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COMPLETING THE CLOSED LOOP FOR CONSUMER ELECTRONICS SUPPLY CHAINS: AN ANALYSIS OF DEVICE END OF LIFE EXTENSIONS BY CORPORATIONS, RECYCLERS, GOVERNMENTS AND SECOND-HAND MARKETPLACES

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ABSTRACT

Over the past few decades, academics and industry leaders alike have identified organizational supply chains as business sectors responsible for the fundamental activities of sourcing, procurement, warehousing, logistics, and transportation. Furthermore, each collection point serves as a center for value-added innovation through automation, analytics, tiered visibility, resiliency, agility, and machine learning principles. Of these trends, the development of a closed-loop supply chain (CLSC) or closed-loop supply chain (CLSC) incorporates tenants of environmental, social, and corporate governance through the incorporation of alternative reverse logistics channels that collect, recycle and reintegrate products that have reached end-of-life (EOL) status, which would have otherwise been disposed of in landfills as e-waste. The goal of this thesis is to investigate the adoption of CLSC principles and practices in the consumer electronics industry and marketplace to garner a summary assessment of initiatives, as well as showcase the efficacy of external entities such as third-party recyclers, governmental bodies and second-hand markets.

The conclusion of this thesis provides a recommended framework for continued circularity efforts that specifies the importance of industry-wide efforts to incorporate sustainability practices into future product design planning, publish annual sustainability innovations, standardize metrics for scope one, two and three emissions, discover additional capabilities to generate negative carbon emissions and continue to work alongside other firms, organizations and governmental bodies to ensure additive innovation in adopting supply chain circularity methodologies across a multitude of stakeholders and communities.

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Finally, a special note of appreciation for Dr. Novack is a requisite. Accompanied with his expertise in research methodology, I could explore topics of interest and importance, and ultimately publish relevant analyses and commentaries within the cross-functional intersections between environment, social and governance investments and supply chain information systems.

Chapter 1

Introduction

Over the course of the past few decades, academics and industry leaders alike have identified organizational supply chains as quintessential sector that constitute the fundamental pillars of sourcing, procurement, warehousing, logistics, and transportation, and as a center for value added innovation through automation, analytics, tiered visibility, resiliency, agility, and machine learning principles. Of these value-added trends, the development of a closed-loop supply chain (CLSC) or closed-loop supply chain (CLSC) incorporates tenants of environmental, social, and corporate governance through the incorporation of alternative reverse logistics channels that collect, recycle, and reintegrate products that have reached end-of-life (EOL) status, which would have otherwise been disposed of as landfill waste. The goal of this thesis is to investigate the adoption of CLSC principles and practices within the current state of the consumer electronics industry and marketplace, as well as showcase the efficacy of external organizations such as third-party recyclers and governmental collection programs.

The research will begin with a contextual literature review detailing pertinent theoretical developments and practical implementations of CLSC methodologies in industry. After this review, the thesis will then proceed to detail the categorizations by which the research will be conducted. In the case for consumer electronics companies, the investigation will be trifurcated into three different avenues:

1) Utilize the original equipment manufacturer's (OEM) established or partnered CLSC channels to return the product through trade in or recycling programs.

2) Seek government affiliated organizations or third-party electronics recycling companies to reclaim valuable metallic materials, dispose of hazardous device components and eliminate digital information associated with the device.
3) Participate in the second-hand consumer marketplace by utilizing an e-commerce channel to sell pre-owned devices to prospective consumers, thereby extending the expected life of your device.

Most of the information concerning these three channels will come from existing published information from a set of selected consumer electronics industry-leading companies and third party organizations. For additional context that is not listed within each firm's supply chain informatics report, interviews can be conducted to garner increased visibility and insight into ongoing company practices and initiatives related to CLSC principles. The thesis will then conclude with a summary analysis of key trends to extrapolate an overall model of existing and developing CLSC practices within the consumer electronics industry. This overarching framework seeks to provide a cohesive visibility assessment through the perspectives of strengths, weaknesses, opportunities, threats towards sustainable circularity development and adoption.

Chapter 2

Background

To understand the importance and relevance of the development of closed loop methodologies within the supply chain industry, a brief aside documenting the contextualization, adoption and continued growth of environmental, social and governance (ESG) investing practices must be conducted. In addition to assessing a corporation's overall state using traditional financial analysis metrics on the various products and services offered to consumers, in 2004, United Nations Secretary General Kofi Annan advocated for CEOs of major financial institutions to incorporate environmental, social and governance factors within their standard business practices to lead to "more sustainable markets and better outcomes for societies". (Kell, 2022) Though initially taken aback due to the negative effect embracing this ideology would have on the maximization of shareholder value, over time, as increasing numbers of companies started to embrace these principles and be rewarded for their efforts by outperforming less sustainable and socially responsible competitors, ESG investment has been proven to net positive financial performance, showcasing an area of fiduciary importance for shareholders and consumers alike. It is through this link that corporations now have sufficient divisions and analysts at work measuring and improving upon climate change metrics, corporate cultures that foster trust and innovative practices, and, most importantly to this thesis, supply chain sustainability metrics spanning across all aspects of the inherent value chain.

When applied to supply chain, ESG investment can encompass the entire scope of operations. As the backbone of the company, supply networks both serve as uncontrollable risks and areas of opportunity when it comes to the implementation of sustainability efforts. It is imperative for procurement and sourcing officials to have near-complete insight to as many

supplier tiers as possible while also sharing ESG metric guidelines downstream and upstream (“ESG and the Global Supply Chain”, 2022). These efforts can be further improved through the explicit generation of sustainability frameworks within the overall contracting and negotiations process of vendor onboarding. From a manufacturing standpoint, perhaps the most popular internal decision stems from the “make or buy” decision, in which the overall business network can either become more complex in scope, usually with lessened unit costs, or more concentrated among key resources such as business headquarters and local suppliers, which could elicit better quality assurance practices and efficient product lines. Within either scenario, ensuring that proper ESG key performance indicators documenting manufacturing waste, operational greenhouse gas emission, non-renewable energy consumption, renewable energy consumption, water usage, and environmental impact can help provide the baseline data for value driven sustainability analysis (“Sustainable Supply Chain KPIs”, 2016). In a similar manner, carbon footprint analyses can also be conducted for each companies’ distribution network, with potential scopes extending to the Nth tier supplier, barring resource constrictions.

One area that is extraordinarily complex lies in the process of conducting reverse flows from the consumer towards the original equipment manufacturer (OEM). In addition to the base physical challenges of implementing a returns management system with adequate capacity to sustain returns or faulty goods, flow through rate flexibility and increased labor to manage reverse modalities, a company would also have to institute quality assurance and verification processes to determine whether to fix a product on site, send it to a partnered facility for repair, repackage the product after refurbishing, or decide to scrap or recycle it on a cost-effective basis (Natarajan, 2022). With the growth of e-tail and increasing outlets for business to consumer marketplaces, new generations of consumers have come to expect stores to not only market a

flawless product supported with adequate quality and seamless delivery, but also have exceptional customer service channels that can easily process reverse flows (Natarajan, 2022).

The closed loop supply chain schema combines both the practices of reverse loop integration alongside tenants of ESG and sustainability. To preserve the finite number of natural resources, reduce the quantity of waste generated as byproduct of operations, and to increase the significance of circularity as a business model, a closed loop supply chain, in practice, relies on two tenants: a collection of all output products of the production system that have reached end-of-life usage and the organization of forward and reverse material flowthrough processes to encourage reuse of collected materials while utilizing recycled materials ("How Creating a Closed-Loop Supply Chain can Make Businesses Greener", 2022). As of 2021, the global economy is only estimated to be 8.6% circular, with growing opportunities to reduce the amount of virgin minerals, fossil fuels, rare earth metals, biomass and other resources that serve as the collective impetus for economic growth (Steinberg et al., 2021). There are a plethora of initiatives that could usher in a cultural zeitgeist of supply chain circularity adoption, but all of them are at various stages of development. Providing value added product packaging that fosters reuse over disposal, instituting incentive-driven take-back programs to corporate partners or OEMs for resource collection and reincorporating recycled materials into products are just a few of the most common plans for implementing sustainable closed loop theory into real-life business applications (Steinberg et al., 2021).

In no other business sphere is this transition be more apparent than within the consumer electronics industry. From a business stakeholder standpoint, the steady accumulation of e-waste that occurs because of consumer devices reaching a "perceived" end-of-life status poses a multitude of risks to human health, environmental conservation, energy usage, and resource

waste. The United Nations estimates that electronic waste is projected to reach 120 million tons by 2050, and this compounding issue both serves as a collective danger and potential impetus for closed loop methodologies to proliferate the means and opportunities for recycling, refurbishment and repairing (Tam, 2021). The current systems for e-waste management have provided an adequate starting baseline for continual innovation and progress. For example, the World Health Organization estimates that 17.4% of electronic waste is recycled properly and in a responsible manner; However, the quantitative evaluation does not capture the entire picture. The other 82.6% of electronic waste is often illegally transferred to low and middle-income countries, an act that further diminishes the health of developing nations by exposing their populations to the toxic materials found within e-waste ("Growing Threat of E-Waste Affecting Millions of Children Worldwide", 2021). It is only through properly managed and partnered organizations that we seek to conserve and recycle resources without sacrificing the safety of workers. Espousing these sentiments in mind, industry leaders must continue to build, test, and revise existing methodologies to include useful and standardized circularity indicators to measure progression towards closed loop attenuation, while also working alongside external stakeholders to foster increased interactions of recycling and refurbishment offerings to extend device life through reincorporation and remanufacturing.

Chapter 3

Methodology

The foundation behind the research presented within this thesis consists of drawing consistent information from as many primary accounts as possible. In terms of structurization, a brief preliminary contextualization is included to highlight the evolutionary innovations of the consumer electronics industry, as well as a definition of what constitutes a consumer electronic device within the realms of this academic paper. Utilizing this highlighted encapsulation of industry reality, the analysis then stems into branching categorizations that serve to represent both micro and macro level depiction of the options presented to consumers when a device has reached its EOL stage of wear.

The initial concentration of analysis focuses on an insular summary of the top earning electronics corporations based upon what type of good(s) each company markets. Most notably, the profiled investigations are not only centralized on what options are available from a consumer sustainability perspective – of which most are predicted to have some varied trade in or refurbishment program – but also of internal practices and initiatives when it comes to any development on closed loop methodology implementation or testing. Some firm choices will be self-evident given the inherent product scope, such as Apple., Microsoft and Dell, however, our definitions for consumer electronic products will also extend to include products from companies such as Nvidia, Amazon and Sony, in addition to others not mentioned in this section. The entire selection is meant to serve as the best proxy for the entirety of the consumer electronics industry. Much of the information retrieved will be garnered through traditional web scraping for program data directly available for consumers on online platforms, as well as through annual

sustainability report publications that illustrate the yearly highlights of what each company has achieved.

