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The need for better measurement and employee engagement to advance a circular economy: Lessons from Biogen's "zero waste" journey

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ABSTRACT

The movement toward "zero waste" and circular economy has recently gained traction as an alternative to the dominant "take-make-waste" model of production and as a viable approach for addressing climate change. Business plays a key role in this transition and a growing number of companies are establishing waste reduction goals, such as "zero waste to landfill" as part of their sustainability commitments. This study however, suggests that companies' efforts presently are inadequate to support such a transition; companies lack effective sustainability indicators to measure progress, identify opportunities, and engage employees. While the Global Reporting Initiative (GRI) guidelines provide standardized indicators for measuring waste reduction through different methods, most of these measure *outputs* versus the *impacts* of source reduction, reuse and remanufacturing. Based on benchmarking data from eight biotech and pharmaceutical companies' waste reduction performance and in-depth analysis of waste management at Biogen, the study finds that: a) companies rely primarily on recycling and waste-to-energy practices to reduce waste and defer to "zero-waste-to landfill" goals rather than focusing on environmentally preferable methods like source reduction and reuse; b) in lieu of standardized reporting, companies report inconsistent waste data that often lack effective indicators for measuring and promoting source reduction and reuse; c) employee awareness and engagement for advancing "zero waste" and circular economic business practices is undeveloped. The study proposes a model for "Expanded Zero Waste" practice, which includes additional indicators for measuring outcomes and impacts of circular business strategies, where employee engagement is seen as a critical strategy for identifying and implementing innovative sustainability approaches and initiatives.

1. Introduction

The movement toward "zero waste" has recently gained traction in developed nations as both an alternative to the dominant "take-make-waste" model of production, and as a key approach for addressing climate change. Although achieving a true "zero waste" society cannot be realized in practice due to the limits of thermodynamics,[1] it is an important guiding principle that can be used to change today's manufacturing practices. The concept involves a hierarchy of waste reduction methods including waste prevention, reuse, recycling, composting, incineration, and landfill (Song el. al., 2015; EPA, 2016a, b). Related to "zero waste" is the more recent concept of the "circular economy" (CE), which is based on the idea that waste in nature is regenerative and human systems can mirror natural processes by being designed to restore natural capital to the biosphere and utilize materials indefinitely in closed loops. While both concepts can work well together, there is a distinction between the two. "Zero waste" focuses on the back end of the manufacturing process, while the circular economy additionally incorporates the design of products and services. It is based on three main principles: a) "designing out" waste, b) separating the biological from technical nutrients where the former are returned

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[1] According to the law of thermodynamics, there are always losses when energy and materials are converted from one form to another.

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back to the biosphere, and the latter are reused indefinitely, and c) using renewable energy to "decrease resource dependence and increase system resilience" (WEF, 2014). Cities and companies around the world are increasingly embracing such strategies and recently the European Union launched an ambitious action plan for advancing the circular economy with concrete waste reduction goals, regulations, and measures of success (EC, 2015). It is estimated that the circular economy will provide an economic opportunity of over $1 trillion as well as significant social and environmental benefits (WEF, 2016).

Yet, making the transition to "zero waste" and CE is challenging due to the economic stake and complexity of the current production system, antiquated policies that tax labor rather than resources, a lack of effective measurement and reporting, and less attention to waste management from policymakers and other stakeholders compared to climate change and water. According to the U.S. Environmental Protection Agency (EPA), approximately 7.6 billion tons of industrial solid waste are generated and disposed of each year in the U.S. (EPA, 2016a, b). This waste is not only endangering human health and the environment, but it also represents a double penalty for businesses – it demonstrates inefficient production processes and increases the costs for disposal. In addition, waste can pose business risks related to enacting new waste regulations or liability risks from accidental exposure or release.

A growing number of companies including GM, Honda, P&G, Hershey, Jones Lang LaSalle, and Unilever, have recognized the business benefits of reducing waste such as reduced disposal costs and risks, improved brand reputation, increased employee engagement, and diversified revenue streams (e.g., when companies sell unwanted products or waste) (Hermes, 2014). Unilever North America, for example, reported $1.9 million savings in 2013 as result of achieving "zero waste to landfill" (Hardcastle, 2015). General Motors made $2.5 billion in revenue through various recycling activities from 2007 to 2010 and presently generates about $1 billion in byproduct reuse and recycling revenue each year (General Motors, 2015). Reducing waste also helps decrease a company's carbon footprint, an important commitment for many multinational corporations.

Most companies and municipalities however are presently focused on recycling and waste-to-energy methods to achieve their waste reduction goals, rather than the more environmentally preferred options of source reduction and reuse (Zaman, 2015). To effectively address the problem of waste and move toward a circular economy, "there needs to be a move beyond recycling into the largely unchartered territory of the higher end of the waste management hierarchy, to reuse, reduce and prevention" (Song et al., 2015). Most work to date has focused on providing guiding principles and case studies for waste reduction. Much less research has been done to examine the **role of effective measurement and employee engagement** in raising awareness and advancing source reduction, reuse and remanufacturing. This paper aims to provide insight into these two areas and offer a new "Expanded Zero Waste" model with recommendations for advancing circular economic business practices through better measurement and employee engagement.

The paper begins with a literature review, research goals and methods. It then provides benchmarking of waste management data by eight biotech and pharmaceutical companies to examine the strategies and indicators used to measure and report waste reduction practices. To gain an in-depth understanding of current corporate practices in this area, the authors analyze Biogen, an innovative and fast growing biotech company considered to be a leader in corporate responsibility. The paper presents the company's current waste management process for achieving its "zero waste-to-landfill" goal, employee awareness and support for waste reduction initiatives, and opportunities to broaden waste reduction efforts and advance a circular economic model. The research is based on interviews with internal and external stakeholders involved in waste management, a survey of employees, and an analysis of waste data. The **goals** of this paper are four-fold: a) to demonstrate that companies rely primarily on recycling and waste-to-energy practices to reduce waste and achieve "zero-waste-to landfill" status rather than the environmentally preferred methods of source reduction and reuse; b) to reveal that companies' reporting of waste data is inconsistent and lacks effective indicators for measuring and promoting source reduction and reuse; c) to demonstrate that employee awareness and engagement for advancing zero waste and circular economic business practices is low; and d) to offer a new model for "expanded zero waste" practice that helps advance circular economic business practices.

