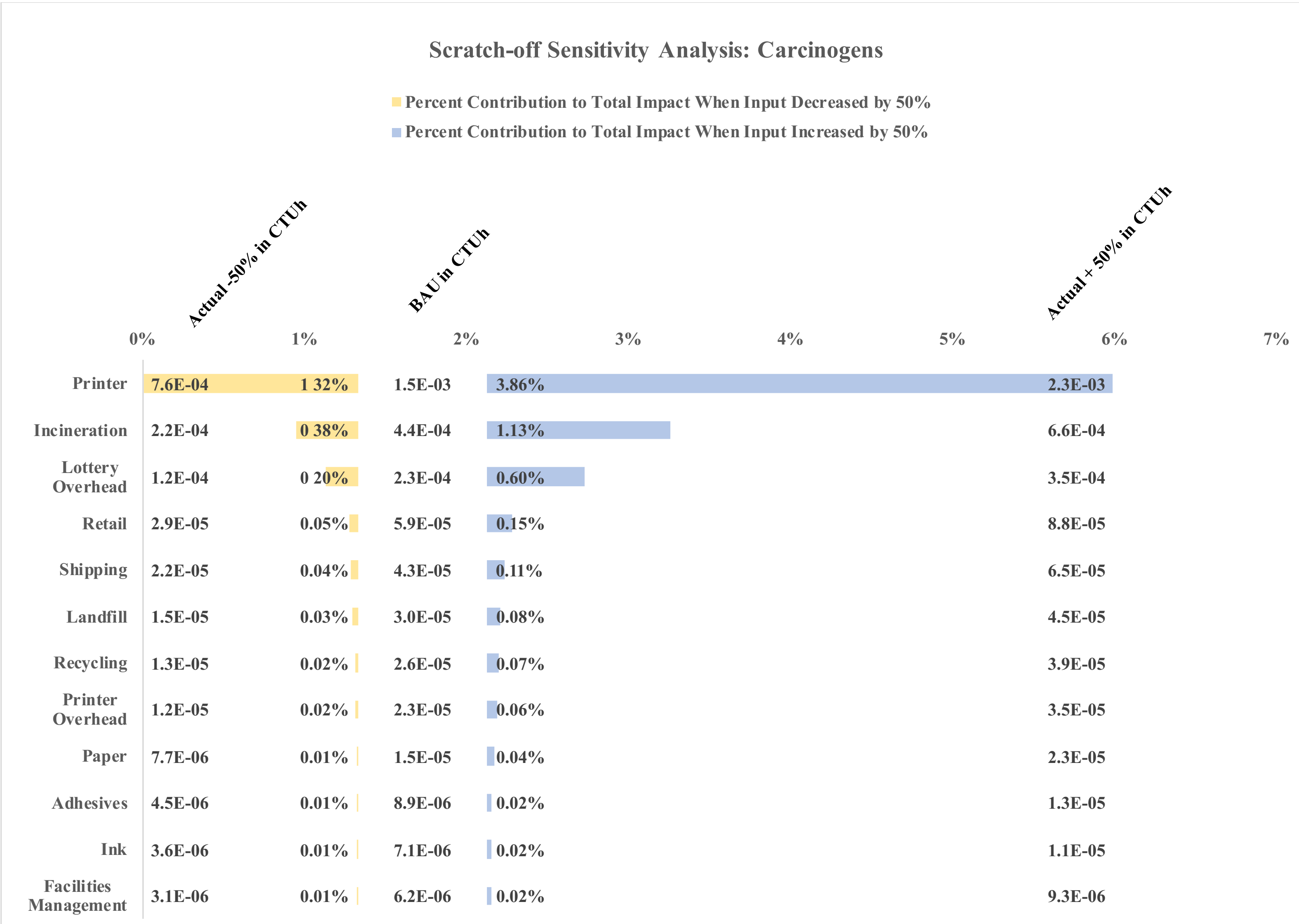

Figure 16. Scratch-off ticket sensitivity analysis: carcinogens.