The following section of research serves to analyze the efficacy and effectiveness of external device recycling and e-waste management organizations. While some of these companies have and maintain partnerships with globally established consumer electronics firms to run some aspects of their recycling programs, others seek to capitalize on the backend of the fast-growing electronics industry by processing and handling the resulting amounts of e-waste production. The continued work of firms such as Tetronics and Aurubis – which are based in Europe – as well as North American recycling firms – Sims Metal Management, Electronic Recyclers International and Global Electric Electronic Processing – demonstrate the growth of an emerging e-waste management market ("Top 10 companies in E-Waste Management"). Most of the analysis for these external recycling companies centers on both the availability and scope of their services, as well highlighting specific relationships. These firms can establish better relations with electronics companies and relative consumers to elicit more refurbishment and recycling services, in due part serving as an entryway for extending product EOL or as another endpoint for obsolete devices.

Similar in analytical content but in another area of expertise, another component of review lies in researching governmental resources for consumer electronics recycling. Whether divided based upon state or borough regulations, an aside is warranted due to the presentation of information that provide another avenue for processing obsolete devices. Key portions of this section include understanding the detail and scope variances of differing governmental programs to effectively handle a population's accumulation of e-waste, whether it is through materials processing, community donation or other unlisted methods.

The penultimate section of analysis seeks to deviate from the previously mentioned consumer to business or consumer to third party interactions. It focuses on the acts of reselling older consumer electronics through external marketplace platforms such as eBay, Facebook Marketplace or Mercari. This exchange has grown to be increasingly popular in comparison to purchasing devices at traditional retail stores or upgrading through mobile carriers, and it also provides an extension of device life through being sold to another interested party. Unlike the other strategies of refurbishment, repair and recycling, however, the extension of EOL seems like a temporary solution, as once the party has reached full usage for a second-hand device, there remains the decision on how to properly handle the product when it ultimately reaches EOL, regardless of how many resales occur.

The conclusion of this research involves the determination of observed trends and relationships between the four sections discussed in relation to achieving industrial closed loop practices and sustainable dealings for engaging consumers to participate in these established systems. Additionally, highlighted findings will serve as an outline to draft key recommendations on how the consumer electronics industry must adapt to address increasing amounts of device e-waste and usher in closed loop sustainability practices to continually innovate to address ESG business principles.

Chapter 4

Analysis

To effectively delve into this paper's proposed method of analysis, clear insights as to what constitutes consumer electronics is necessary to define research scope. Smartphone ownership has arguably demonstrated the most drastic growth in the past decade, as it is estimated that eighty-five percent of United States adults had the device in 2021 ("Mobile Fact Sheet", 2022). Laptop computers follow at levels around seventy-seven percent, while handheld tablets are utilized by roughly fifty-three percent of the US adult population ("Mobile Fact Sheet", 2022). An even more recent development, wearable technology, showcased through the popular adoption of smartwatches, with consumers captivated by monitoring personal health and fitness in addition to their other notifications. These devices could be found on roughly twenty percent of Americans in 2020 (Vogels, 2020). In addition to these popular devices, traditional staples such as game consoles, televisions, and cameras will also be included in the scope of analysis.

While the core consumer electronics products are listed in the above section, there are additional items that have inherent value in researching using the proposed methodology. For example, ancillary equipment such as computer monitors, printers, headsets and keyboards all serve to improve or heighten user accessibility or performance with existing devices. Furthermore, given the current trends of consumers seeking to custom construct personal computers through the acquisition of a central processing unit (CPU), graphics processing unit (GPU), motherboard, memory, storage, power supply unit, system cooling unit and operating system, this paper includes additional highlights on these items as well ("How to Build a Gaming PC", 2023). Consumer trends continue to emphasize customizability as a heightened value per

dollar, and with a variety of video resources and guides easily accessible online, it is projected that there is a market of 1.8 billion gamers who prefer personal computers as their way to play (Thimangu, 2021). As a result of this growing interest, companies specializing in providing unparalleled CPU and GPU hardware have sustained immense sales in recent years. However, with every technological innovation that receives widespread adoption, key stakeholders must also ensure that there will be established programs and measures in place to handle the projected future e-waste figures.

Proposed Analysis Structure

The analytic structure this paper seeks to establish when evaluating electronics industry leaders centralizes on three key criteria regarding internal closed loop principles. These three highlights are listed as follows:

1) Company Practices
    a. What leading strategies outline the company in question's closed loop supply chain practices? What circularity measures have already been established, and what initiatives are they currently seeking to implement?
2) Industry Leading Innovations
    a. Has the firm published any industry-wide recommendations for various companies to pursue to achieve broader circularity practices to combat the growing estimates of e-waste generation?
3) Overall Assessment

a. How robust is the company's overall sentiments regarding the adherence of innovation through the establishment of continuous closed loop sustainable methodologies?

Apple Inc.

Apple's brand is ubiquitously renowned for the manufacturing, marketing and selling of personal devices and lifestyle services. In addition to flagship luxury products such as iPhones, Macs, iPads, iWatches and other accessories, the firm also provides streaming services through Apple TV, cashless payment services through Apple Pay and device support services through Apple Care ("Apple Inc. Company Profile & Facts", 2021). Most consumers associate Apple devices with a uniquely innovative yet simplistic user experience (Moorman, 2022). While this value proposition accounts for a majority of the brand's global popularity, these sentiments are heavily supported by regional sales data. For example, within the United States, Apple's percentage hold of the smartphone market share is roughly thirty-four percent ("Mobile Consumer Survey", 2019).

1) Being an innovative, market-leading firm within the electronics industry, Apple has successfully outlined, executed and achieved many an initiative that demonstrate the importance of sustainable circularity within the company's value chain. From a collective view, Apple's emphasis on heightening product durability, maintaining exclusive trade in programs for refurbishment and recycling, utilizing robotic process automation for product disassembly and conducting yearly recycler audits for waste diversion KPIs all serve as evidence for the

company's understanding of robust reverse logistics flow, resource collection, and materials management, key principles of closed loop methodology.

On the forefront of EOL modeling, prior to marketing a new electronic within the various product lines of Apple, the firm publishes forecasts of estimated carbon emissions, breakdowns of device material composition and coalesces both areas of data to publish an overall environmental impact report from make to use to recapture ("Environment", 2023). This documentation also highlights key tenants of product recyclability and durability, two intrinsic aspects of Apple devices. Conducted by an external third party, Apple's iPhone 14 display protects against scratches from objects that score up to level five on Mohs harness scale and boasts a strong structural integrity in terms of aluminum framing (Mogg, 2022). Furthermore, Apple's attitudes on the battery, a component that is responsible for sustaining devices until EOL, are showcased through the extension of the firm's Battery Exchange Program, in which consumers can rejuvenate their current devices through purchasing a new device battery and installation service for $80-$250, depending on the device in question.

In addition to innate product durability and battery replacement, Apple has reacted to the ongoing developments of right to repair movements within the tech industry, as the company continues to expand restoration options, such as having the broken device mailed to a service center or actively sending a repair kit to educated consumers. This self-service or opt in option, when combined with existing repair, trade in, refurbishment and recycling services that the company traditionally offers, covers most all bases for customers who wish to extend the lifetime of their electronic devices. The latter bundle of collection methods can be found in ninety-nine percent of the countries where Apple products are sold, with established trade in initiatives available across twenty-five countries ("Environment", 2023). Often, eligible devices for trade in

can be redeemed for in store credit or digital gift cards, while most all Apple accessories and devices may be recycled free of charge (“Environment”, 2023). The company provides an updated table of devices and their corresponding trade in values for consumers to reference, and for any necessary data backup and erasure, Apple has an easy step-by-step guide also available online (See Appendix A).

Apple consistently employs an innovative, forward-thinking mindset regarding the role that automation has in establishing circular sustainability principles. Perhaps the most notable expression of these attitudes is through the investment into robots named Daisy, Dave and Taz that perform quintessential return duties for product disassembly (“Environment”, 2023). Respectively, each robot handles the breakdown of iPhones, Taptic engines and rare earth magnets to retrieve valuable materials from previously owned devices (“Environmental Progress Report, 2022). With the aid of automation, Apple has continued to set and achieve comparable sustainability metrics, as well as showcase these achievements through the publishing of waste diversion KPI’s and initiatives. For example, key notes to highlight include that all of gold wiring, rare magnetic earth elements and tin solder within logic boards are created from completely recycled materials (“What to do before you sell, give away, or Trade in your iPhone or iPad”, 2022). Additionally, the company has replaced sourcing aluminum, one of the key elements in any electronic device, with a one hundred percent recycled alloy that still meets the hefty, qualitative demand for performance and durability that is associated with Apple branded products (“Environment”, 2023). Overall, it is estimated that upwards of ninety-eight to one hundred percent of Apple’s flagship device brands contain recycled earth elements (“Environmental Progress Report”, 2022). However, sustainability is not solely built into device production, as the firm has also established and achieved a seventy-five percent decrease of

virgin plastic use in packaging (“Environment”, 2023). The current goal the company plans to pursue is to eliminate any waste sent to landfills from corporate facilities and suppliers, an initiative that is sustained through the continual usage of recycler audits on a global scale, with each site attaining e-Stewards or R2 certifications “(Environmental Progress Report”, 2022). The collective view and implementation Apple has set in place for circularity entails clear and coherent understanding of the need to recycle and reuse.

2) In terms of industry-wide supply chain environmental stewardship, Apple takes time to first reframe the situation by addressing five prevalent challenges the companies must seek to address and overcome. These are listed as follows: sourcing transparency, scale of investment needed to establish recycler sites, recycled material quality and risk of contamination, availability and access to reputable third-party recycler sites and regulatory barriers limiting supply chain visibility (“Environment”, 2023). While other firms may attempt to tackle the first three themes internally through the creation and adherence of a company specific circularity program – stipulating sourcing guidelines, innovation program budgets and qualitative criteria and additional research and development efforts – the latter two affect the consumer electronics industry on a global level.