2. Literature review

The term "zero waste" has been used for decades and researchers have traced its origin to 1973 when a company called Zero Waste Systems was founded by American chemist Paul Palmer (Krausz, 2012). The company's primary business was to reuse chemical byproducts, which were supposed to be disposed of as waste. The term gained greater popularity in the 1990s with the growing environmental and sustainability movement. Despite its long use, however, the understanding and practice of the term still varies greatly from a waste reduction goal, aspirational statement, a tool for resource management and a solution to pollution and global climate change (Kozlowski, 2009). More recently, "zero waste" has been seen as a strategy for better industrial design and waste management and is replacing the dominant waste disposal practices of landfilling and incineration (Connett and Sheehan, 2001). Researchers have defined "zero waste" as a new paradigm that promotes recapturing resources from the general waste stream, reducing consumption, and applying a life-cycle approach to product design (Dinshaw et al., 2006). The Recycling Council of British Columbia introduced a "Six R" hierarchy for reducing waste, defined by the following: reconsider, reuse, reduce, recycle, recover, and retain. This hierarchy has been used to emphasize the importance of reduced consumption rather than recycling and recovering (RCBC, 2014).

Another term closely related to "zero waste" is the "circular economy" (CE), which traces its origins to the concepts of "industrial ecology", "cradle-to-cradle", "biomimicry" and "natural capitalism" introduced by sustainability thought leaders in the last two decades. While "zero waste" is concerned primarily with the back end of manufacturing (how we eliminate or reduce waste), CE relates to both – the front end (or how we design products and services so they can be repurposed or recycled into new products indefinitely), and the back end (how we foster collaborations among users and waste generators to ensure high rates of source separation to continuously reuse materials and minimize associated environmental impacts). Such an economy is based on several main principles, including a) "designing out" waste, b) separating the biological from technical nutrients where the first are returned back to the biosphere, and the second are reused indefinitely, and c) using renewable energy to "decrease resource dependence and increase system resilience" (WEF, 2014). Compared to the zero waste movement, CE places a greater emphasis on using renewable stock and composting to capture and return the biological nutrients to the biosphere. China and the European Union are currently leading global efforts to enact policies, establish targets and measure progress towards a CE (Murray et al., 2017).

A more recent phenomenon is the adoption of "zero waste-to-landfill" goals by a growing number of cities around the world including San Francisco, USA, Toronto, Canada, and Canberra, Australia. Companies including GM, Unilever, GSK and Biogen have also adopted such goals. In the United States UL is offering independent third-party validation and certification for three waste reduction claims: "zero waste to landfill" (100% waste diversion), "virtually zero waste to landfill" (between 98% and 100% waste diversion from landfill) and "landfill waste diversion" (between 80% and 98%) (Burger, 2014). The U.S. Zero Waste Business Council (USZWBC) is another organization offering independent certification to companies and communities, which divert 90% of their non-hazardous waste from landfills and incinerators (USZWBC, 2016). As part of its strategy to advance a global movement toward "zero waste", General Motors for example, has outlined nine key steps to achieve "zero waste to landfill", including defining zero waste, tracking waste data, prioritizing waste-reduction activities, engaging employees and building a sustainability culture, strengthening supplier partnerships, and sharing best practices (WMW, 2012).

Recent studies however, outline two issues with the "zero waste to landfill" goals. Such initiatives emphasize diversion from landfill as a primary goal, thus focusing on percent reduction and not the total waste generated. Secondly, the "zero waste to landfill" goal does not address the issue of over-consumption and as a result, companies continue to rely predominantly on recycling and waste-to-energy methods of disposal (Krausz, 2012).

It is critical to raise awareness and develop better measures and goals for moving towards "zero waste" and CE where the emphasis is on source reduction, reduced consumption, product and service redesign, and reuse. Measuring these methods and the associated environmental and social impacts however is challenging. As Bartl (2014) states, "how do you measure something that is not there?" Measuring reuse is more straightforward yet few companies are tracking and reporting such data. In many cases, third parties collect used products and no information is relayed back to the manufacturer or end user of the product. Moreover, should reuse be measured as a percent of products reused, as total tonnage of waste prevented through reuse, or the value of reused products? The answer will most likely depend on the type of product and presently no commonly accepted indicators exist to measure such practices or related impacts such as GHG emissions avoided, water and materials saved, jobs created and non-profits served, among others. Beyond jobs, measuring the social impacts of waste reduction and CE is almost entirely missing presently (Murray et al., 2017). The recently proposed Material Circularity Indicator also focuses entirely on the environmental aspects of material selection, design and end of life management, with no attention paid to social issues such as social justice, health, equality, and opportunities for underprivileged populations (Ellen MacArthur Foundation, 2015).

Furthermore, future research and policies to advance the CE should focus on developing goals, strategies and guidance on minimizing simultaneously the materials (including water), energy and waste flows at a company level while also considering related social impacts. Instead of focusing just on zero carbon, zero waste or water/chemical reduction, there is a need to better understand and link "material, energy and waste process flows in a manufacturing facility from a holistic viewpoint" (Ball et al., 2009). Similar to the use of lifecycle assessment (LCA) at the product level, there is a need to develop tools and indicators to simultaneously analyze and minimize energy, materials (including water), and the use of hazardous chemicals at a company level (Dangelico and Pujari, 2010; Smith and Ball, 2012). This requires systems view and better measurement of the impacts of different product design, supply chain management and waste reduction options on GHG emissions, water, hazardous air pollution and energy reduction (EPA, 2009). For instance, 42% of total U.S. GHG emissions are associated with materials management but current zero waste frameworks rarely measure and communicate such impacts (EPA, 2009).

The most widely used framework for measuring and reporting waste data currently is the Global Reporting Initiative (GRI), which was used by 81% of S&P 500 companies in 2015 (Hardcastle, 2016). Its guidelines call for reporting the total weight of hazardous and non-hazardous waste by different disposal methods including reuse, recycling, composting, recovery (including energy recovery), incineration, deep well injection, landfill, and onsite storage (GRI, 2015a, b, p. 123, G4-EN23). Under "product responsibility" the GRI G4 guidelines focus only on health and safety, labeling, marketing, customer privacy and compliance (GRI, 2015a, b). The guidelines call for measuring the percentage of reclaimed products and packaging (GRI, 2015a, b, p. 129). Most of the indicators, however, measure "outputs" with just a few focusing on "impacts" (e.g., emissions, biodiversity, monetary value of fines). No indicators exist for measuring source reduction, the value of reused products, (e.g., fair market value) or the associated environmental, social and economic outcomes and impacts such as greenhouse gas emissions avoided from reuse, jobs created, dollars saved, or increase in market share. As a result, most companies report recycling, waste-to-energy, incineration and landfill quantities. Hewlett Packard for instance reports significant increases in reuse and recycling but the actual data provided by the company only includes pounds recycled (HP, 2012). Even when it comes to recycling, an area well understood and developed globally, studies have reported challenges with establishing a standardized measurement. Hotta et al. (2016) identified four main types of recycling rate indicators based on their focus – input focused, resource recovery focused, collection focused and waste diversion focused, and called for caution when using such measures. In addition, any effective results-oriented framework must also measure outcomes and impacts in addition to inputs and outputs (UNDP, 2002).