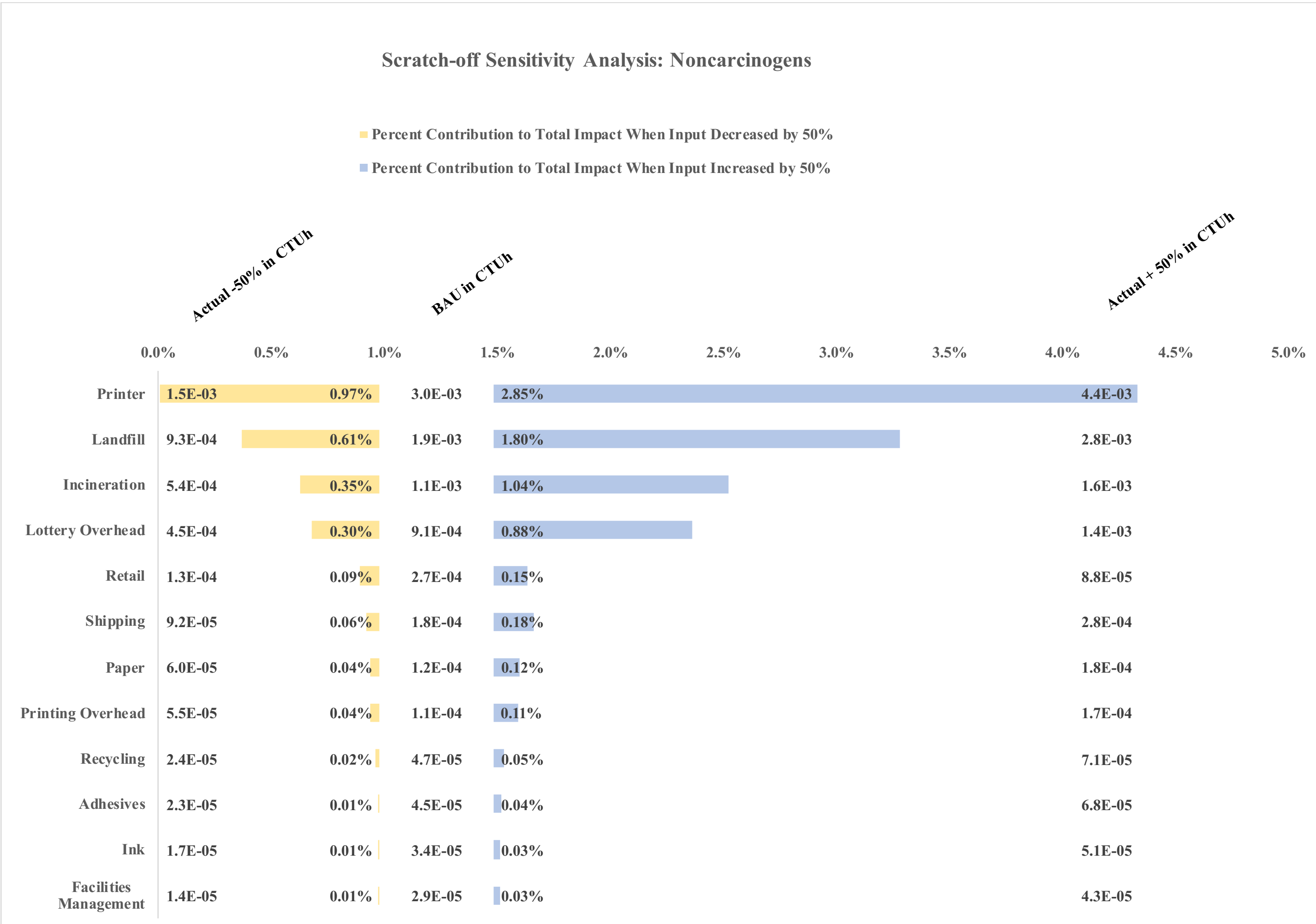

Figure 17. Scratch-off ticket sensitivity analysis: noncarcinogens

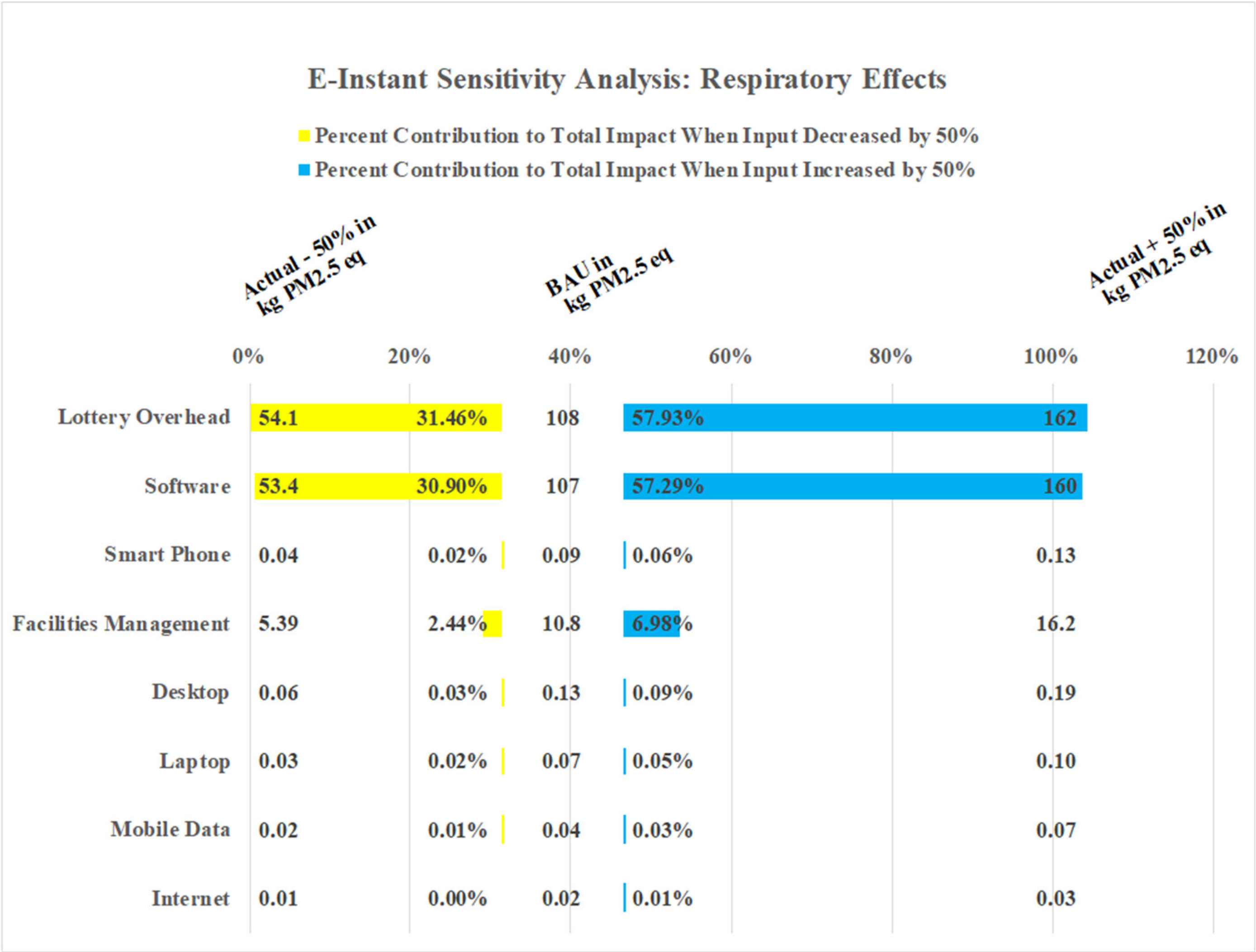

Figure 18. E-Instant sensitivity analysis: respiratory effects.

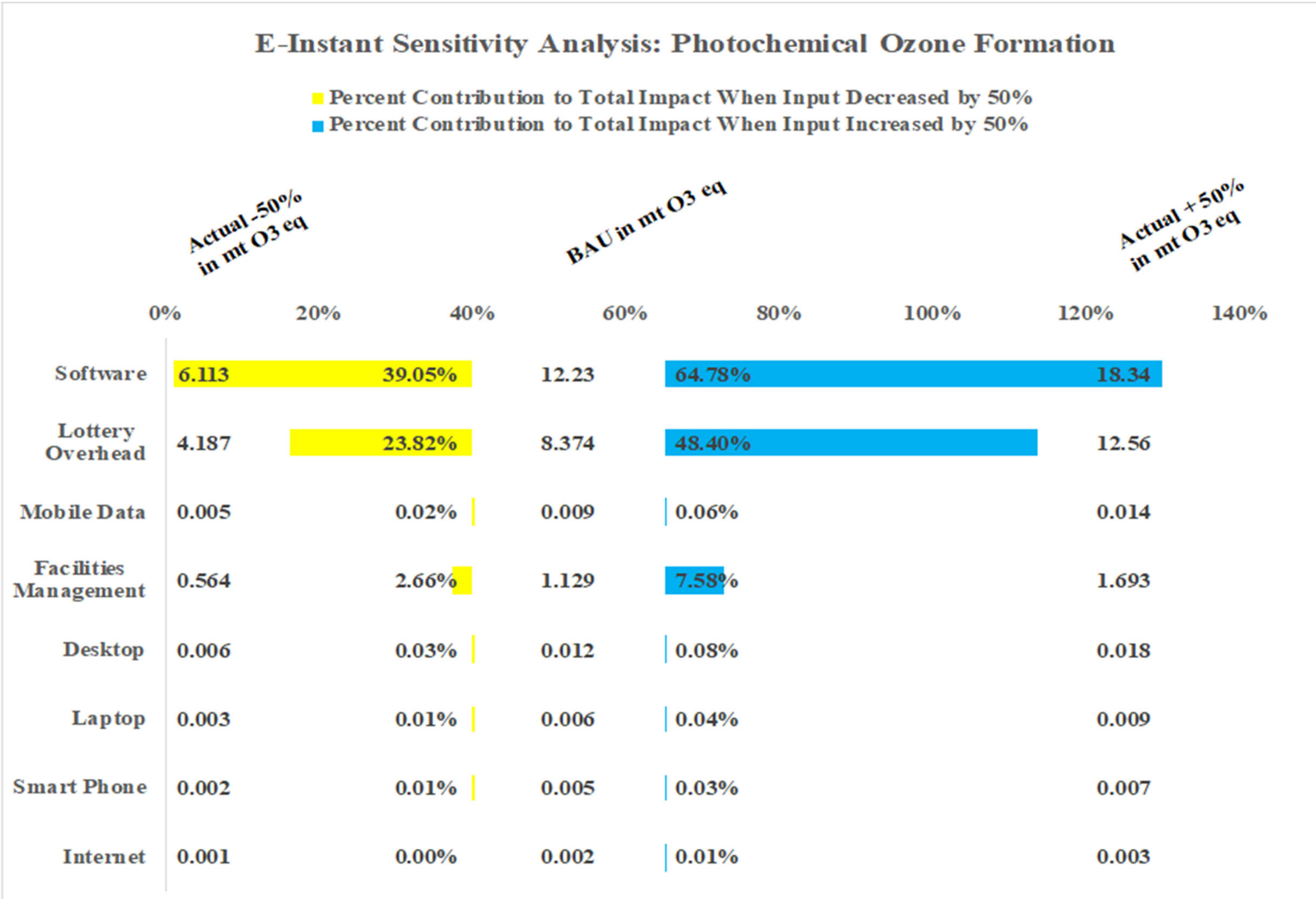

Figure 19. E-Instant sensitivity analysis: photochemical ozone formation.