Apple proposes two specific solutions to address the last two issues outlined above. The first is to address global regulatory barriers through the ratification of the Basel Convention, a multinational environmental agreement to protect human health and the environment against adverse effects of hazardous wastes (“The Basel Convention at a Glance”, 2011). In doing so, the United States and the corporations residing within the nation would have a general, outlined precedent for recycling and disposal programs that can be executed in an environmentally responsible manner. Additionally, upon ratification, the United States would be privy to and have

direct influence on any matters regarding subsequent policy initiatives or amendments to the convention itself. To address the establishment of good company relationships with reputable recyclers, Apple suggests for companies to pursue relations on a global scale, often using a third-party nonprofit organization as an introductory liaison. Through partnerships with the International Organization for Standardization (ISO), The Conservation Fund and the Worldwide Wildlife Foundation (WWF), Apple has successfully propelled its sustainability initiatives to various countries within its recycle and collection channels ("Environmental Progress Report", 2022). A common theme amongst all partnerships is the fact that the company seeks to promote circularity practices through extensive site programs such as the Aluminum Stewardship Initiative and Platform for Accelerating the Circular Economy guideline ("Environmental Progress Report," 2022). In conjunction with the WWF, Apple has instituted an environmental program in China in which all parties seek to catalyze the foundations for responsible forestry practices to establish a relationship built on improving policy frameworks for resource management and establishing long term market incentives with the country as a future source of responsibly sourced paper materials ("Environmental Progress Report", 2022). Similar efforts, albeit on a conservation front, are also occurring simultaneously on a domestic basis, such as Apple's partnership with The Conservation Fund and The Working Forest Fund. This initiative seeks to purchase forests threatened by large scale fragmentation, revitalizing the land via sustainable growth, restoring wildlife and impacted habitats, developing a conservation easement to protect the land from future degradation and ultimately selling the now protected land on the open market to sustainable enthusiasts ("Environmental Progress Report", 2022).

3) Upon holistic assessment, Apple demonstrates industry-leading closed loop practices through a variety of programs and initiatives. Through exhaustive implementation of

environmental impact reports for each produced device, scorecard analysis for key recyclable materials, emphasis on product durability, easy to follow trade in, recycle and refurbish program, use of disassembly automation, conduct of annual recycler audits and industry wide recommendations that generates insights and holds influence on a global scope, the firm has successfully demonstrated its historical and continued commitment to implementing closed loop methodologies within its value chain.

Microsoft Corporation

Microsoft develops, licenses and supports software, services, devices and solutions on a global scale. The company is split into three segments: productivity and business processes, intelligent clouds and personal computing ("Microsoft Corporation Profile & Facts", 2023). When analyzing Microsoft's effect on the personal electronics marketplace, the firm directly advertises Windows operating licenses, surface laptops, PC accessories, tablets and entertainment consoles, in addition to the variety of suite software. Of this product variety, Microsoft nearly has a seventy-five percent share on the desktop operating system market through Windows 10 and 11 licenses (Downie, 2022). When viewing the company's hold on the mobile devices and tablets market, however, Microsoft is far less dominant as consumers favor leading brands such as Apple and Samsung.

1) Microsoft has outlined the roadmap for meeting circularity goals through key approaches. These include a focus on operations – primarily supply chain, campuses and data centers, transformational R&D and systems change – affecting global, policy, investment, research and corporate partnerships ("2021 Environmental Sustainability Report", 2021).

Additional objectives include the cutting of GHG emissions by over fifty percent across all components of the company's value chain, satisfying and maintaining LEED gold certifications for all campuses and data centers, eliminating all single use plastics by 2025, implementing recyclable packaging and additional recyclable product components by 2030, utilizing one hundred percent renewable energy for data centers and campus facilities, continuing the already allocated $571 million to the Microsoft Climate Innovation Fund to investigate R&D carbon neutral strategies and realizing a net zero carbon impact by 2050 ("2021 Environmental Sustainability Report", 2021). Focusing on completed sustainability metrics, Microsoft also highlights a forthright carbon removal purchase of 1.4 million metric tons, an emerging stratagem that can combat climate change and environmental degradation ("2021 Environmental Sustainability Report", 2021). In addition, through gradual expansion, the company has also opened circularity centers, company owned asset recollection sites that diverted over fifteen thousand metric tons of e-waste, across multiple countries with recent launches in Amsterdam and Virginia ("2021 Environmental Sustainability Report", 2021). The launch and sale of Microsoft Cloud for Sustainability, a data driven insights platform for businesses to monitory circularity across their own operations, is another unique method for the company to help other organizations undergo their own sustainability efforts. This technology is exactly what Microsoft utilizes with their own first and second tier suppliers, of which eighty-seven percent complied and reported carbon emissions data for Microsoft to include in their 2021 Sustainability Report ("2021 Environmental Sustainability Report", 2021).

Through establishing a universal trade-in and recycling program, Microsoft partners with Teladvance a leading provider of IT asset management solutions for businesses. On the company's trade-in website, there is an interactive trade-in calculator that indicates the value of

any customer device, regardless of if it is a Microsoft product or not ("Microsoft Trade in & Recycling Program", 2023). Shipping is prepaid by the company, and the interested customer would receive either a PayPal, bank transfer or in-store credit within two weeks of receipt, given the device is in eligible condition ("Microsoft Trade in & Recycling Program", 2023). Similarly, the Microsoft recycling program's website also has an interactive geographical filtering to determine any partnered local compliance recycling initiatives and programs ("End-of-life Management and Recycling", 2023). In addition to running an acclaimed trade-in and recycling program, Microsoft also upholds requirements for becoming a Microsoft Authorized Refurbisher (MAR). For third party individuals to repair products, several application criteria must be met, including data security and environmental industry certifications, an extensive global scope for receipt and shipment of devices, appropriate security measures to ensure safe storage, strong financial stability and credit history and specific value adds to the MAR sales channel through differentiation, additional form factor benefits or specialized services and solutions ("Microsoft Authorized Refurbishers Resource Center", 2023). As showcased through this application process, Microsoft prides itself on setting quality baselines for consumers to purchase up-to-standard secondhand devices, while also incentivizing a steady stream of refurbishment and recycling supplies through attractive trade in programs and recycling initiatives.

2) Microsoft leverages a vast array of partnerships when it comes to collaborative efforts on sustainability research and development, carbon reduction efforts and environmental restoration initiatives. From allocating a $100 million grant donation to Breakthrough Energy Catalyst in hopes of researching direct air capture, green hydrogen, long duration energy storage and sustainable aviation fuel to partnering with Rheaply, a startup that aids companies in adopting circular practices by illustrating the monetary savings from carbon emissions

reductions, Microsoft takes a leading stance when it comes to amassing support efforts from third parties (“2021 Environmental Sustainability Report”, 2021). Regarding additional contributions towards carbon footprint reductions, Microsoft is a member of the Global Logistics Emissions Council, which works towards developing solutions to accurately track scope three transportation emissions in their totality (“2021 Environmental Sustainability Report”, 2021). Furthermore, the company rewrites its Supplier Code of Conduct in partnership with ENGIE Impact, WSP and CDP Worldwide to help its suppliers adhere to sustainability requirements (“2021 Environmental Sustainability Report”, 2021). Microsoft also places value on partnerships that disseminate information concerning the value of circularity efforts, as demonstrated by the company’s role as partner for the Ellen MacArthur Foundation, an organization that allows individuals to learn more about the circular economy through digital platforms, workshops, courses, projects and events (“2021 Environmental Sustainability Report”, 2021). Another example is through the company’s participation in the Circular Electronics Partnership, in which experts, business leaders and international organizations, come together to co-design solutions and coordinate theory into practice to create a model for a viable and implementable circular economy (“2021 Environmental Sustainability Report”, 2021).

Perhaps one of the most important lessons that Microsoft has had experience with is the realization that each company’s journey to net zero emissions will not be a linear journey (See Appendix A). For the year of 2021, Microsoft’s scope three emissions increased by twenty-one percent due to the ramping up of electricity generation and construction production to meet increased device demand (“2021 Environmental Sustainability Report”, 2021). Different sources of emissions will have to be addressed and monitored based on different time frames, with notable discernment between scope one, two and three emissions. To wit, one industry

recommendation is for all leading companies to come together to collaborate with policy makers to standardize the definition of what net zero entails and apply a common unit of measurement for assessing sustainability impacts on climate change ("2021 Environmental Sustainability Report", 2021). Once established, Microsoft also recommends for its peers to invest in two specific areas of sustainability. The first is to explore carbon removal through direct purchases and indirect R&D donations. The Intergovernmental Panel on Climate Change (IPCC) estimates that the planet requires ten gigatons of carbon dioxide removal by 2050, and carbon removal is one fruitful contributing factor not only to hit this criterion, but also to improve industry wide circularity efforts through continued ESG investments ("2021 Environmental Sustainability Report", 2021). Three key challenges to the growth of carbon removal practices are that high quality removal providers are scarce, purchased removals are not well accounted into current definitions of sustainability metrics of net zero and that the removal market is still developing, particularly for permanent carbon removal initiatives ("2021 Environmental Sustainability Report", 2021). Therefore, to supplement these uncertainties, Microsoft also recommends for corporations to switch to pursuing power purchase agreements over renewable energy certificates. The latter is not always a direct contract for new renewable energy generation, which can cause a delinking between energy production and consumption in both dimension of geography and time ("2021 Environmental Sustainability Report", 2021). Power purchase agreements do constitute a direct relationship between purchaser and supplier for the generation of new renewable energy via projects, providing greater investor confidence and net positive renewable energy creation ("2021 Environmental Sustainability Report", 2021).

Besides those two actionable recommendations, Microsoft also provides structural frameworks for sustainable industry and circularity implementation. For the former, the firm

emphasizes strategies such as setting the tone for sustainability at the top, not with regards to CSR, but through a shared ESG mindset, keeping up with the science, scaling strategies to the whole of the business – with key regard to the value chain – centralizing efforts by showcasing relevance to internal business groups, accelerating markets using innovation while protecting ecosystems and driving global progress through policy, being transparent when things are not always going well and holding every stakeholder to the same level of accountability through shared sustainability tracking metrics. With key focus on the last recommendation of accountability, Microsoft institutes a carbon fee of $15 per metric ton for business groups, has all operations undergo scorecarding measurements, sustainability commitments and progress reviews on a semiannual basis and convenes its Climate Council to engage business leaders from all divisions and drive sustainable alignments (“2021 Environmental Sustainability Report”, 2021). For additional improvements to company-wide circularity, equity and economy must be equally important themes of corporate strategy, zero waste roadmaps need to be adaptable to all levels of visibility, directly involving upstream procurement activities, downstream manufacturing, packing and shipping, and best practice sharing across all networks (“2021 Environmental Sustainability Report”, 2021). Additionally, having a core system to monitor quality reintegration flows help optimize the usability of collected metrics over time (“2021 Environmental Sustainability Report”, 2021).