Another problem with current indicators for measuring and reporting waste reduction efforts is that in some cases, waste declines as result of economic recession or revenue declines. Therefore it is critical for any effective indicators to take such variables into consideration. Some studies have offered approaches for waste prevention (Gottberg et al., 2010; Sharp et al., 2010; Gentil et al., 2011) and a zero waste index (ZWI) has been developed as a tool to measure waste prevention (Zaman and Lehman, 2013). However, according to Bartl (2014) these approaches and tools do not correlate with waste prevention as they still focus on recycling and subsequent savings. Developing effective indicators for advancing circular economic business practices therefore is critical. While indicators alone cannot bring change, they are critical for raising awareness and empowering employees and other stakeholders to progress towards a zero waste economy. Indicators are also a key element of any performance management system by providing critical feedback for ensuring continuous improvement (Veleva et al., 2001). However, there is presently a lack of well-designed and effective indicators to help companies transition from linear to circular economic practices (Elia et al., 2017). Most efforts to date are focused on recycling rather than reuse of products (Ghisellini et al., 2016).

Despite its numerous business benefits, developing a "zero waste" strategy is challenging, as it requires engaging a variety of stakeholders across the supply chain, including innovative actors such as designers and product/service entrepreneurs who can provide key services and solutions (Ghisellini et al.,2016). In addition, such a strategy requires significant management commitment as "it can impact every facet of a business, including product design, choice of manufacturing processes, logistics and supply chain decisions as well as waste management and recycling considerations" (Barnish, 2013). Since it often sounds overly ambitious, it is difficult to initially engage employees and managers as they are facing their own cost and time pressures (and waste reduction often goes against production goals, which may determine employees' compensation). At the same time research confirms that employees are a company's best ambassadors for identifying and implementing innovative sustainability initiatives (Sharma et al., 2009; Du et al., 2010; Mirvis, 2012). Educating and empowering employees to identify and support innovative strategies for source reduction, reuse and remanufacturing is critical for the success of any "zero waste" or CE strategy. Such engagement can also lead to business benefits. Many researchers have examined the link between corporate social responsibility (CSR) and employee engagement, which Gallup defines as "the involvement with and enthusiasm for work" (Markos and Sridevi, 2010). Studies have confirmed that greater employee engagement is associated with improved job satisfaction, retention, profitability, customer loyalty, and organizational citizenship behavior (Ellis and Sorensen, 2007; Valentine and Fleischman, 2008; Markos and Sridevi, 2010; Veleva et al., 2012).

At the same time research has confirmed that most employees are still not engaged. A 2007 Towers Perrin survey of 90,000 employees in 18 countries reported that only 21% of them felt fully engaged at work (Towers Perrin, 2007). Yet, nine out of ten employees globally state they are interested in participating in their company's CSR initiatives (Mirvis, 2012). Researchers have examined the factors for increasing employee engagement and have provided frameworks for such strategies (Robinson et al., 2004; Penna, 2007; Markos and Sridevi, 2010). For instance, Development Dimensions International (DDI, 2005) outlined five steps in creating a highly engaged workforce, including a) align efforts with strategy b) empower c) promote and encourage teamwork and collaboration d) help people grow and develop and e) provide support and recognition where appropriate. Robinson et al. (2004) demonstrated that the key driver of employee engagement is an employee's "sense of feeling valued and involved". This is in line with CIPD survey of 2000 employees in Great Britain, which found that communication is the top priority for improving employee engagement. This includes not only "being kept informed about what is going on in the organization" but also providing opportunities for employees "to feed their views and opinions upward" (Markos and Sridevi, 2010).

The importance of actual involvement versus being informed is examined in a greater detail by Kim et al. (2010) who analyzed the link between employees' *perception* of CSR initiatives compared to employee *participation* in such activities. The researchers found that CSR participation has a direct influence on employee company identification and thus is more effective way for companies to maintain a positive relationship with their employees. CSR participation is defined as "participative behaviors including having a say in the organization for CSR initiatives" (Kim et al., 2010). Mirvis (2012) outlines three different ways that companies can engage their employees through CSR: a *transactional approach* (developing programs to meet the needs of employees passionate about CSR), a *relational approach* (based on psychological contract between employees and the company around CSR), and *developmental approach* (which aims to go beyond corporate actions to educate and empower employees to take actions in their personal lives). Ongoing communication, training and empowering employees to take actions are critical.

In summary, an effective approach to advancing zero waste and circular economic business practices must include two key elements. First it must engage employees through continuous communication and empowerment to participate and initiate innovative approaches to "zero waste". Second, it must include effective indicators for measuring both outputs as well as impacts, in order to communicate the significance of source reduction and reuse compared to recycling and waste-to-energy methods.

3. Study design and methods

To conduct the study, the researchers selected eight biotech and pharmaceutical companies that use the GRI reporting framework and have been recognized by third parties for their sustainability efforts over the last couple of years, including the Dow Jones Sustainability Indexes (World Index and North America Index), Newsweek Green Rankings, and Corporate Knights, among others. The companies are: **Amgen, Biogen, Genentech, GSK, Johnson & Johnson, Merck, Novartis,** and **Pfizer**.[2] Data for each company was obtained from their annual sustainability/citizenship reports, which are developed in accordance with GRI guidelines. In addition, revenues and number of full-time employees was included in order to measure and compare waste intensity (e.g., waste generated per employee per year). The authors believe that focusing on a single sector would provide greater consistency and comparability of reported waste data.

To better understand current corporate waste management practices, including measurement and employee engagement, the research team analyzed Biogen, a fast growing biotech company and recognized sustainability leader that has achieved both "net zero carbon footprint" and "zero waste to landfill" status (according to their most recent citizenship report). The research team aimed to analyze current best practices and identify strengths and weaknesses of Biogen's "zero waste" strategy, and resulting implications for research and practice. The company was chosen because it is regarded as an industry leader in sustainability and waste management, which helped contextualize the results. Information was obtained from interviews with internal and external stakeholders involved in waste management at the company's Cambridge facility. The research team interviewed representatives from several departments including Environmental Health, Safety and Sustainability, Facilities Services, Procurement, and Communications. In addition, several vendors were also interviewed including E.L. Harvey, the Furniture Trust, Triumverate Environmental, Janitronics, Aramark, Cambridge Scientific and Seeding Labs. The study began with mapping out the main streams of non-hazardous waste at the Biogen Cambridge facility and analyzing waste data for the period 2012–2015 in order to identify trends and opportunities for improvement.