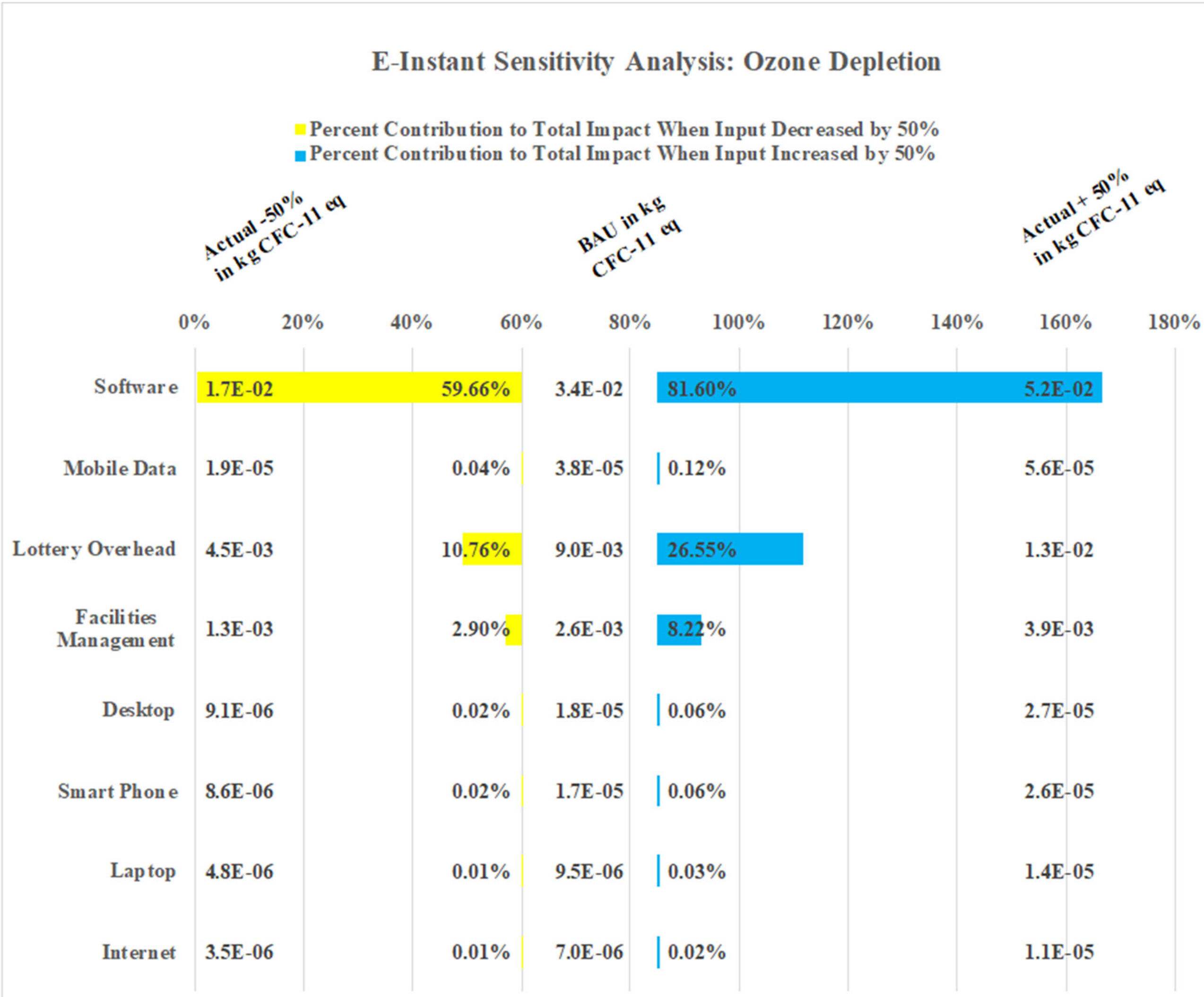

Figure 20. E-Instant sensitivity analysis: ozone depletion.

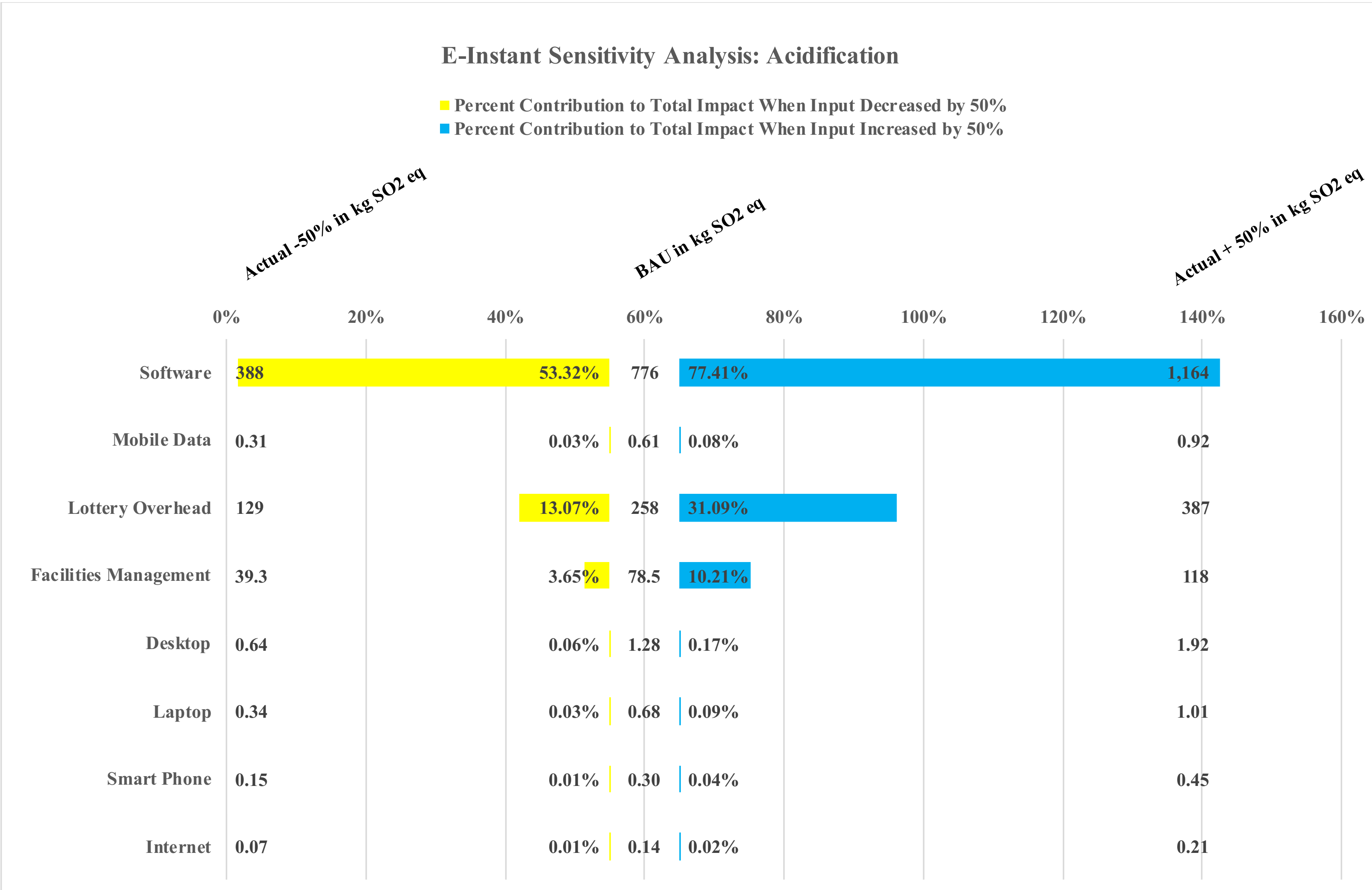

Figure 21. E-Instant sensitivity analysis: acidification.