3) Microsoft practices a balanced approach when it comes to both internal and collaborative sustainability operations. With high levels of supplier sustainability engagement, dedicated budgeting for research and development into finding differing strategies to employ to reach net zero emissions, advocation for carbon metric standardization and collaboration with third party NGOs, organizations, charities and other companies, Microsoft demonstrates leading

principles of circularity, not only for the company itself, but also for the overall expansion within the industry. The company's continued commitment to reducing scope three emissions and, most notably, the recognition that each organization's sustainability journey may not follow a linear path on an annual basis is incredibly poignant, to increase transparency with stakeholders and key consumer groups.

Sony Corporation

Sony is a privately owned company that engages in the development, design, manufacture and sale of electronics, game consoles and other devices ("Sony Company Overview & News", 2023). In terms of product assortment, Sony primarily focuses on marketing TVs, headphones, cameras and lenses, sound systems, portable speakers and smartphones to consumers ("Featured Products", 2023). Like most leading firms within the electronics industry, Sony promotes and sustains a brand identity of quality and design perfection in all its devices. Having been established in 1995, the company has demonstrated its capacity to innovate and adapt to changing external market effects and demographics over time to consolidate and remain one of the electronics industry's most prominent ESG leaders ("Establishing the Sony Brand", 2023).

1) Many of Sony's sustainability initiatives are outlined within the company's overall Road to Zero initiative (See Appendix A). This program stipulates that Sony seeks to achieve a net zero environmental footprint throughout its business activities and product lifecycles by 2040 ("Road to Zero", 2023). This is to be achieved through dedicated engagement of four perspectives and six product life cycle stages, climate change, resource conservation,

biodiversity promotion and chemical substance control and planning and end design, operations, procurement, logistics, take back and recycling and innovation, respectively (“Road to Zero”, 2023). Within the differing product life cycle stages, Sony places emphasis on taking into account environmental principles when it comes to the design process of its products, forecasting and achieving global targets for waste KPI reductions across their value chain, establishing supplier partnerships that fixate on adopting sustainability efforts, utilizing freight transport with smaller packing materials to heighten loading efficiencies to reduce overall emissions per product, partnering with local recycling stations to facilitate the take back of EOL products and strengthening strategic insights and technological innovations to find new, effective strategies to reduce the company’s global environmental impact (“Road to Zero”, 2023).

In addition to this principled strategic framework, Sony also heralds another initiative through Green Management 2025. Initially established in 2010, this program serves as a checkpoint for Sony’s Road to Zero program by highlighting key goals and metrics that should be achieved midway to 2040 (“Green Management 2025”, 2023). Supported by three key pillars of improving product resource efficiency, expanding renewable energy usage in operations and enhancing supply chain engagement of sustainability principles, Green Management 2025 espouses a robust structural framework that guides Sony’s collective sustainability efforts (“Green Management 2025”, 2023). Key recognitions under this platform include a one hundred percent reduction of plastic packaging in small products, a less than one percent landfill rate across all Sony operations and the improvement of one point five times recycling efficiency of tantalum, a valuable rare earth metal that can be reconstituted into new products (“Green Management 2025”, 2023). Furthermore, through innovative research and development, Sony has designed SORPLAS, a flame retardant, virgin plastic substitute that is created from used

water bottles and waste optical discs (“Sorplas”, 2023). This resource is not only marketed to other businesses as a substitute input for plastics during the manufacturing process, but also it has been integrated into Sony’s own product line, as it is a component material in the popular BRAVIA TV and Sony Soundbar (“Sony Sustainability in BRAVIA TVs”, 2022). In terms of renewable energy utilization, roughly thirty-five percent of Sony facilities across Japan, Europe and North America employ stable renewable electricity usage, either through direct purchases, certificate contracts or on-site solar operations (“Sony Environment”, 2023). Of all facilities, the Sony UK Technology Center and Sony Pictures Entertainment Headquarters in California are two examples that run on one hundred percent renewable energy (“Sony Environment”, 2023). In terms of future initiatives, the company is seeking additional sustainability collaboration with its suppliers and manufacturers through the implementation of third-party evaluations and the structurization of an incentivized Sony Green Partner System that would reward value chain partners for circularity commitments (“Sony Environment”, 2023).

Unlike most electronics companies, Sony does not offer a direct trade in program for purchased consumer devices. However, in place of that is a far more robust recycling and take back initiative that Sony has cultivated and developed alongside its partner, Electronic Recycling & IT Asset Disposition (ERI). Through the Sony ERI Take Back and Recycling website, end users can find the nearest recycling station by entering their product of choice and zip code. Sony has effectively invested into this partnership, as their recycling program holds NAID, AAA, R2 and e-Stewards certifications, ensuring the highest level of data sanitization and environmentally responsible recycling practices, substantiated through periodic quality control auditing across eight facilities (“Sony ERI Take Back Program”, 2023).

2) Sony has a history of industry collaboration when it comes to implementing and improving sustainability efforts. To begin, the company itself was a founding member of the Responsible Business Alliance, one of the world's largest industry coalitions dedicated to the advancement of corporate social responsibility within corporate supply chains ("Responsible Business Alliance", 2023). Additionally, Sony's co-founder, Akio Morita, served as the first chairman for Japan's Council for Better Corporate Citizenship ("Sony 2022 Sustainability Report", 2022). Sony places exceptional value on partnering with top tier sustainability and recycling firms, as seen in the firm's relationship with the Green Cycle Corporation, an external firm that provides tailored expertise in helping Sony to incorporate automated disassembly for easier recycling of EOL products ("Sony 2022 Sustainability Report", 2022). Another unique aspect of Sony's contribution to industry sustainability is through its licensing of Triporous material, a product derived from Japanese rice husks, as a fuel alternative that produces drastically less air pollutants and filtration resource for cleaning to other businesses ("Sony 2022 Sustainability Report", 2022). Sony also continues to invest in sustainable practices via the Sony Innovation Fund, a venture capital group that seeks to address environmental ecosystem rejuvenation ("Sony 2022 Sustainability Report", 2022). While these initiatives clearly showcase Sony's commitment to furthering circularity through partnerships and B2B collaborations, there has not been as much published discussion as to any supply chain specific recommendations that could help further the narrative of circularity within the electronics industry.

3) Upon collective review, Sony demonstrates clear commitments to furthering sustainability efforts by continuing to invest and implement circularity initiatives within the scope of company operations. The firm's Road to Zero and Green Management 2025 programs both provide key value frameworks that seek to reduce operations emissions, invest in

environmental biodiversity and perfect take back and recycling initiatives. On an industry-wide level, Sony's aptitude for cultivating and maintaining relationships with key sustainability partners is its most notable contribution. As for a recommendation, Sony should continue to research and develop specific supply chain circularity implementations that can hopefully provide value added insight to the broader consumer electronic industry as the firm continues its sustainability journey.

Nintendo Co., LTD

Nintendo engages in the development, manufacture, and sale of digital entertainment consoles, software and hardware. Most notably, the company specializes in the marketing of various handheld and household consoles, such as the GameCube, Nintendo Wii, Nintendo DS, Nintendo 3DS and Nintendo Switch ("Nintendo Company Overview & News", 2023). While these physical devices comprise most of Nintendo's tangible assets, the most value-added component of the company's worldwide success lies in the widely popular and unique number of video game franchises. Classics such as Pokémon, Mario, Zelda, Kirby, Metroid, Pikmin, Animal Crossing and Super Smash Bros. have all stood the test of time, joining newer additions like Fire Emblem, Xenoblade Chronicles and Splatoon. Nintendo's sustainability through continual innovation of its intellectual property coalesces into a key brand identity that in turn cultivates an intergenerational consumer base that provides long-lasting competitive advantages in an industry that is dominated by performance powerhouses such as Sony's PlayStation or Microsoft's Xbox.

1) Nintendo provides a highlighted summary of its ESG profile through publication of five key sustainability tenants that guide overall operations. To begin, the company places heavy focus on product design, ensuring not only continual innovation through energy efficiency improvements for all its flagship consoles, but also through the reduction of composite materials to improve the ease of device disassembly ("Nintendo CSR Report 2021", 2021). For the updated models of the company's popular Nintendo Switch consoles, battery life has been extended from two to six hours per full charge in handheld mode to an average of four to nine hours depending on the software being run ("Nintendo CSR Report 2021", 2021). Two additional initiatives that fall under this categorization include the labelling of products with constituent or synthetic materials for easy recycling identification and the expanding usage of procuring resource conserving materials to manufacture products with second-hand inputs ("Nintendo CSR Report 2021", 2021).

Following from design, another valued area for sustainability initiatives lies in the activities of procurement and production. Nintendo espouses a "Green Procurement" policy that zeroes in on balancing energy, resource and environmental ("CSR Information: Environment", 2023). To support this, Nintendo has also published a corporate sustainability procurement model that the company requires all its suppliers to adhere to. First tier suppliers must directly communicate with Nintendo's procurement division through business status surveys, factory status surveys, and responsible mineral procurement surveys, which address corporate social responsibility, employee discrimination and compliance with Nintendo's Responsible Mineral Procurement policy ("CSR Information: Procurement", 2023). Additionally, suppliers must allow for the regular annual enforcement of third-party audits and factory verifications, in addition to enhanced communication to second and third tier suppliers to create a branching

network culture of continuous improvement (“Nintendo CSR Report 2021”, 2021). The next focus lies in transportation methodologies, in which Nintendo addresses the reduction of overall company carbon emissions by leveraging both European and North American railroads, only shipping product with full truckload capacities in these regions, a feat that is consolidated by a world class IT system that handles the company’s outbound shipments (“Nintendo CSR Report 2021”, 2021).

The last two competencies encompass the traditional closed loop practices of product repair support and recycling channeling. In addition to the Nintendo Service Center located in Japan, there are multiple physical regional repair sites in other major countries (“Nintendo CSR Report 2021”, 2021). For consumers and any external third-party repairs, Nintendo also publishes a reference page of actions to prevent any internal damage to console systems (“Nintendo CSR Report 2021”, 2021). For U.S. and Canada customers, Nintendo offers a take back program for any video game consoles and accessories in which the company will supply postage, direct instructions to R2 certified recycling sites, and fully recycle packaging options for customer shipping (“Nintendo CSR Report 2021”, 2021). For Japanese consumers, Nintendo heavily abides by and advocates for the Small Electronic Appliance Act to promote the proper recycling of any small electronic appliances, and in Australia, the company also offers free recycling collection at various repair and service centers (“CSR Information: Environment”, 2023). Through tandem efforts, Nintendo recycled one and a half tons of materials consisting of seven thousand electronic items in 2021 (“CSR Information: Environment”, 2023).