To assess employee awareness and support for waste reduction initiatives, the research team designed a seven-question non-probability convenience sample survey based on input from internal and external stakeholders, including Biogen managers and their waste management contractor E.L. Harvey. This type of survey was chosen to fit the location of where the survey was being administered. Biogen cafeterias host employees from varying departments and at varying levels of management, and therefore a non-probability sample survey was best suited to maximize data collection and minimize variables. The survey was administered to employees at the Biogen Cambridge Building 6 cafeteria during lunchtime on March 17, 2016. A total of 3765 employees and supplemental staff are based in Cambridge, of whom 351 are based in

[2] Biogen, Amgen, and Novartis were included in the DJSI World Index in 2015; Roche (parent company of Genentech) ranked as industry leader in DJSI 2016; GSK was included in DJSI World Index 2016; J&J was part of DJSI North America in 2015; Merck was included in DJSI North America in 2016; Pfizer was on the CDP Leadership Index in 2014.

Building 6. A sample of 102 individuals of 1877 (population size, about half of all Biogen Cambridge employees) was used.[3] The rationale behind implementing a sample survey and not a census was because the research team had limited resources. As incentive for participation in the survey, employees were entered into a raffle for a $100 gift card. The survey was conducted on paper, however results were entered in an Excel spreadsheets and analyzed with SPSS 23. For the analyses the study used non-parametric methods to test the hypothesis. We conducted a test of independence (chi-square test of a contingency table), to analyze the relationship between two qualitative variables.

4. Results and discussion

4.1. Benchmarking waste reduction strategies of select biotech and pharmaceutical companies

For each of the eight selected biotech and pharmaceutical companies the research team analyzed current waste reduction goals and data on different disposal methods, which are summarized below and included in Table 1.[4]

Amgen has a 2020 goal to reduce the amount of waste sent to landfill or incineration by 1490 tons based on year 2012 levels. The company reports separately the percent of waste reused, recycled, and composted. Due to the acquisition of three additional manufacturing facilities in Turkey and Brazil in 2015, its total waste increased but its total waste diversion rate (including recycling, reuse and composting) improved from 50% in 2014 to 52% in 2015 for all waste (Amgen, 2016). **Biogen** has a “zero waste-to-landfill” goal and since 2012 has achieved “virtual zero-waste-to landfill” in all of its owned operations (defined as diversion rate of 98%–99%). In 2015 it diverted 98.9% of its waste from landfill, however 14% was incinerated and 23% was sent for energy recovery (Bodkin, 2016). **Genentech** reports using the 4Rs (rethink, reduce, reuse and recycle) in its waste management approach, however it does not provide separate data for waste reuse and no indicators were included to measure source reduction (Genentech, 2015). **GSK** has a goal to reduce its operational waste by 50% and achieve “zero waste to landfill” status in all of its facilities by 2020. The company reported some innovative approaches in waste reduction such as composting of 1500 tons per year of eggshells from flu vaccines approved in its Canadian manufacturing. However, it aggregates waste reused, recycled, composted or sent for energy recovery and reports these quantities as “waste recycled”, making it impossible to benchmark improvements in strategies that promote the circular economy (e.g. reuse, composting and recycling) (GSK, 2015). **Johnson & Johnson** defines total waste as both hazardous and non-hazardous but excludes waste that is recycled, reused, or disposed/treated. Its reporting is in kilograms requiring conversions to compare against other companies in the sector (J&J, 2016). **Merck** does not report separately the percent of waste reused, recycled, composted or send for energy recovery (Merck, 2015). In 2015 **Novartis** reported achieving a 75% recycling rate for its non-hazardous waste compared to 65% for the previous year, however it is not clear how the company defines “recycling” and whether it includes composting, energy recovery or reuse (Novartis, 2016). **Pfizer** has the lowest waste generation intensity (non-hazardous waste per employee) among all eight companies, an indirect measurement of source reduction. Interestingly it also has the

Table 1
Benchmarking of waste management by select biotech and pharma companies, 2015.

Company	Biogen	Amgen	Genentech	GSK	Novartis	J&J	Pfizer	Merck
Revenues ($B)	$10.7	$21.66	NA	$35.46	$50.39	$70.07	$48.85	$39.5
FTE	7500	17,900	12,300	96,500	123,000	127,100	78,300	68,000
Waste reduction goal	Achieve “zero waste to landfill”	↓ waste to landfill or incineration by 1490 t	↓waste to landfill per employee by 80% by 2020	↓ waste 50% &achieve zero waste to landfill	↓ 30% waste and per-associate waste intensity	10% absolute reduction in total waste disposed	By 2020 ↓ 15% total waste vs. 2012 baseline	Send less than 30% operational waste to landfill or incineration
Total non-haz waste (metric tons)	5492	8599	8674	159,000	83,000	115,897	32,000	41,000
Waste/employee	0.73	0.48	0.71	1.65	0.67	0.91	0.41	0.60
% reused	NA	2%	NA	NA	NA	8.5%	NA	NA
% recycled	19%	46%	41%	NA	NA	52%	60%	NA
% composted	42%	11%	24.5%	NA	NA	NA	NA	NA
% energy recovery	23%	8%	NA	NA	NA	16.8%	NA	NA
% incinerated	14%	3%	0.07%	NA	15%	2.8%	NA	14%
% sent to landfill	1%	30%	32%	6%	9%	12.9%	40%	9%
% reused, recycled, &composted	61%	59%	68%[a]	NA	75%	NA	NA	NA
% reused, recycled, composted, or energy recovery	84%	67%	NA	75%	NA	NA	NA	77%
% sent to landfill or incinerated	15%	38%	32%	NA	24%	NA	NA	23%
% biological/chemical treatment or other	NA	5.6%	NA	NA	NA	6.7%	NA	NA
% landfill diversion	98.9%	NA	68%	94%	90%	~87%	60%	91%

[a] This percent includes 209 tons of e-waste, which was reused or recycled.

[3] Since Biogen Cambridge campus has only two cafeterias it is assumed that about half of the employees could come to Building 6 for lunch.

[4] In most cases provided information is for 2015, however, in a few instances 2014 data was used due to the lack of more recent reporting.

lowest landfill diversion rate (60%) among the eight companies (Pfizer, 2015). This could be a result of Pfizer's strong focus on source reduction through green chemistry (Veleva and Sarkar, 2015) rather than landfill diversion.