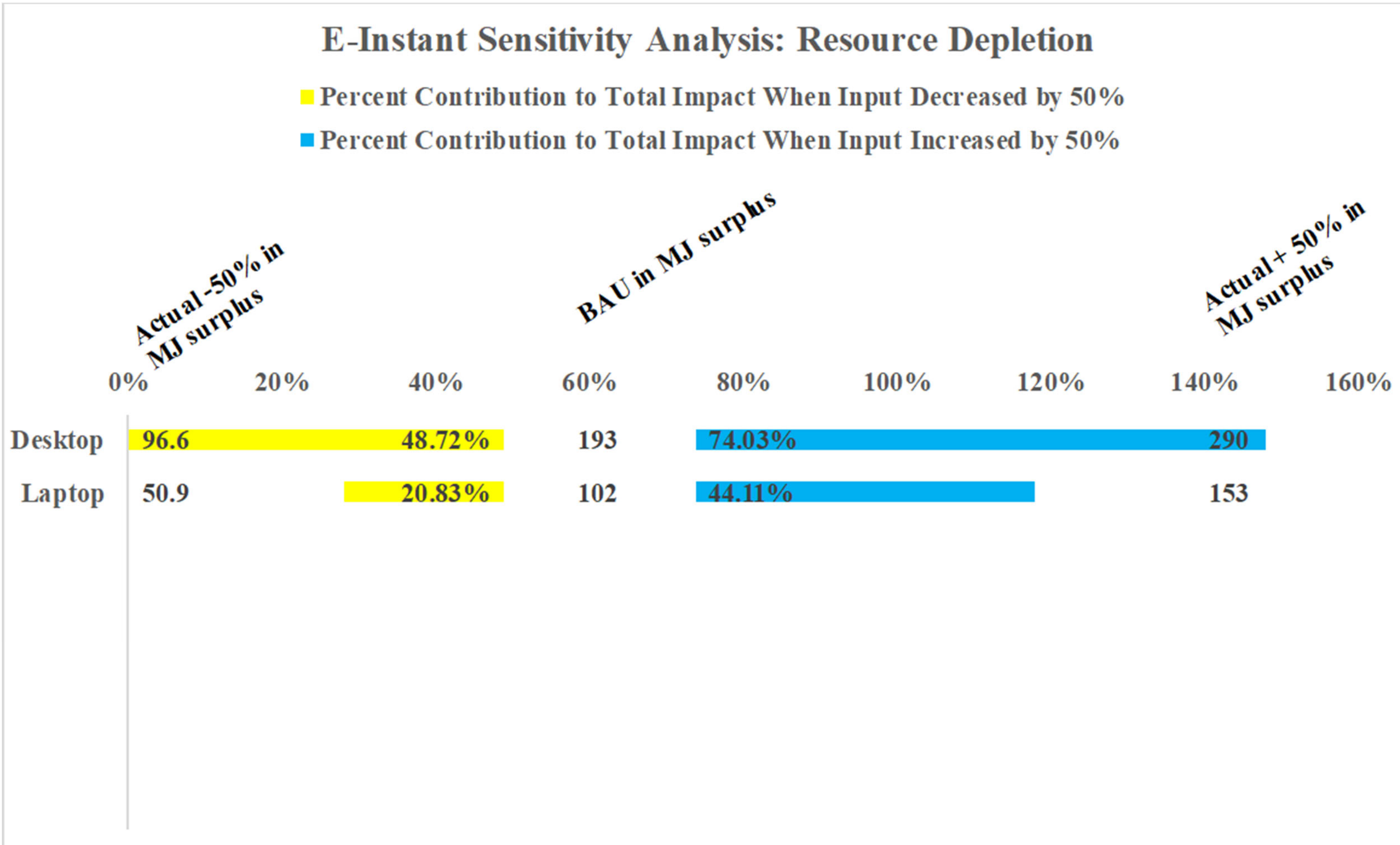

Figure 22. E-Instant sensitivity analysis: fossil fuel resource depletion.

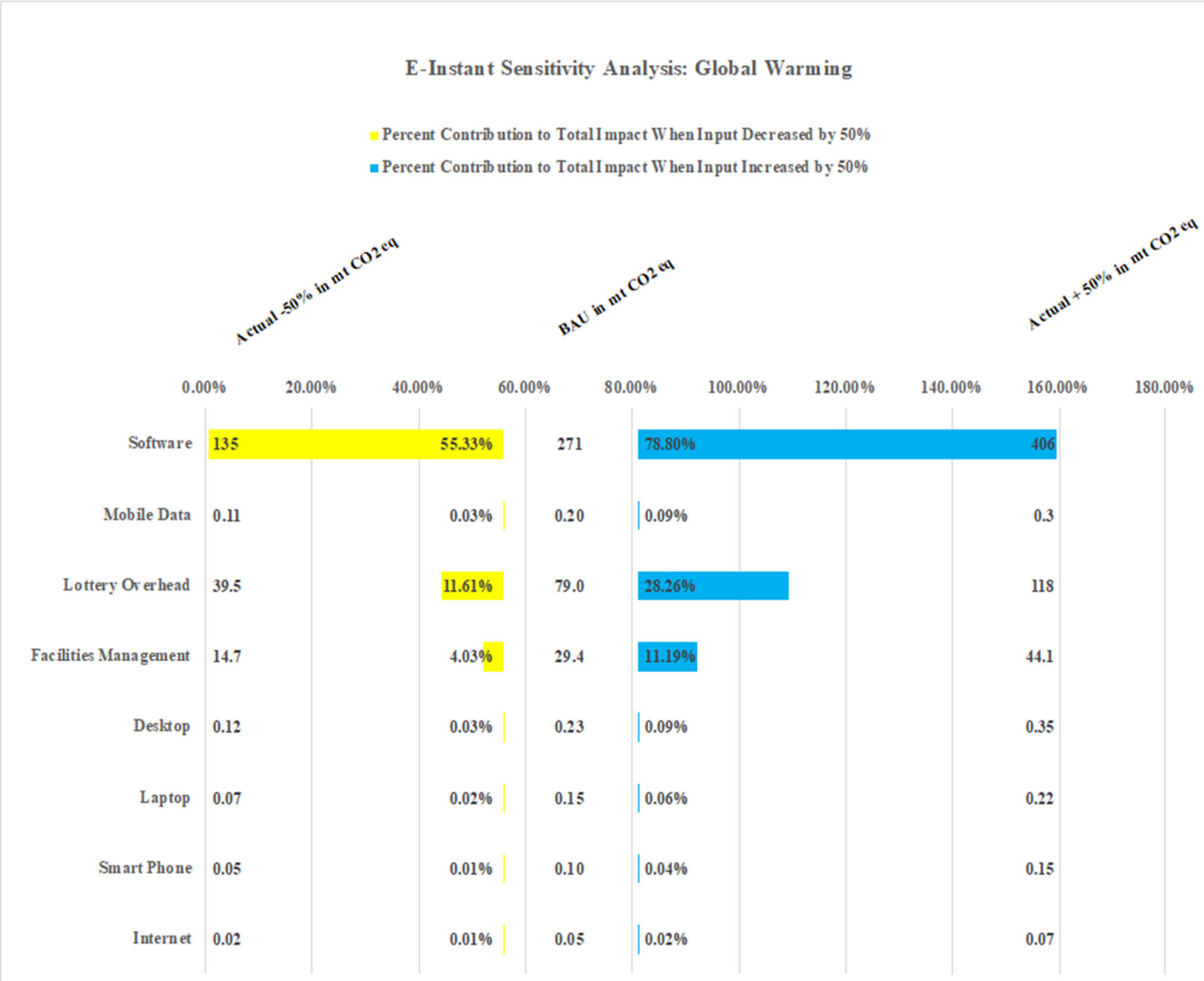

Figure 23. E-Instant sensitivity analysis: global warming.