Nintendo also holds environmental considerations within its corporate office spaces, with multiple initiatives on energy conservation. For example, within Nintendo’s Development Center located in Kyoto, the facility is designed to incorporate high energy efficiency, solar and wind

power generation and rainwater system reuse (“CSR Information: Environment”, 2023). Similar sites in Germany and Spain have achieved similar performance levels, with Nintendo’s Ibérica site achieving a twenty-five percent energy reduction in consumption in 2021, whilst also achieving a platinum certification for facility sustainability from LEED (“CSR Information: Environment”, 2023).

2) While Nintendo’s scope of presence within the broader electronics industry may be smaller than other tech companies that cast a wide net when it comes to consumer device adoption, Nintendo actively leads and pushes for the evolution and continual implementation of closed loop practices. As a member of the Responsible Business Alliance, Nintendo upholds all the recommended sustainability practices, with particular emphasis on aspects of information sharing and supply chain visibility concerning corporate social responsibility. On a more specialized basis, Nintendo also upholds the Games Console Voluntary Agreement within the European Market, alongside Sony and Microsoft. This pact to reduce the cumulative environmental impact of gaming consoles, from a manufacturing to disposal timeline, stresses the importance of innovation to achieve energy and resource savings in the design process without any compromise on performance and quality (“CSR Information: Environment”, 2023). Additionally, frequent collaboration and continuous dialogue between Nintendo, the other signatory companies, national governments and NGOs is built into the agreement to ensure that visibility for value-beyond-savings sustainability developments are easily accessible between all participating stakeholders (“CSR Information: Environment”, 2023). In terms of Nintendo’s commitment to responsible mineral sourcing, the company directly collaborates with the Responsible Minerals Assurance Process of the Responsible Minerals Initiative NGO and incorporates the Organization for Economic Cooperation and Development’s due diligence

guidance for conflict minerals into its procurement practices (“CSR Information: Procurement”, 2023). Specific target items such as tin, tantalum, gold, cobalt and other materials with complex history of human rights violations are incorporated with high scrutiny into basic supplier contracts (“CSR Information: Procurement”, 2023).

Nintendo depends on its Sustainability Committee and the global Green Teams to spearhead initiatives and disseminate knowledge, respectively, to manage internal operations while also establishing positive externalities through community-based, employee volunteering (“CSR Information: Environment”, 2023). When it comes to technology enabled insights, akin to leading companies within the consumer electronics space, Nintendo utilizes an ISO 14001 standard for environmental management systems coordination to fully balance social and economic stakeholder engagement (“CSR Information: Environment”, 2023). These technical competencies highlight key insights, whereas the overarching “Plan, Do, Check and Act” process improvement strategy illustrates the methodology for starting, completing and monitoring sustainability initiatives (“CSR Information: Environment”, 2023). Establishing new objectives and reviewing previous benchmarks, implementing decisions through resource conservation or product-related improvements, conducting performance evaluations through internal audits, external audits and other compliance metrics (“CSR Information: Environment”, 2023). A principal requirement for all key suppliers lies in data and information disclosure on an as needed basis. This collection of measures such as air and water usage, soil composition, resource consumption, waste generation and GHG emission aids in consolidating both overall sustainability company and industry strategies for additional focus areas for future improvements (“Nintendo CSR Procurement Guidelines”, 2021).

3) Nintendo has an established framework to develop, integrate and sustain sustainability initiatives and closed loop takeback programs. In comparison to the other analyzed companies, key distinctions can be found in the firm's ability to leverage efforts throughout its value chain, instilling masterful practices on downstream and upstream activities alike (See Appendix A). While the abilities and features for industry-wide collaboration differ slightly in comparison to more mainstream devices, Nintendo has cultivated many relationships with NGOs, governing bodies and console competitors in favor for bolstering sustainability innovations. As for a recommendation, Nintendo should consult both its internal Sustainability Committee alongside these external partners to establish a specific future date for when comprehensive developments into closed loop methodologies should be met and well-integrated within its global network. In addition to providing a future pinpoint in time to achieve a clear, consistent goal, this tactic would also indirectly center more of Nintendo's sustainability activities under a central pillar.

Advanced Micro Devices Inc.

Advanced Micro Devices (AMD) is a global semiconductor company that primarily operates across multiple market areas, specifically the Data Center, Client, Gaming and Embedded technology segments ("Advanced Micro Devices", 2023). The primary product offerings of the firm comprise of microprocessors and graphics processing units (GPUs) and system-on-chip products ("Advanced Micro Devices", 2023). Under the AMD brand, processors such as the AMD Ryzen, AMD Ryzen PRO, Ryzen Threadripper all constitute elite GPUs that provide high quality graphical computer processing for enhancing personal computer visuals and gaming experiences. OEMs, design manufacturers, cloud service providers, online and brick and mortar retailers and independent distributors constitute most

AMD's primary customers, of which overall demand has been heightened in the past decade because of the growth and adoption of home and cloud computing ("Advanced Micro Devices," 2023).

1) Environmental sustainability at AMD focuses on the notion that the consumer technology sector plays a critical role in maximizing product energy efficiencies and enabling innovation to aid in the reduction of GHG emissions ("Environmental Sustainability | AMD", 2022). Following these sentiments, the firm is committed to accelerating the transition to a sustainable, low carbon dependent economy through the support of three pillars: minimizing AMD's overall environmental impacts throughout its supply chain, advancing environmental performance efficiency for its consumers and innovating on collaborative solutions to address societal environmental challenges ("Environmental Sustainability | AMD", 2022). This guideline has allowed for firm-wide initiatives to minimize energy use, work alongside manufacturers to mitigate GHG emissions during production, optimizing system level efficiencies to produce the least amount of waste and sustaining fewer central computer servers while still allowing data centers to meet and exceed performance needs.

The central goal AMD seeks to fulfill is the reduction of GHG emissions for all firm operations by fifty percent for 2030 ("Environmental Sustainability | AMD", 2022). As of 2021, this mission is on a healthy track progression, as indicated by the twenty-five percent reduction in scope one and two emissions compared to 2020. On the energy efficiency front, AMD seeks to provide products and services that are thirty times as effective than current energy standards for all AMD processors and accelerators for high performance computing and AI training by 2025 ("Environmental Sustainability | AMD", 2022). This initiative has experienced steady improvements, as halfway through 2022 the firm achieved an estimated 6.8 percent increase in energy efficiency compared to 2020 standards ("Environmental Sustainability | AMD", 2022). For specific processor improvements, a thirty-one point seven times increase in performance per watt for mobile device processors has already been achieved in 2021 (See Appendix A). Additionally, AMD Ryzen processors deliver energy efficiency in laptops that correlate to a

forty-three percent higher power efficiency than Energy Star 8.0 requirements ("Environmental Sustainability | AMD", 2022).

Pivoting from product efficiency, as of 2021, AMD operates in thirty-five worldwide locations and offices. Utilizing the prior year as a base standard, in 2021 the company managed a thirteen percent reduction in energy consumption, twenty-five percent reduction in GHG emissions, fifty percent reduction in water usage and a fourteen percent reduction in waste generation – with an eighty-five percent% landfill diversion rate – across all the firm's owned offices ("Environmental Sustainability | AMD", 2022). Most notably, operations in China and India serve as highlights of sustainability. AMD's Shanghai R&D Center has relied on renewable energy sourcing since 2018, but as of 2021, sustainable energy options now cover one hundred percent of AMD operations in China ("Environmental Sustainability | AMD", 2022). In India, the firm has also taken efforts to source eleven thousand megawatt hours of wind and solar energy in 2021 to account for one hundred percent of electricity usage for its offices, in addition to collecting eight million liters of rainwater for facility operations and water conservation efforts ("Environmental Sustainability | AMD", 2022).

AMD values manufacturing partnerships that emphasize cooperation when it comes to jointly pursuing sustainability efforts. Built into the firm's core supplier contract is the stipulated requirement of annual Responsible Business Alliance (RBA) Validated Assessment Program Audits, of which forty-three were conducted across all of AMD's global operations ("Supply Chain Responsibility | AMD", 2022). The average audit score for all these suppliers was twenty-six percent higher (181.4/200) than companies' overall RBA averages (138.8/200) for the same year ("Responsible Minerals Sourcing | AMD", 2022). AMD Procurement and Corporate Responsibility Teams monitor reported metrics that include social and environmental commitment, RBA audit score performance, timely disclosure of nonconformance and environmental performance and closely collaborate with suppliers when nonconformance behavior is discovered or reported ("Supply Chain Responsibility | AMD", 2022).

2) The central outline for AMD's supply chain sustainability framework would be greatly hindered if it had not cultivated a multitude of relationships with many prospective stakeholder groups. AMD emphasizes engagement with industry peers, governmental regulators, civil society organizations and humanitarian groups to advance environmental sustainability efforts across its value chain ("Environmental Sustainability | AMD", 2022). Akin to other corporations, the firm embraces the practices of lifecycle management through engineering design to extend product life ("Environmental Sustainability | AMD", 2022). In addition to continually improving energy efficiency for GPUs and reducing GHG emissions for existing and new data centers, additional production for motherboards with backwards compatibility features that utilize previous generation processors ensures that previously used GPUs can be used in second-hand computing systems and be sold in the consumer-to-consumer marketplace ("Environmental Sustainability | AMD", 2022).

Another distinguishing methodology AMD employs is the direct mirroring of external advocacy group recommendations into the firm's supplier and manufacturing codes of conduct. For example, AMD has aligned the human rights policies portion of both guidelines with recommendations specified in the United Nations' Universal Declaration of Human Rights, OECD's Guidelines for Multinational Enterprises and the International Labor Organization's Declaration on Fundamental Principles and Rights and Work ("Supply Chain Responsibility | AMD", 2022). On the specific concerns of conflict minerals sourcing, AMD has instituted its own Responsible Minerals Sourcing Guideline based on the OECD's Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict Affected and High-Risk Areas ("Supply Chain Responsibility | AMD", 2022). Although the product offering of AMD is more specialized than those of other traditional consumer electronics companies, key recommendations the firm has adopted as a part of responsible sourcing remain universal. Establishing strong management systems that allow for transparency when it comes to identifying and assessing potential risks is crucial ("Responsible Minerals Sourcing | AMD", 2022). Furthermore, conducting annual assessments through third party auditing firms and reporting pertinent statistics to investors, consumers and the public is also a

must, both to highlight progress and potential challenges to remaining on track for firm-wide sustainability goals (“Responsible Minerals Sourcing | AMD”, 2022).