Results from the analysis demonstrate that despite the existence of standardized guidelines, reporting of waste data differs greatly, which makes it impossible to effectively compare companies' waste reduction practices and identify opportunities for improvement. This is exemplified by the example stated earlier, highlighting GSK's inclusion of waste sent to waste-to-energy plants into their recycling numbers. This confirms previous research, which found a lack of standardized measures and called for caution when making comparisons (Hotta et al., 2016). In addition, while most companies structure their waste management hierarchy via the "prevent, reuse, reduce and recycle" paradigm, the indicators they currently use do not inform or empower employees to seek more desirable waste management options, which undermines sustainability efforts. Comparing the non-hazardous waste generated per employee (a potential indicator of source reduction) reveals great variability with GSK performing at 1.65 tons per employee per year, and Pfizer scoring best at 0.41 tons per employee per year. In terms of total waste diversion from landfill Biogen performed best at 98.9% and Pfizer performed worst at 60%. This demonstrates the variability of reportable waste metrics amongst companies and confirms the need for standardized indicators for moving from linear to circular business practices (Elia et al., 2017).

The analysis of the eight biotech companies also demonstrates that companies rely predominantly on recycling, energy recovery and incineration to reduce waste rather than source reduction and reuse, which confirms previous research (Zaman, 2015; Song et al., 2015). Biogen, the company with the highest landfill diversion rate of 98.9%, sent 23% of its non-hazardous waste for energy recovery and 14% for incineration in 2015. GSK reported a 94% landfill diversion rate however its percent recycling includes waste-to-energy disposal, which confirms previous studies reporting the lack of standardized measurement of recycling rate (Hotta et al., 2016). Coincidentally, the company scores worst in terms of the amount of non-hazardous waste generated per employee (1.65 tons), an indirect indicator of source reduction.

Despite the fact that all eight companies follow the GRI G4 guidelines and indicators, their reporting of waste data varies significantly. For instance, only Biogen and Amgen report the percent of waste reduced separately, using each of the GRI listed methods. In contrast, GSK, Novartis, and Merck only report percent of waste reused, recycled, composted or sent for energy recovery as one number, which is problematic. First it demonstrates that the specific strategy does not matter as long as waste is reduced, even if that involves waste-to-energy or incineration methods. Second, it does not offer the ability to effectively measure and track progress in reuse and composting versus recycling. Employees do not have the right measures to track improvement over time through source reduction, donations, or composting. Reporting composting and recycling as one indicator is also problematic as the circular economy calls for separately measuring and managing biological and technical waste (WEF, 2014). With goals focused on waste reduction and achieving "zero waste to landfill" the main focus is on landfill diversion, which raises the question – **does it really matter how a company gets there?** GSK for instance, includes waste-to-energy when reporting the percent of non-hazardous waste recycled. The results demonstrate that presently there are no commonly accepted and effective waste management indicators that would raise awareness among internal and external stakeholders to support a transition to a circular economic waste management system. In addition, the results confirm Song et al. (2015) findings that waste reduction efforts so far have been focused on recycling rather than the more desirable options. It also confirms Krausz (2012) finding that "zero waste to landfill" goals are problematic, as they do not address the problem of over-consumption.

The next section examines the waste management process at Biogen in greater detail. The company was the top performer of landfill diversion and reporting transparency. The main goal is to better understand the current challenges and potential opportunities in waste measurement and employee engagement.

4.2. Waste management at Biogen

Headquartered in Cambridge, Massachusetts, Biogen is a $10.7 billion global biotechnology company with over 7500 employees in 2015 (Biogen, 2015). It focuses on treatments and therapies for neurological, autoimmune and rare diseases, including multiple sclerosis and hemophilia. The company was ranked 3rd amongst Fortune 500's "fastest growing pharma companies in 2015" and 298th in their overall rankings (Lorenzetti, 2015). In addition, Biogen has been recognized as a leader in social responsibility. In 2015 *Newsweek* ranked the company #1 in their *Green Rankings* (Biogen, 2015). In 2014 it was designated as the Dow Jones Sustainability Index (DJSI) World biotechnology leader and included in the North American DJSI for the fifth consecutive year. In addition, Biogen was also listed as the world's most sustainable company in 2015 by Corporate Knights' *Global 100* and among the *50 Best Places to Work in America*. Since 2012 the company had achieved "virtual zero-waste-to landfill" in all of its owned and operated facilities. In 2014 it achieved net zero carbon footprint (Biogen, 2015). Between 2012 and 2015 Biogen almost doubled its revenues and as result its waste also increased (see Table 2; Bodkin, 2016).

Biogen Cambridge campus consists of seven buildings and has five main waste streams: manufacturing equipment, manufacturing and R&D supplies and components, food waste, office equipment and office supplies (see Fig. 1). Only manufacturing components generate hazardous waste; thus over 95% of campus waste is non-hazardous and includes food waste, packaging, paper, and plastics from the kitchen areas and offices. Construction and demolition (C&D) waste is not counted under non-hazardous waste as it is highly cyclical but according to company data, of the 1505 tons generated in 2015, only 14 tons were landfilled, thus 99% of the C&D waste was recycled.

To offset the impact of its non-hazardous waste, Biogen has created innovative solutions to reduce, recycle and compost waste. A key factor within this strategy is the development of strategic partnerships with local vendors and entrepreneurial companies with business models based on reuse, remanufacturing, recycling and composting.

Biogen has a long partnership with **Cambridge Scientific,** a small entrepreneurial company based in Watertown, Massachusetts. They take roughly 90% of Biogen's surplus R&D equipment and extend its useful life through remanufacturing, reuse, and leasing laboratory equipment and space. The majority of the equipment is reused with only about 15% sent to landfill. Biogen gets proceeds from the profits of the equipment re-sale. Cambridge Scientific does not track the tonnage of the repurposed equipment but only the fair market value. As a result, Biogen does not presently track or report any data related to the R&D equipment reuse. The Facilities-Lab Services department manages the program, however internal awareness and information sharing is limited (Gummadi, 2015).

The remaining 10% of the R&D equipment is donated to **Seeding Labs**, a non-profit organization based in Boston, which donates used equipment to researchers and universities in developing countries. The partnership is managed through Biogen's Department of Community Relations. According to Seeding Lab's Director

Table 2
Biogen waste reporting, 2012–2015.