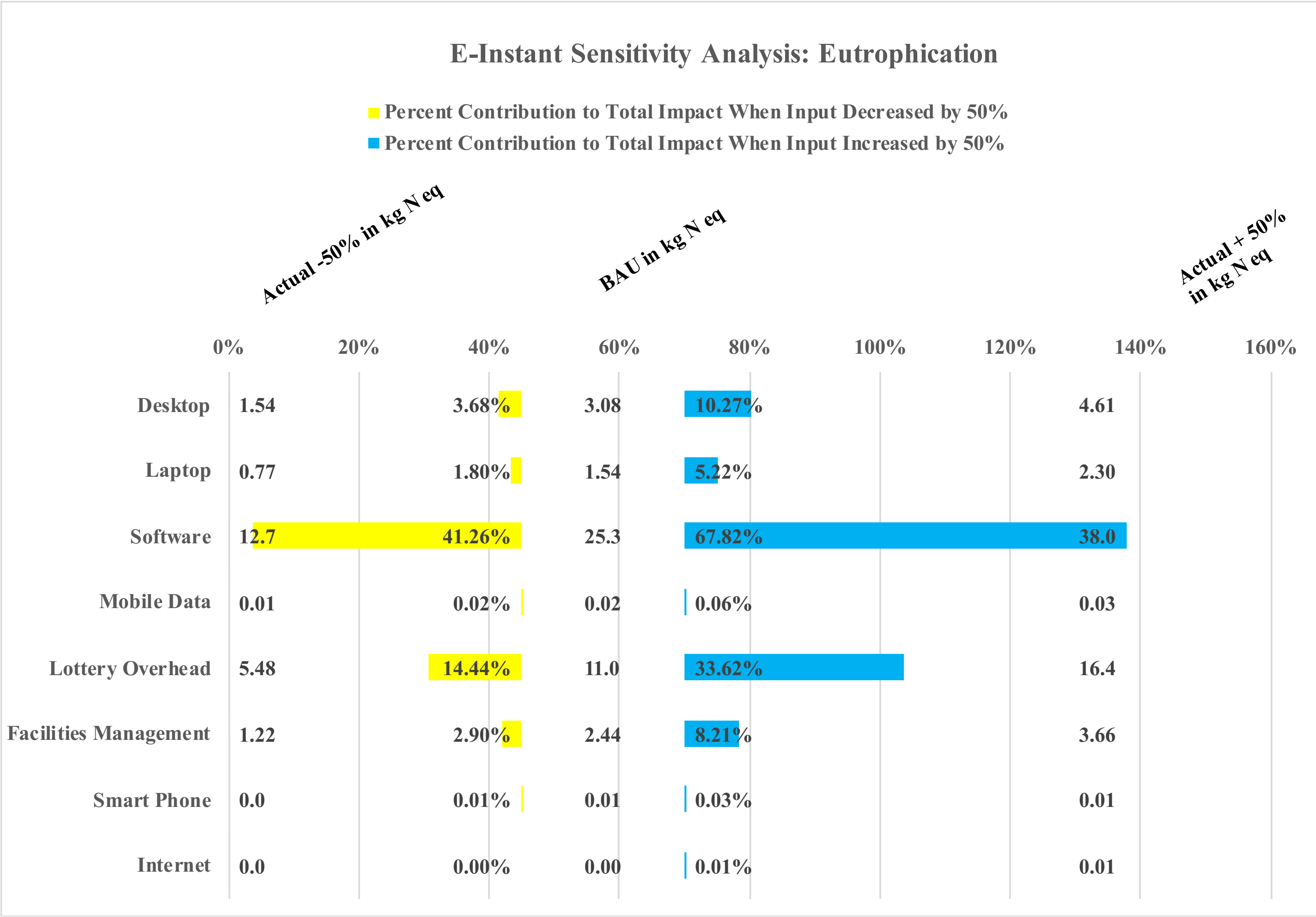

Figure 24. E-Instant sensitivity analysis: eutrophication.

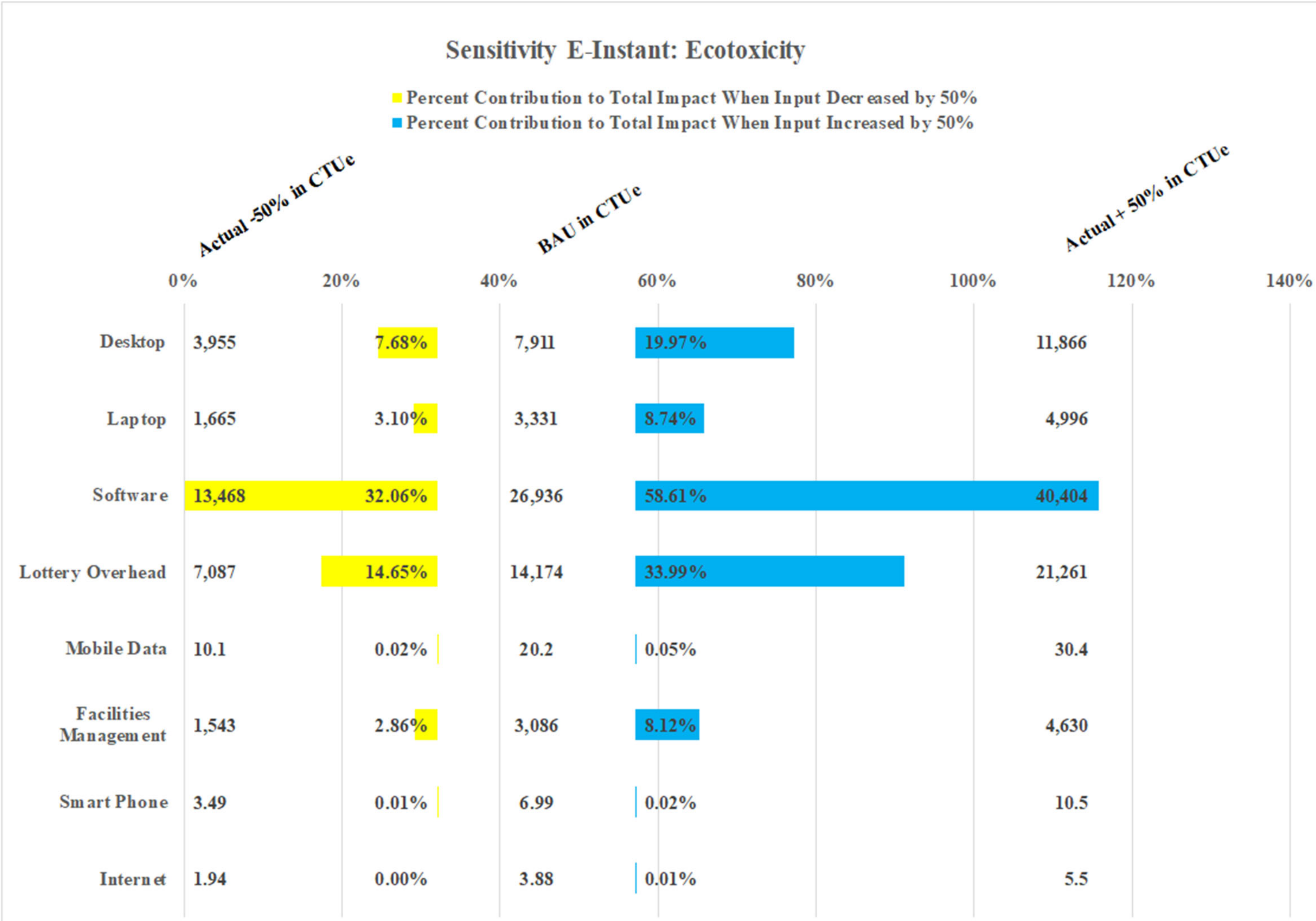

Figure 25. E-Instant sensitivity analysis: ecotoxicity.