Being a consumer electronics company that provides state of the art graphical computing enablement, AMD has also actively contributed technology parts to many of the world’s most powerful supercomputers. One of these, LUMI, espouses an AMD processer that is powered by one hundred percent renewable energy to run projects focused on tracking climate modeling and weather irregularities (“Environmental Sustainability | AMD”, 2022). The Finland supercomputer produces waste heat that can power twenty percent of its local district’s heat, indirectly reducing the city’s carbon emission by twelve thousand metric tons on an annual basis (“Environmental Sustainability | AMD”, 2022). With AMD’s processor in its internal systems, LUMI touted the epithet of being “the most energy efficient supercomputer” and received the Best Sustainability Innovation in High Performance Computing Wire’s 2021 publication (“Environmental Sustainability | AMD”, 2022).

3) Despite AMD’s decision to market products that service a more niche demographic segment of the broader consumer electronics industry, the firm’s ability to realize competent sustainability initiatives matches and sometimes even exceeds the efforts of its peers. With clear proceedings on how to actively monitor sustainable sourcing practices, improve product and service efficiency and minimize environmental impacts across the entire value chain, AMD espouses an extremely robust structurization to allow for continual innovation and value beyond savings improvements. This framework is further supported by external stakeholders such as RBA auditing teams and NGO recommendations. Unlike previous companies discussed in this thesis, AMD does not offer a traditional take back and recycling program for most products. However, this is not due to a lack of aspiring to attain closed loop methodologies within the firm’s supply chain. In terms of computing hardware like motherboards and GPUs, these core parts constitute the fundamental backbone of personal computers. Consumers still derive value from old parts when purchasing a new upgrade or computer. It is incredibly feasible to construct a spare PC using older components, and another potential avenue for EOL extension is to sell

previously used component on the secondhand market. AMD's lack of an entirely closed loop supply chain presents itself as a strategic decision rather than a lack of innovation, as constructed flows for dealing with matured products already exist through consumer-to-consumer channels.

Third Party Recyclers – ERI

While the listed companies both have similar and unique initiatives when it comes to circularity and sustainability initiatives, to maximize the positive environmental externalities, it is imperative that ESG centric firms partner and interact with multiple key stakeholders. Of these external groups, third party recyclers and governmental entities have the most influence in contributing value-added knowledge to increase sustainability and recyclability practices while diminishing the growth of e-waste.

ERI is a global firm that falls within the former classification (See Appendix A). Having conducted a study regarding the composition of e-waste that is properly processed, the third-party recycler estimated that on a global scale, only fifteen to twenty percent is responsibly recycled, with the remaining eighty percent being directed to landfills, stockpiled in warehouses and homes or exported to developing countries that do not have the capacity to properly recapture recycled materials ("Electronics Recycling", 2022). In comparison, ERI maintains an annual capacity to repurpose up to a billion pounds of device materials, alongside a total of a million square feet of indoor, secured facility space with industrial length shredders and waste handling robotic tools to efficiently break down batteries, cellphones, copy machines, desktop computers, DVD players, keyboards, laptops, light bulbs, mice, monitors, network equipment, televisions, printers, fax machines, solar panels, stereo equipment and CRT TVs ("Products We Recycle", 2022). With nine facilities spanning across the United States and multiple partnered recyclers worldwide, ERI espouses top tier certifications from AAA NAID, E-Stewards, R2 Responsible Recycling, ISO 9001, ISO 14001, ISO 45001 and AICPA SOC 2 ("Electronics Recycling",

2022). Further adding to core circularity capabilities, ERI also cultivates strong relationships with downstream processors that repurpose recycled materials – plastic, metals and glass – through active management of its Downstream Vendor Management Program ("Electronics Recycling", 2022).

ERI's environmental impact data highlights the core competencies of external recyclers' specialization that directly satisfy company-outlined sustainability frameworks. Through coordinated efforts, ERI has received more than 125 million pounds of electronics, diverted 3.7 million pounds of landfill bound waste for component reuse, recycled 122.5 million pounds of waste and prevented 762 million pounds of carbon dioxide emissions in 2021 ("ERI Sustainability", 2018). In the same time span, automated yet detailed recovery machinery captured 14.1 million pounds of glass, 1.6 million pounds of battery component materials, 26 million pounds of plastics, 50.4 million pounds of metals and 17.5 million pounds of rare earth metals ("ERI Sustainability", 2018). Additionally, through offering consultative expertise for tailoring specialized solutions, ERI has also demonstrated its flexibility in providing customized services. For example, with one Fortune 500 client, ERI serviced twelve thousand company owned franchise locations by coordinating two hundred network optimized pickups, resulting in a collective recycling of over 36,000 IT assets ("ERI Fortune 500 Professional Services Case Study", 2017). Furthermore, this action cut the client's annual spending for IT asset disposition by fifty percent, from $400,000 to $200,000 ("ERI Fortune 500 Professional Services Case Study", 2017). ERI's ability to provide recycling, refurbishing and component disassembling, when coupled with tangible, efficient results, positions ERI, and many other third-party recyclers such as Stena Metal Group, Enviro-Hub Holdings, eLoop and Global Electric Electronic Processing, as must-have services for companies when it comes to outsourcing downstream circularity recapture collection to specialized third party recyclers.

Governmental Regulations

In addition to third party recyclers, governmental bodies are another key stakeholder when it comes to the introduction and implementation of broader circularity efforts. Policy makers and individuals within local, state and federal institutions have the capacity to pass legislation that dictates both the scope of sustainability efforts and the minimum requirements for compliance. Additionally, companies and other organizations are usually offered incentives such as tax benefits for the adherence to IT asset disposition and recycling guidelines.

While the federal level of policy jurisdiction can bring about the most impactful impetus for circularity efforts, there have not been any significant pushes for these sentiments in the past decade. Policy makers within the Environmental Protection Agency (EPA) outlined the National Strategy for Electronics Stewardship in 2011, which encompassed a list of strategies for the design of environmentally suitable electronics ("National Strategy for Electronics Stewardship", 2023). Within this outlined vision, key takeaways included principles of ensuring safe and effective management and handling of used electronics on a domestic front, while simultaneously reducing the amount of used electronics being exported to developing countries ("National Strategy for Electronics Stewardship", 2023). Additionally, the National Center for Electronics Recycling compiled all state regulations regarding electronics sustainability and developed an interactive map for consumers to consult if confusion arose ("National Strategy for Electronics Stewardship", 2023). After the finalization of this documentation, policy makers hosted an annual EPA Electronics Forum, which invited a cross-functional demography of stakeholders that included OEMs, retailers, trade associations, NGOs, recyclers, refurbishers, universities, governmental representatives and academic faculty ("National Strategy for Electronics Stewardship", 2023).

In terms of the current state of e-waste legislation, the United States has no federal laws that incriminate companies or other entities for not practicing e-waste recycling and sustainability efforts. Furthermore, as mentioned previously, the U.S. signed the Basel Convention, an international document

that controls the international movement of hazardous wastes since 1990. However, the country has not ratified the convention due to a domestic inability to implement the provisions within the convention ("Basel Convention on Hazardous Wastes", 2021). Recently, there have been efforts within Congress to push forth additional legislation concerning the impacts of e-waste, but a majority consensus hold the belief that tax incentives already provide a good of enough reason for organizations to implement sustainability efforts. Representative Espaillat Adriano of New York and Senator Whitehouse Sheldon of Rhode Island are two individuals who fall under the former categorization, as the duo have been advocating for the Secure E-Waste Export and Recycling Act ("Secure E-Waste Export and Recycling Act", 2022). This bill would redefine what e-waste constitutes and require standardized processes for exporting misprocessed e-waste, with reported metrics including the e-waste in question, quantity of e-waste, export destination and written confirmation of both buyer and seller ("Secure E-Waste Export and Recycling Act", 2022). As of 2022, this proposed legislation has been read twice to the Senate and has been referred to the Committees on Banking, Housing and Urban Affairs ("Secure E-Waste Export and Recycling Act", 2022).

As of 2023, twenty-five states, and the District of Columbia, have passed legislation regarding standards for electronics recycling, and all states within this grouping, barring California and Utah, utilize the Producer Responsibility approach in which manufacturers will cover all the costs of recycling ("State E-Waste Legislation in the U.S.", 2019). In addition, nineteen states and the District of Columbia have an express landfill or disposal ban on most electronics devices ("U.S. States with Landfill Bans", 2018). For Pennsylvania, the Electronics Recycling Covered Device Recycling Act requires manufacturers to provide recycling programs for computers, monitors, other computer peripherals and televisions sold in Pennsylvania ("Pennsylvania Electronics Recycling", 2023). While the state governmental device collection sites can be utilized by patrons and small businesses, companies and other large public entities must conduct their own sustainability initiatives to adhere to these requirements ("Pennsylvania Electronics Recycling", 2023). Furthermore, manufacturers must establish, manage and submit a plan that

encompasses device collection, transportation, and recycling to the Pennsylvania Department of Environmental Protection on an annual basis for compliance reviews (“Pennsylvania Electronics Recycling”, 2023).

Circularity in Secondhand Markets

Alongside the continuous development of supply chain circularity, from a downstream perspective, the recognition of “recommerce” as a term to describe the marketing and sale of previously owned goods has also begun to rise in popularity. Whereas the term used to have connotations of purchasing unreputable goods from reselling platforms like eBay and thrifting at discount outlets, consumers are now adopting a more nuanced mindset regarding these practices, particularly within the consumer electronics industry (Shah, 2022). While used devices are relatively easy to understand from a conceptual standpoint, refurbished devices typically fall under the same definition with a few caveats. Primarily, these types of secondhand goods were either sent back to the OEM or another third-party facility to repair any damaged components. These fixes seek to extend the life cycle of the original device, which is why most refurbished products are often coupled with warranties and price reductions of twenty to forty percent, relative to directly purchasing the same device new (Freyberg et al., 2022).

The refurbished mobile device market is estimated to encompass $140 billion by 2030. While there are a myriad of reasons for this evaluation, the most impactful can be attributed to the decreasing purchasing powers of consumer spend for consumer electronics, raw material and components price increases for devices, shifting consumer interests and demands for sustainable consumption and slowing product innovations for flagship models of devices (Freyberg et al., 2022). As options for device adoption increase, under a capitalistic model, consumers will gravitate towards offerings that yield them not the best quality or price, but personal utility. However, while sustained interest for secondhand and refurbished consumer electronics is growing, refurbishment practices work best for products that have

limited, replicable numbers of core components (Freyberg et al., 2022). These sentiments are further reflected in the most popularly marketed and sold refurbished offerings, which include smartphones, laptops, game consoles, televisions, tablets and smartwatches (Freyberg et al., 2022).