	2012	2013	2014	2015
Revenue ($ Billions)	5.5	6.9	9.7	10.76
Hazardous Waste (metric tons)	228	138	186	114.2
C&D (construction & demolition) waste (metric tons)	NA	NA	240	1505
Non-hazardous waste generated (metric tons)	3326	4446	3809	3598
Non-hazardous Waste Composted (metric tons)	1650 (53%)	1562 (37%)	1501 (41%)	1681 (47%)
Non-hazardous Waste Recycled (metric tons)	804 (26%)	1854 (43%)	1009 (28%)	854 (24%)
Non-hazardous Waste to Energy (metric tons)	592 (19%)	875 (20%)	1104 (31%)	992 (27%)
Non-hazardous Solid Waste to Landfill (metric tons)	52 (1.7%)	18 (0.4%)	9 (0.2%)	63.7 (1.8%)
Non-hazardous waste generated intensity (metric tons/million $ revenues)	0.60	0.64	0.39	0.33

of Corporate Relations, between 2003 and 2016, Seeding Labs had provided over $3.5 million of equipment to 41 institutions in 27 countries. It has over 90 partners who donate equipment (74% are corporate partners) and the overall tonnage of repurposed equipment is 110 tons. Seeding Labs does not currently measure the total tons diverted from landfill for each company, only the fair market value of donated equipment. Similar to Cambridge Scientific, Biogen does not currently track and report the equipment reuse through this program and the related social and environmental benefits (e.g. number of researchers benefitted, jobs created, air pollution and greenhouse gas emissions prevented).

Another innovative partnership for promoting product reuse was established by a Biogen Senior Associate Site Planner, who in 2014 came across the **Furniture Trust**. The company is a non-profit organization based in Boston that takes unwanted furniture from corporations and donates to schools and non-profits as an alternative to landfill disposal. This partnership has helped Biogen divert over 136 tons of furniture from landfill between January 2015 and June 2016. Moreover it has extended the useful life of this furniture and benefitted non-profits and high school students participating in their annual Eco-Carpentry Challenge[5] organized by the Furniture Trust. In 2015 Biogen began measuring and reporting the tons of furniture diverted from landfill through this partnership. However, all donations are currently listed under the category of recycling, making it challenging to communicate the greater environmental and societal benefits of reuse compared to recycling.

For its e-waste management Biogen has partnered with **ReStream**, a small green logistics company based in Waltham, Massachusetts, which offers electronics recycling in addition to secure shredding, asset recycling, decommissioning, and relocation services. As a result of this partnership, Biogen Cambridge removed over 18,000 pounds of electronic waste, of which 87% was responsibly recycled (Bodkin, 2016).

The main non-hazardous waste vendor for Biogen Cambridge is **E.L. Harvey**, a privately held waste hauling and recycling company based in Westborough, Massachusetts, with 2015 revenues of $950,000. E.L. Harvey manages over 89% of Biogen Cambridge's non-hazardous waste through composting, single-stream recycling and solid waste incineration. The company has partnerships with vendors who purchase their materials such as cardboard, paper, plastic, metals, and solid waste that have been separated and aggregated at their facility in Westborough. Compost is sent to two partner organizations, Mass Natural and WeCare Organics, who use anaerobic digestion methods to break down biodegradable materials such as polylactic acid-based kitchenware. Solid waste is shipped to incinerators in North Andover, Haverhill, Millbury and Cape Cod, Massachusetts, as well as locations in Maine, where it is converted to energy. Other recyclables such as aluminum cans, plastics, paper and cardboard are sent to various U.S. and foreign purchasers depending on the price offered. Biogen can reduce both its disposal costs and waste if a greater percent of its waste is composted or recycled. In 2015 Biogen Cambridge diverted 53% of its non-hazardous waste processed by E.L. Harvey through recycling or composting (10% composted; 43% recycled). According to an E.L. Harvey Territory Manager, this statistic is above average for Massachusetts companies. Opportunities still remain however, to divert a greater percent of recyclables and compostables such as cardboard and compostable kitchenware from the solid waste stream. For comparison, Biogen's North Carolina facility was able to institute a composting program for a specific byproduct of its manufacturing, which helped it achieve a 69% diversion of all solid waste through composting.

Two other important partnerships exist between Biogen and its office supply vendors. **W.B. Mason** is an office supply company and has instituted a "Go Green" program that utilizes eco-friendly products. These incorporate recycled materials and are designed

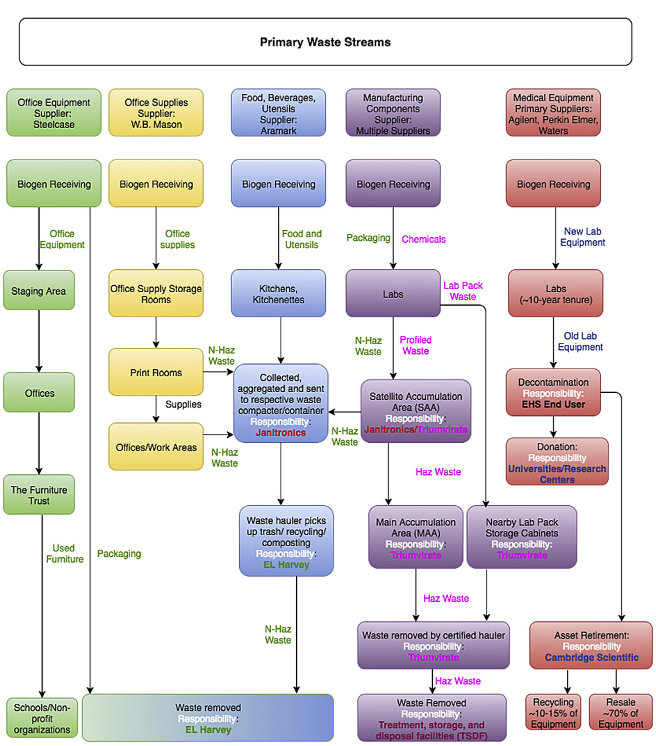


Fig. 1. Biogen Cambridge waste management process (Bodkin, 2016).

[5] A competition in which high school students exhibit recycled furniture projects from corporate donors around the Boston area.

for remanufacturing and recycling. Biogen's printing vendor **Ricoh** has helped implement a paper reduction program via paperless technology in addition to offering 100% recyclable printers (Bodkin, 2016).

Overall, Biogen's partnerships with local entrepreneurial companies focused on reuse and remanufacturing have been critical in promoting circular economic business. In nearly all cases, either upper level management or employees who were passionate about sustainability initiated these partnerships. Yet, there is no viable system in place currently to measure and communicate the environmental, social, and business benefits of such practices to raise awareness and promote continuous improvement. A survey of Biogen employees revealed that a significant percent of them are unaware of their ambitious "zero waste to landfill" goal and how they can contribute to it.