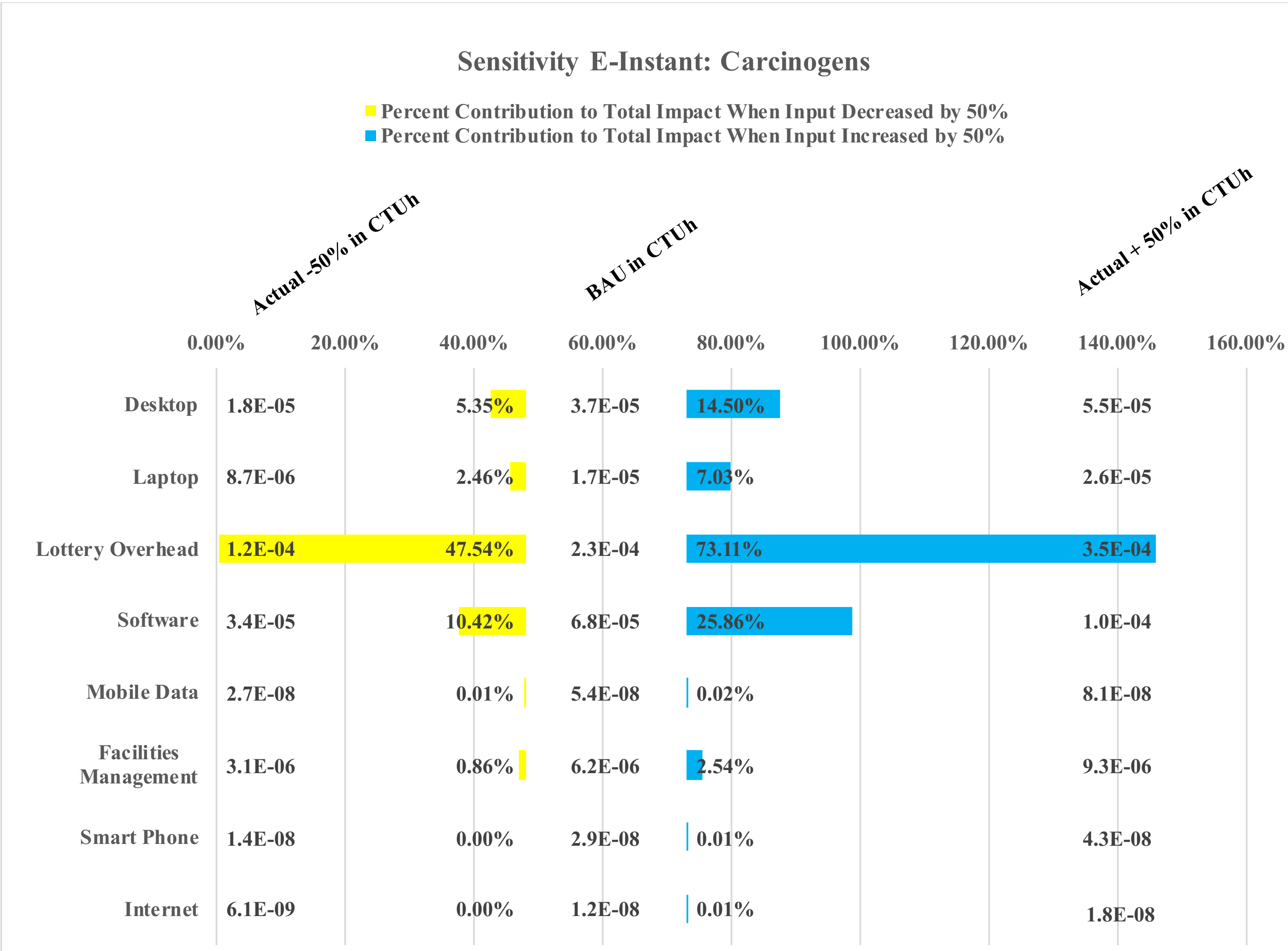

Figure 26. E-Instant sensitivity analysis: carcinogens.

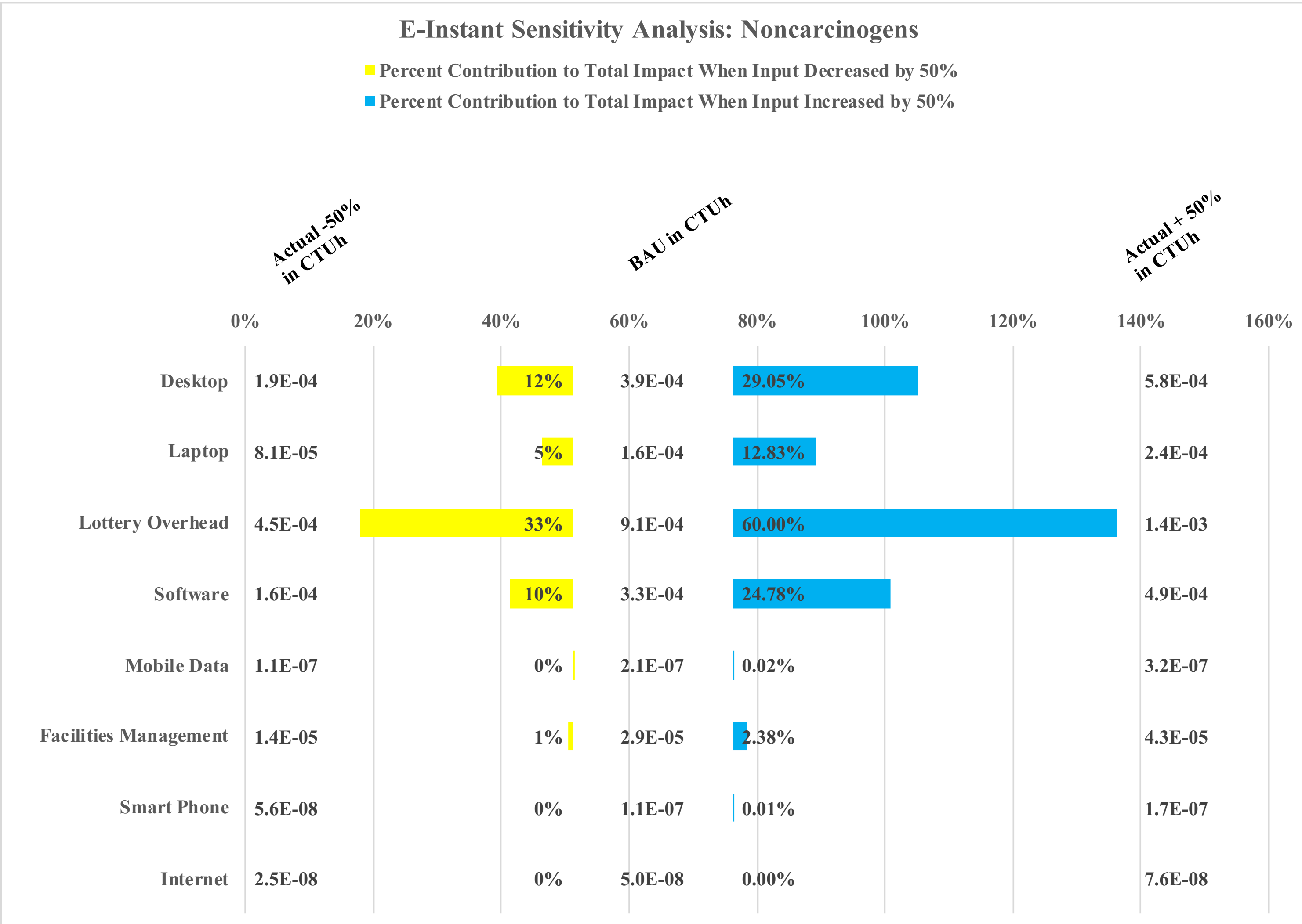

Figure 27. E-Instant sensitivity analysis: noncarcinogens.