When it comes to the sale of secondhand electronic devices, sellers' actions typically fall into two channels: interactions with the consumer to consumer (C2C) marketplace or consumer to business, business to business and business to consumer (C2B, B2B, B2C) OEM or independent party (IP) stakeholders (Brunn, 2022). While this notion mainly pertains to the latter channel, the continual evolution of a secondary marketplace for electronic devices serves as the bridge portion of the bisection between economic viability and sustainable circularity practices, as it serves as a centralized node for active reverse materials flow. For IPs and OEMs, most products that cannot be repurposed for refurbishment will most likely be sent to accompanying disposal institutions to properly extract any valuable materials from devices and handle the accompany disposal of e-waste (Brunn, 2022). In investigating the key metrics sellers consider when selecting where to send their used devices, it should be noted that estimated personal utility increases based on higher compensation prices for secondhand devices, reduced lead times between the initial shipping and final payment and multiple online reviews commending the reputability of various OEMs and IPs (Noh et al., 2020).

While there are a multitude of online and physical channels for the sale and purchase of secondhand or refurbished electronic devices, a few prominent ones will be listed here to discuss the relative nature and ease of conducting a transaction. Decluttr self-defines itself as a "one-stop website to buy and sell refurbished technology," and the company promises prospective users that they will "make money, save money and help reduce e-waste." (Holly, 2023) The core advantage of the service includes an efficient bidding marketplace that allows the sale of all differing kinds of technology (Holly, 2023). Interested sellers solely need to enter details of their devices(model, condition, storage capacity, etc.) into a form, and after shipping it to Decluttr, users will receive payments via PayPal or banking direct deposit (Holly, 2023). Amazon Device Trade In operates on a similar model, with only a few alterations that

include free shipping for the device and a payment in the form of an Amazon eGift card credit that will be linked to the seller's Amazon account (Holly, 2023). In contrast to these two previous marketplace models for used devices, eBay espouses its own idiosyncrasies as a dedicated platform for third party buyers and sellers for almost any product imaginable. Since the marketplace is based on seller to buyer trust, verification for goods is not as foundational as other avenues since the seller has no obligation to send products to anyone other than the final buyer. Nonetheless, there are still classifications for refurbished, manufacturers refurbished and certified refurbished tags to differentiate between levels for increased consumer confidence (Holly, 2023). Furthermore, the increased feasibility of communication that comes from marketing and selling devices to a forum of interested consumers is a distinct competency of eBay, as individuals can message sellers with counteroffers and negotiations from anything regarding price flexibility and bids to shipping and authenticity clarifications (Holly, 2023).

Chapter 5

Conclusion

The Bureau of Economic Analysis estimates that Americans currently spend five times more on telephone and electronic equipment now compared to expenditures in 2010 (Semuels, 2019). As device adoption continued to manifest into a global standard alongside the growth of the digital interface of the internet, the consumer electronics industry has developed a hidden incentive to speed up the pace of technological obsolescence within their product offerings. While USB C, USB 4.0 and Thunderbolt 3 ports are the recommended universal standards for electronic devices, companies can design products with differing charging ports and laptop cables for each subsequent product generation as an attractive selling point to specified consumer bases (Semuels, 2019). In addition to hardware, electronic devices are subject to limited software update support, with obsolete products receiving little to no attention or continuity as companies continue to bolster flagship, new products (Semuels, 2019).

In response to these emerging trends, consumer electronics companies, governmental bodies, third party recyclers and consumers within the second-hand market, have all started to adopt unique mindsets and preferences when it comes to levels of sustainability associated alongside consistent consumption of these electronic devices. This thesis sought to provide a general state of circularity and ESG for relevant key stakeholders within the broader electronics sphere and disseminate specific insights to help progress sustainability efforts across industry as a whole. These summary insights have been derived from a combination of industry reports, consultancy assessments, governmental legislation and public market knowledge, and they are listed as follows:

Circularity efforts begin in the product design and manufacturing phases for any electronic device. Within both the conceptual and tangible generative processes, products that have a set list of

popular component materials, ease of assembly and recycled material usage will have a much easier time traversing through closed loop supply chains compared to other devices. Continued marketability of devices that espouse sustainability tenants through qualities such as power efficiency and resource conservation will strive to capture sustainably conscious customers as well. As products continue to move downstream, leading companies must realize the importance of collecting sustainability data to capture metrics concerning resource utilization and greenhouse gas emissions. Industry leaders must establish consistent standards regarding the breadth of carbon emissions, specifically on the notion if scope one, two and three emissions should all be required when reporting, in addition to adopting more direct definitions classifying key differences between each dimension. Regardless of year over year ESG performance, consolidating and releasing sustainability data through annual environmental progress reports is necessary to keep stakeholders aware of progress and wary of potential industry wide hindrances that pose threats to continuous improvement efforts. While leading electronics companies currently have instituted overarching sustainability goals that all fall under reaching net neutral emissions by 20XX, the primary sustainability initiatives are concerned on reducing operational dependencies on virgin materials and carbon-based fuels. However, as companies continue to excel in this manner, they will undoubtedly experience increasing diminishing returns as they masterfully reduce overall carbon emissions through renewable energy generation. Therefore, in addition to sustaining an operational based, reductionist mindset, firms also have opportunities to actively research and develop external carbon removal initiatives to collectively bypass the diminishing emissions yields over time through the employment of natural tree restoration, agricultural soil management, direct air capture and enhanced bioenergy capture (“Carbon Removal”, 2023). These efforts and recommendations must not occur in a vacuum, as electronics companies shall continue to work alongside peer leaders in addition to multiple stakeholder groups – like NGOs, charities and conservation foundations – to share, both successful and unsuccessful, strategies, circularity implementations and sustainability initiatives.

Third party recyclers play an quintessential, active role in providing specialized expertise in device breakdown and e-waste processing. Through continued services via partnerships with companies, governments and local communities, independent recyclers provide dual value-added contributions in extending the lifespan of used or broken devices and establishing circularity pathway inflows for devices to be repaired for refurbishment, disassembled for core materials or destroyed for component processing. Secondhand markets, akin to third party recyclers, also provide multi-stream avenues for refurbishment and device usability extensions. The monitored growth of continuing trusted and verified sales of pre-owned devices must be conducted in tandem with changing consumer patterns, as used devices provide verifiable similar performances at discounted prices, thus providing another attractive option for a sustainably conscious customer profile.

While governmental bodies have legislative power to enforce baseline requirements regarding e-waste processing, most regulation tends to focus on extending positive externalities to firms, universities and other large entities through tax incentives. However, all levels of bureaucracy can combat the growing amounts of e-waste that in turn bring about health, environmental and economical threats. In the federal sphere, establishing a cross functional sustainability team utilizing industry and departmental representatives to evaluate the ratification of multinational agreements on the handling of e-waste, such as the Basel Convention, is a necessary step to determine leadership guidelines on how all devices' EOL should be managed. At the state level, expediting standardization on e-waste exportation guidelines increases tracking visibility, both in terms of commerce and metric analysis. Within a local scope, governments should continue to provide netizens and small businesses with resources showcasing communal recycling centers and recommended third party companies for responsible digital asset disposition.

Appendix A

Accompanying Contextual Figures

Your device	Estimated trade-in value[1]
iPhone 13 Pro Max	Up to $650
iPhone 13 Pro	Up to $550
iPhone 13	Up to $450
iPhone 13 mini	Up to $380
iPhone 12 Pro Max	Up to $480
iPhone 12 Pro	Up to $400
iPhone 12	Up to $300
iPhone 12 mini	Up to $250
iPhone SE (2nd generation)	Up to $100
iPhone 11 Pro Max	Up to $330
iPhone 11 Pro	Up to $250
iPhone 11	Up to $200
iPhone XS Max	Up to $200
iPhone XS	Up to $160
iPhone XR	Up to $150
iPhone X	Up to $130
iPhone 8 Plus	Up to $100
iPhone 8	Up to $75
iPhone 7 Plus	Up to $60
iPhone 7	Up to $40