4.3. Biogen employee survey

To assess employee awareness and support for waste reduction initiatives, the research team used a seven-question survey that was administered to employees at the Biogen Cambridge Building 6 cafeteria for two hours during lunchtime on March 17, 2016. A total of 102 employees completed the survey (a copy of the survey is provided in Appendix C).

The results revealed that *85.5% of Biogen employees participating in the random survey perceive their company as "a sustainability leader" or "above average"* (with 26.5% and 59%, respectively). This perception however, does not appear to be based on actual awareness of one of the company's most ambitious sustainability goals as *43% of surveyed employees did not know of Biogen's "zero waste to landfill" goal*. Since 44% of the participants reported working at Biogen for two years or less, the research team conducted a statistical analysis to find out whether there was a difference between the awareness among recently hired employees compared to the rest. Results revealed no statistically significant correlation between the length of service and awareness of Biogen's zero waste to landfill goal (see Appendix A). This finding confirms the importance of ongoing communication about sustainability goals and initiatives.

The survey also revealed limited awareness regarding the separating and disposing of kitchen and office waste. *Forty three percent of surveyed employees reported that the signage for separating waste from recycling and composting was either **not clear** (8%) or **somewhat clear** (35%).* This explains findings from several waste audits conducted by E.L. Harvey, which found improper disposal of recyclables in solid waste bins (in particular cardboard and compostable kitchenware). Moreover, *61% of the survey participants did not know whether or not their blue office recycling bins were just for **paper** or for **all recycling*** (only 41% knew that they are for all recyclables as the company had moved to single stream recycling). In all of these cases a statistical analysis revealed no significant difference between new employees with less than two years of experience compared to the rest (see Appendix B for the analysis of employee knowledge about the company "zero waste to landfill" goal).

The study aimed to determine employee engagement regarding the most important strategies to reduce non-hazardous waste. Results are presented in Fig. 2. A total of 10 options were included in the survey question, which were identified in collaboration with Biogen's Director of Global EHS and Sustainability. Each employee was asked to select their top three options, while also given the opportunity to suggest additional areas for improvement. Results revealed that the three most important strategies for reducing non-hazardous waste according to employees are: *eliminating plastic water bottles* (suggested by 54%), *improving recycling in labs* (51%), and *using compostable utensils* (51%). In addition, *47% suggested expanding the K-cup Recycling Program*[6] and *31% suggested expanding green purchasing*. Interviews with Procurement revealed that Biogen did not have any sustainability guidelines for selecting suppliers. During the survey one employee shared that he selects vendors who take back Styrofoam packaging, a practice that could be implemented company-wide to promote source reduction.

To gauge current employee engagement around waste reduction and their willingness to do more, the survey included a question regarding employee's current contribution towards waste reduction efforts using a 5-point Likert scale. Results showed that *57% of surveyed employees rate their contribution as "very significant" or "significant"* (see Fig. 3). When asked about future participation, *67% indicated they would like to play a "significant" or "very significant" role* to support the company's waste reduction goals. This demonstrates the opportunity for further engaging and empowering employees to advance waste reduction efforts and confirms Mirvis (2012) findings that majority of employees globally are interested in participating in their company's CSR initiatives.

As the case with Biogen demonstrates, even when companies have implemented innovative strategies for source reduction or reuse, such achievements are often not effectively measured or communicated. For high-value equipment sent for donation or resale, there is a need to measure and report the social outcomes and impact as well, including the number of non-profits served, jobs created, greenhouse gas emissions avoided, researchers or students benefitted, an area that is currently most underdeveloped in the CE research and practice (Murray et al., 2017). Such reporting will send a strong message to internal and external stakeholders regarding the significance of reuse compared to recycling and waste-to-energy diversion. Furthermore, it is important to develop and implement indicators measuring source reduction, or the amount of waste avoided and the resulting environmental and social benefits (Bartl, 2014). For example, after redesigning its blockbuster drug Lyrica using green chemistry principles, Pfizer reported a 92% reduction in solvent used, an 82% reduction in energy use, an 81% reduction in water use, an 87% reduction in nickel catalyst use and an E-factor reduction from 86% to 9% (E-factor is the amount of waste generated for each pound of active pharmaceutical ingredient) (Veleva and Sarkar, 2015). Biogen could measure and report pounds of paper waste prevented resulting from its switch to paperless printing, and the related reduction in air pollution, greenhouse gas emissions, water, and tree savings. One simple indicator that indirectly measures source reduction is the total amount of waste per employee, which when tracked over time, can reveal whether a company is making progress in preventing waste.

5. Proposed model for "Expanded Zero Waste" practice

To address identified gaps in promoting "zero waste" and CE, the authors propose a new model for "expanded zero waste" practice (see Fig. 4). It is based on the widely accepted waste reduction hierarchy of reduce-reuse-recycle/compost-recover-dispose but incorporates two additional dimensions. First, it includes additional indicators for **measuring the "outcomes" and "impacts" of each waste reduction strategy** in order to better communicate the significance of reduce and reuse compared to recycling and waste-to-energy recovery. Second, "zero waste" is seen as integral part of an employee engagement strategy where employees are informed, educated and empowered to take action. The model offers potential indicators to **track employee engagement** such as 1) percent of

[6] Kuerig's official recycling program set up to retrieve used K-Cups for recycling.