Normalized Results

The scenarios were normalized to total US impacts in 2008, as that is the most recent information available for LCIA analysis (Figure 28). Normalization allowed me to look at how much each impact category result compared to the US's total impacts. The results tell us that overall, one game from one US lottery contributes very little to the overall impacts in the US. When considering trade-offs or changes in the system, it's essential to see if this goes up or down. The goal is to decrease all US impacts, and therefore, trade-offs that result in increases should be discouraged.

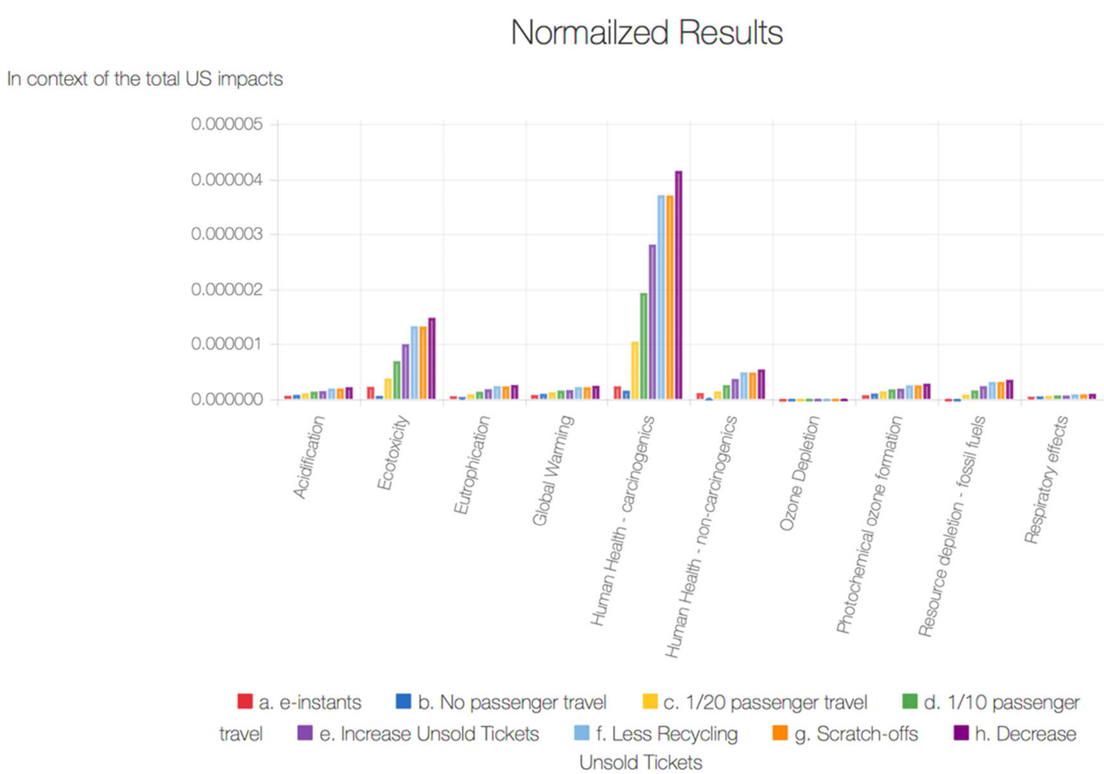

Figure 28. Normalized results of both BAU systems, and Scratch-off scenarios from OpenLCA.

Chapter IV

Discussion

To my knowledge, this research was the first product-level environmental research in the gaming industry. LCA was conducted to look at the entire product system to reduce gambling-related harms. First, I will discuss how I interpreted the results in the context of my research questions and hypotheses. I will make some recommendations to the industry, regulators, advocates, and players, all of whom can help reduce harms. Finally, I'll talk about the research limitations and future research needs.

LCIA Interpretation

My research question was: what are the significant environmental impacts of Scratch-off tickets and E-Instants? I hypothesized that E-Instant tickets had less overall significant impacts than Scratch-off tickets. The results from the LCA analysis initially showed that my hypothesis was correct. However, we cannot merely take the face-value data and assume it is correct without doing additional testing for robustness. When eliminating play travel for Scratch-offs, E-instants still have less total impacts, but the numbers come much closer and comparable based on uncertainty in the data, especially in the areas of human health and ecotoxicity.

Scratch-offs

The most significant issue with the Scratch-off system was the degree to which individual customers traveling to retailers contributed to the results (between 45-99% depending on the impact category). If we were to stop selling all lottery tickets at retailers, trips to retail locations might not decrease at all. The reason for this is that lottery tickets are often an impulse purchase, except for the most loyal players or players experiencing a problem or compulsive gambling. Therefore, there may be some effect on the total trips to a retail location, but attributing 1/5 of a trip to the lottery purchase is questionable.

The lottery industry gives mixed information on customer trips to retailers. On the one hand, it convinces retailers to sell lottery by saying it will attract players to the store. On the other hand, it sells online wagering by telling these same retailers that the online platform will not decrease or compete with brick and mortar retailers. At the moment when online wagering is in its infancy, both are true statements. However, as online wagering grows to the levels assumed in this LCA, we're not sure what will happen to player travel. As many states in the US are about to launch mobile sports betting, and we will likely see online wagering at the levels assumed in this LCA.

The sensitivity analysis helped solve the player travel issue by comparing BAU E-Instants with Scratch-offs that assumed zero customer travel to retail locations. The scenarios showed a mixed view of impacts category results, and data quality and uncertainty analysis became very important to the interpretation.

Before considering data quality and uncertainty, I looked more in-depth at the contribution tree of the BAU E-Instants, and the "no player travel Scratch-off," and ran a few more scenarios. Another research question arose – what if we changed the destruction method of the Scratch-off tickets? My new hypothesis was that incineration was contributing negatively to the overall results. The scenarios showed that this sub-hypothesis was false and that the system overall was not significantly affected by changing the destruction method. There was a relative decrease in the global warming impact category when reducing landfilled tickets. I interpreted the relative decrease to mean that lotteries can reduce greenhouse gases by switching from landfill to either recycling or incineration for energy production. However, addressing the destruction method is not the best way to reduce impacts.

The next largest inputs on the Scratch-off system were retailers, lottery overhead, and printer overhead. All of these were a percentage of sales, and when the total system scenario was tested to see if overall sales affected results, it did not. The total system scenario results directly contradicted what the tornado graphs showed for the sensitivity of retail, lottery overhead, and printer overhead. The reason for this is that in real life, these would all go up and down together. Therefore, the OAT analysis tells us that should the retail base expand rapidly, or the lottery office expands suddenly, or the printer expands operations – those would significantly increase impacts.

Paper and ticket shipping were also sensitive in the system. I interpreted this to mean that lotteries and printers can try to use less paper per ticket to decrease impacts without negatively affecting security standards. Additionally, tickets ship to retailers in "packs," which have a set amount of tickets. The current lottery business model charges retailers when they receive the packs, not when they sell tickets. This inventory system has some disadvantages, including needing to ship tickets in smaller quantities since the retailers do not want too much inventory on hand (which can negatively affect their cash flow). The inventory system also negatively affects the lottery's ability to decrease its environmental impacts from shipping tickets.

E-Instants

E-Instant results showed that the inputs of software (meaning, the creation of the games and the platform from which they are offered), lottery overhead (cost of operations), and facilities management (central system operations) were the top contributing factors to the impact categories. The OAT sensitivity analysis showed that all three were the most sensitive inputs in the system. I interpreted this to mean that sudden expansion of the platform or games offered would greatly affect the impact category results.