Figure 1: Apple Trade In

Figure 2: Microsoft Emissions Data

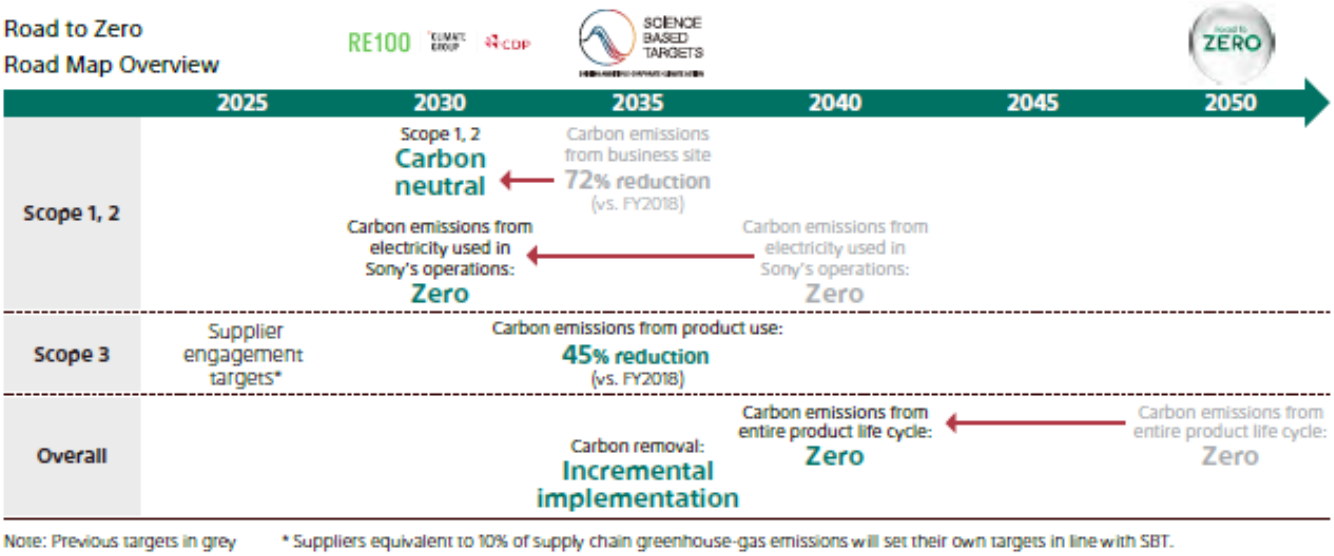

Figure 3: Sony Road to Zero Initiative

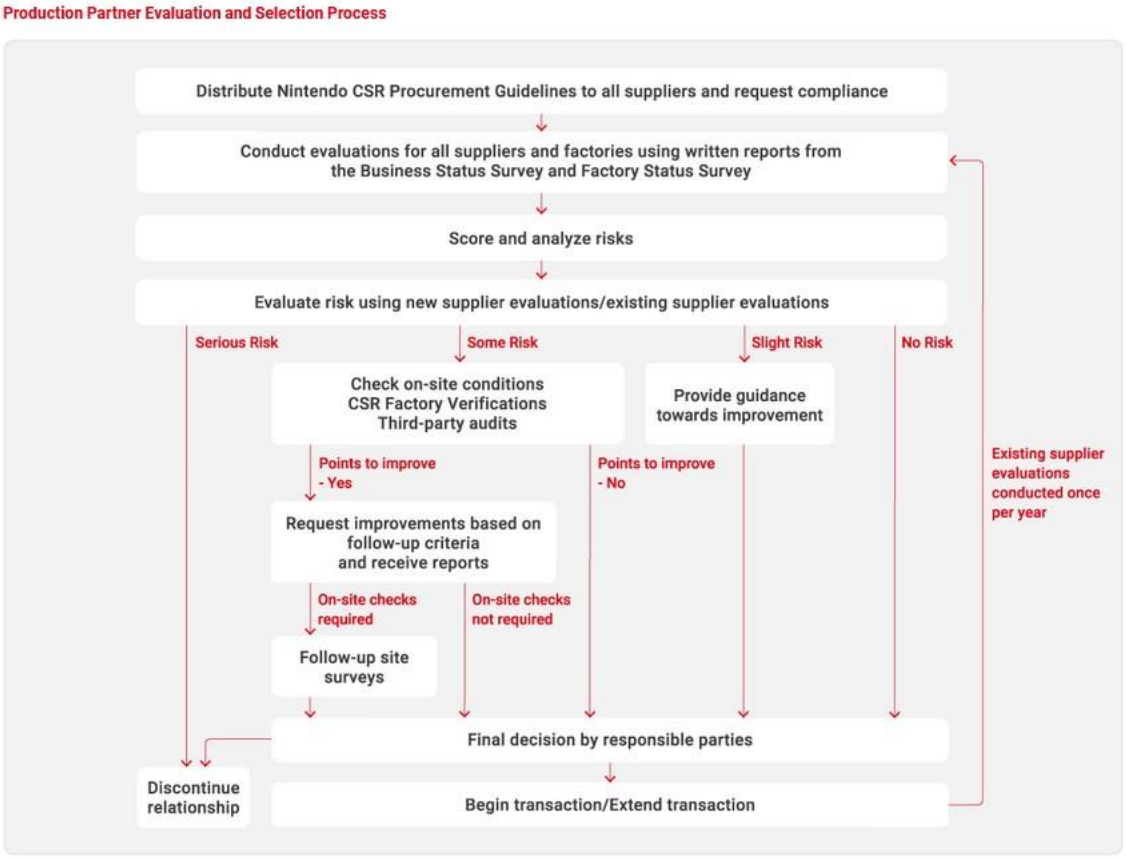

Figure 4: Nintendo Production Partner Evaluation and Selection Process Diagram

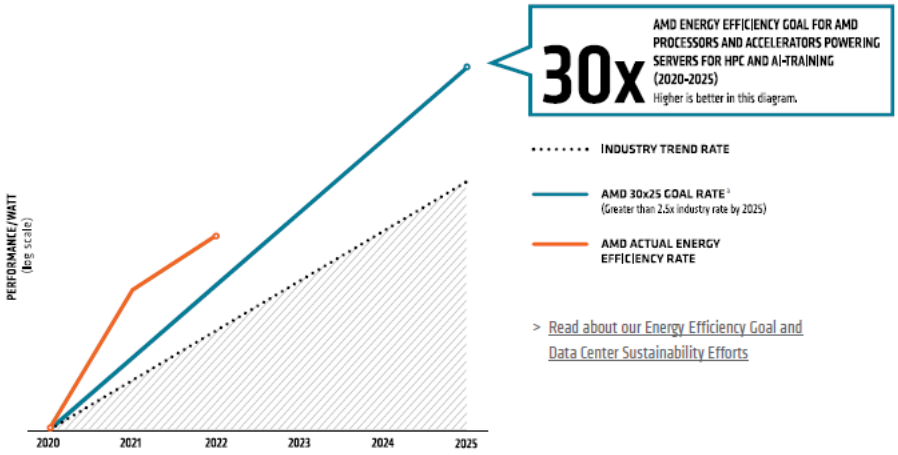

Figure 5: AMD Energy Efficiency

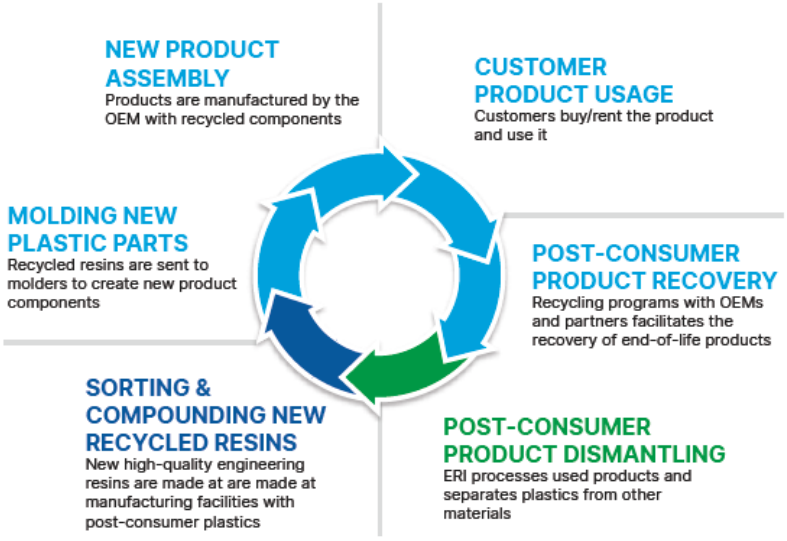

Figure 6: ERI Circularity Methodology

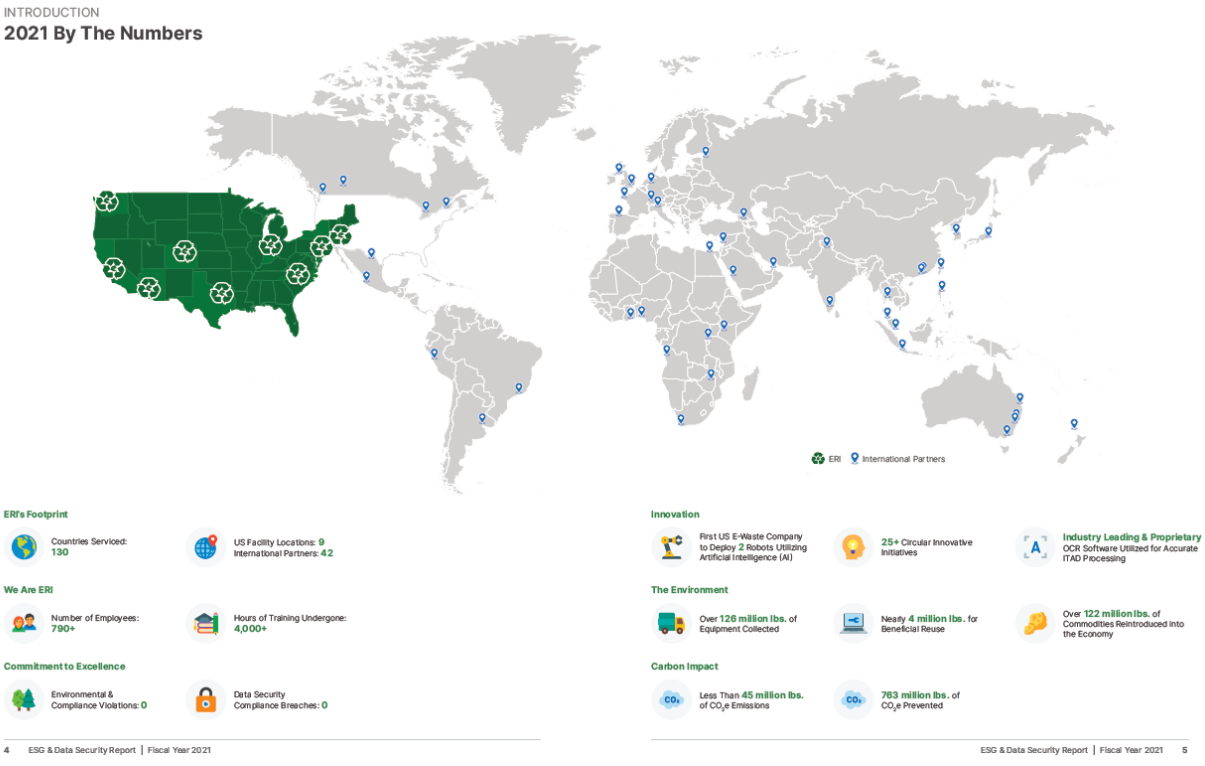

Figure 7: ERI Global Locations

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EDUCATION

The Pennsylvania State University — **University Park, PA**
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Smeal College of Business
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Minor in Security Risk Analysis

WORK EXPERIENCE

PwC — **Philadelphia, PA**
Advance Intern — *June 2022 – August 2022*

- Spearheaded contingent labor spend initiative analysis and presented client findings totaling potential $2.5-$4.0M savings via a consolidated staff augmentation program
- Investigated individual contract turn-around-time and showcased visualized regressions on the dimensions of supplier, industry, client team, and employee

DuPont — **Wilmington, DE**
Global Procurement Co-op — *January 2022 – June 2022*

- Led a team of specialists in designing a process flow escalation system to retrieve 800+ missing energy invoices to be processed for 2021 Sustainability Metrics Reporting
- Enhanced team's understanding of categorical spend data on a global scope through the usage of Power BI analytics software and automated contract agreement database matching

Johnson & Johnson — **Titusville, NJ**
Global Supply Chain Finance Intern — *June 2021 – August 2021*

- Implemented exhaustive automation efforts to improve upon the Global Supply Chain Finance FP&A's internal Microsoft Excel Quarter Calendar for expedited deliverable dissemination to Regional SC FP&A stakeholders
- Streamlined virtual Global Consumer Headcount reporting processes and end-to-end Dashboard Reporting for essential business partners to coordinate improved Quarter Close and Business Plan procedures

CAMPUS INVOLVEMENT

Penn State Ascend — **University Park, PA**
President — *September 2020 – May 2021*

- Presented personal development events for members to continually enhance individual business acumen
- Hosted weekly corporate recruiting events to provide members an opportunity to professionally network

THON 2020 Student Run Philanthropy — **University Park, PA**
OPPerations Sustainability Ambassador Leader — *September 2019 – February 2020*

- Advocated and implemented sustainability initiatives such as the Thon Recycling and Environmental Effort yearlong fundraising campaign, to encourage efficient waste management for THON 2020
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Interests: Personal Asset Management, Information Technology, Language Learning, Weightlifting, Card Collecting