The total system scenario testing showed that a drastic change to the time-to-wager (from thirty seconds per wager to thirty minutes per wager) would affect the system, with the largest impacts being laptop and desktop computer use, and mobile data. Time-to-wager amplified the effects of which device and transmission system (Wi-Fi or mobile) contributed to the results. Lotteries can design products that reduce time-to-wager, and thus reduce impacts (while taking social impacts under consideration). When wagering for long amounts of time, customers that wager via mobile devices over Wi-Fi will reduce the impacts of the system. I've anecdotally confirmed that mobile wagering is the most popular form of wagering in the US (DeHaven, Weyant, & Walker, 2019) by attending a panel discussion on the topic. However, formal reporting by the industry would be helpful to understand the percentage of wagers and if the player was connected to a Wi-Fi or was using mobile data. It would be helpful if the iLottery platform was designed to collect this type of information to assess its impact on the environment. Lotteries could educate players by designing messaging to communicate how collectively, they have contributed to reducing environmental impacts by using a mobile phone via Wi-Fi.

Research Limitations

The research was set up as a "streamlined" LCA to assess initial hotspots and critical overarching issues. It is possible that a complete collection of data for individual tickets or games could lead to different conclusions. The results of this research should be seen as a starting point, not an endpoint, of gathering information on environmental harms from gambling. This research did not comply with the ISO 14040 and 14044 standards for making a comparative assertion. Therefore, it is inappropriate to say that E-Instants are better than Scratch-offs for the environment. A more detailed LCA with specific product measurements would be needed to assess if that is true or not.

There were no specialized databases, commonly used inputs, or industry agreement on which databases and input factors were appropriate. In a few years, as internet gaming becomes more popular in the US, we may know more about the common ways in which e-gaming is conducted, and changes to the functional unit assumed in this model may be warranted. Ecoinvent 2.2 had limited information on the gaming industry and contained little information specific to the US. While USEEIO was a great substitute since it had gambling information and was relevant to the US, many of the inputs included a broad range of activities that may have over or understated impacts. The LCIA method TRACI 2.1 is not the most recent or up-to-date method of conducting LCIAs. The ReCiPe method is the most recently updated LCIA method but doesn't contain relevant results for US jurisdictions.

More work needs to be done by researchers to look at the life cycle assessments of sports betting, casinos, horse racing, and gamified slot machines. The industry may find some competitive advantage by looking into comparative assertions with LCA and, at the same time, driving competition to address environmental impacts. The social impact of gaming is a serious issue, and we need research that can critically look at trade-offs between environmental impacts and social impacts.

The purpose of this research was to show how environmental impacts contribute to gambling-related harms. Normalization was the best way to contextualize this concept. Figure 28 gives us a snapshot of what the harms look like per game compared to the total environmental impacts in the US. The normalized numbers are incredibly small and show that while there is an impact, it is considerably diluted on a per-game basis. It would be better to understand what the total industry impacts were on the environment, and then normalize the results of this research to that data point.

References

Acero, A. P., Rodríguez, C., & Ciroth, A. (2015, March 16). *LCIA Methods*. Retrieved from https://www.openlca.org/wp-content/uploads/2015/11/LCIA-METHODS-v.1.5.4.pdf

All Lottery Games | Michigan Lottery. (n.d.). Retrieved June 23, 2019, from https://www.michiganlottery.com/games

Althaus, H.-J., Doka, G., Dones, R., Heck, T., Hellweg, S., Hischier, R., … Wernet, G. (2007). *Data v2.0 (2007) Rolf Frischknecht, Niels Jungbluth (Editors)*. (1), 77.

Analytical Environmental Services. (2016). *Wilton Ranceria Fee-to-Trust and Casino Project* [Environmental Impact Assessment]. Retrieved from Environmental Protection Agency website: https://cdxnodengn.epa.gov/cdx-enepa-II/public/action/eis/details?eisId=223689

ANIELSKI Management. (2008). *The Socio-Economic Impact of Gambling (SEIG) Framework: An Assessment Framework for Canada: In Search of the Gold Standard*. Retrieved from http://deslibris.ca/ID/252320

Bagchi, T. P., & Lin, S. (1997). Factorial Design Applications in Sensitivity Analysis. *Opsearch; New Delhi*, *34*(4), 242–258. http://dx.doi.org.ezp-prod1.hul.harvard.edu/10.1007/BF03398529

DeHaven, S., Weyant, S., & Walker, L. (2019, June). *iLottery Manager Pannel*. Presented at the La Fleur's iLottery eConference. Retrieved from https://lafleurs.com/product/ilottery-econference/

Finkbeiner, M. (2014). The International Standards as the Constitution of Life Cycle Assessment: The ISO 14040 Series and its Offspring. In *LCA Compendium – The Complete World of Life Cycle Assessment*. *Background and Future Prospects in Life Cycle Assessment* (pp. 85–106). https://doi.org/10.1007/978-94-017-8697-3_3

Gaudreault, C., Samson, R., & Stuart, P. R. (2010). Energy decision making in a pulp and paper mill: Selection of LCA system boundary. *The International Journal of Life Cycle Assessment*, *15*(2), 198–211. https://doi.org/10.1007/s11367-009-0125-1

Griffiths, M., & Wood, R. (2001). The psychology of lottery gambling. *International Gambling Studies*, *1*(1), 27–45. https://doi.org/10.1080/14459800108732286

Isidore, C. (2017, August 24). We spend billions on lottery tickets. Here’s where all that money goes. Retrieved July 12, 2018, from CNNMoney website: https://money.cnn.com/2017/08/24/news/economy/lottery-spending/index.html

Jolliet, O., Saade-Sbeih, M., Shaked, S., Jolliet, A., & Crettaz, P. (2016). *Environmental Life Cycle Assessment*. Florida: CRC Press.

Klinglmair, M., Sala, S., & Brandão, M. (2014). Assessing resource depletion in LCA: A review of methods and methodological issues. *The International Journal of Life Cycle Assessment*, *19*(3), 580–592. https://doi.org/10.1007/s11367-013-0650-9

Marotta, J., Hynes, J., Rugle, L., Whyte, K., M Scanlan, K., Sheldrup, J., & Dukart, J. (2017). *2016 Survey of Problem Gambling Services in the United States*. https://doi.org/10.13140/RG.2.2.35101.41443

Markle, T., La Fleur, B., & La Fleur, B. (2017). *La Fleur’s 2017 World Lottery Almanac*. In *Silver Edition* (pp. 246–295). TLF Publications, Inc.

NASPL. (2016). North American Lotteries [Non-profit]. Retrieved July 8, 2018, from About Our Members website: http://www.naspl.org/nasplmembers/

Ryberg, M., Vieira, M. D., M, Zgola, M., Bare, J., & Rosenbaum, R. K. (2014). Updated US and Canadian normalization factors for TRACI 2.1. *Clean Technologies and Environmental Policy; Berlin*, *16*(2), 329–339. http://dx.doi.org.ezp-prod1.hul.harvard.edu/10.1007/s10098-013-0629-z

Shaffer, H. J., LaBrie, R. A., & LaPlante, D. (2004). Laying the Foundation for Quantifying Regional Exposure to Social Phenomena: Considering the Case of Legalized Gambling as a Public Health Toxin. *Psychology of Addictive Behaviors*, *18*(1), 40–48. https://doi.org/10.1037/0893-164X.18.1.40

Walker, D. (2007). Problems in Quantifying the Social Costs and Benefits of Gambling. *The American Journal of Economics and Sociology*, *66*(3), 609–645.

Williams, E. A. (2000). *The illusion of local aid: Extractive and distributive effects of the Massachusetts State Lottery on cities and towns* (Ph.D., University of Massachusetts Amherst). Retrieved from http://search.proquest.com/docview/304605658/abstract/77AAADB01DE94BFDPQ/1

Yang, Y., Ingwersen, W. W., Hawkins, T. R., Srocka, M., & Meyer, D. E. (2017). USEEIO: A new and transparent United States environmentally-extended input-output model. *Journal of Cleaner Production*, *158*, 308–318. https://doi.org/10.1016/j.jclepro.2017.04.150

Yu, S., Yun, S.-T., Hwang, S.-I., & Chae, G. (2019). One-at-a-time sensitivity analysis of pollutant loadings to subsurface properties for the assessment of soil and groundwater pollution potential. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-019-05002-7