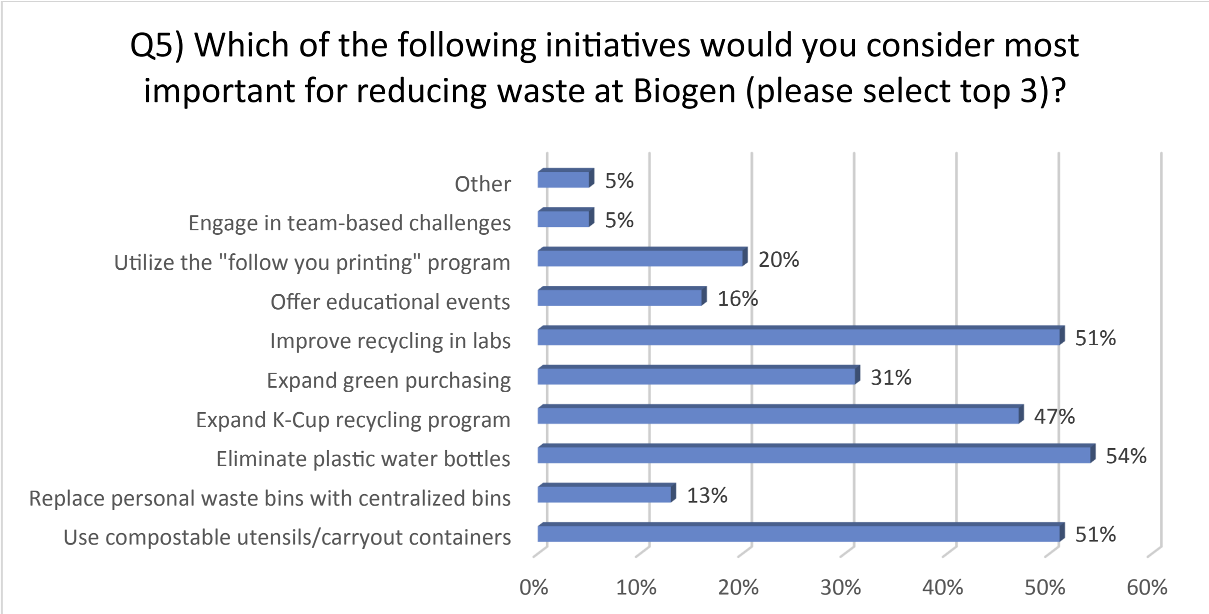


Fig. 2. Most important strategies for reducing non-hazardous waste at Biogen (Bodkin, 2016).

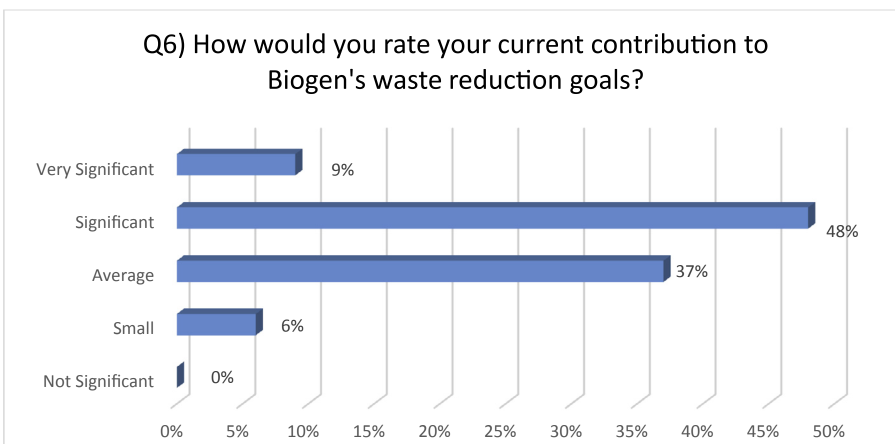
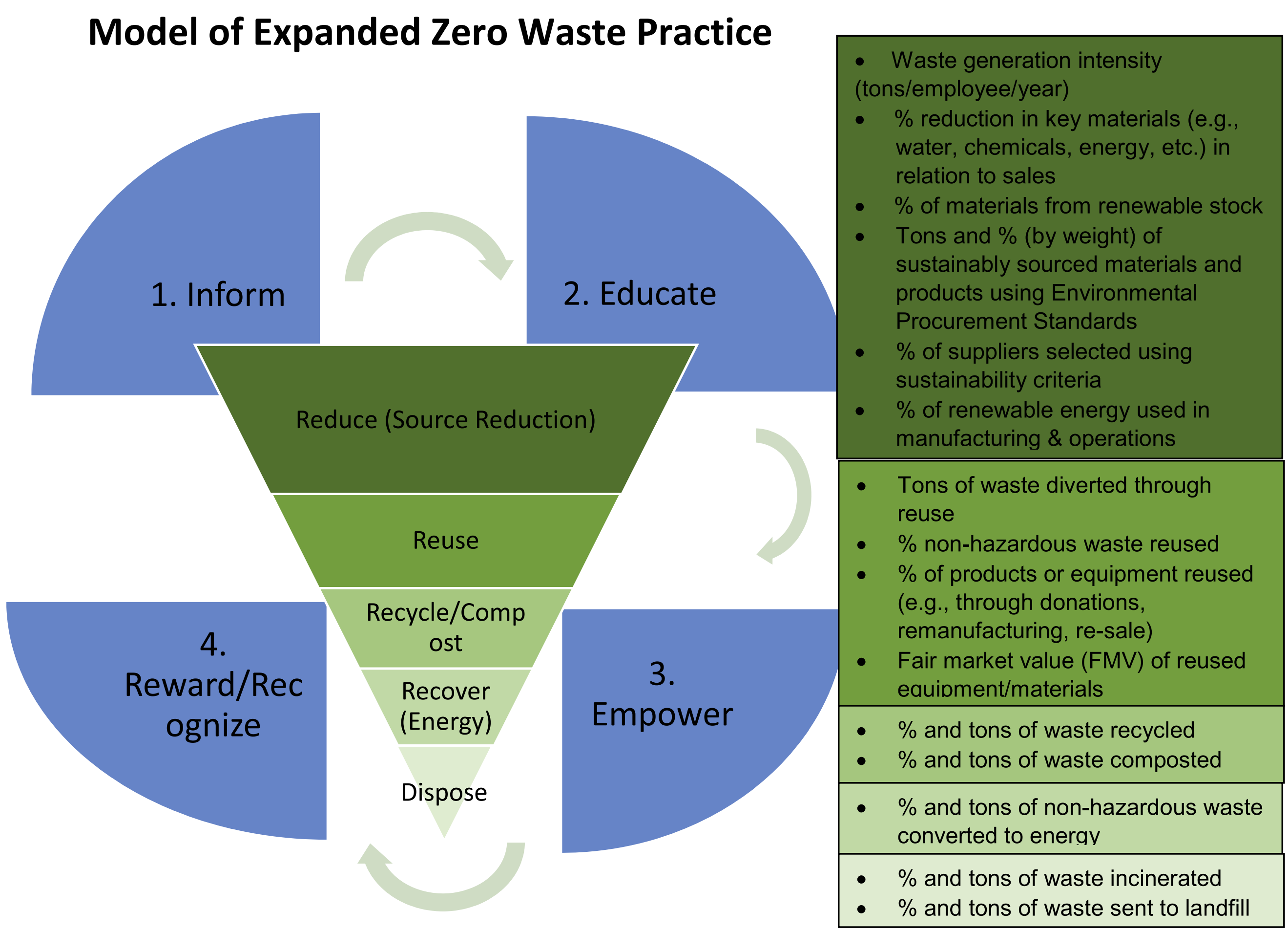


Fig. 3. Biogen employee current contribution to waste reduction goals.

employees aware of company waste reduction goals 2) number and percent of employees awarded/recognized for waste reduction efforts and 3) percent increase in employee engagement as a result of “zero waste” practices. While the list of indicators is not comprehensive, it provides a starting point for companies to develop their industry/company-specific measures of waste reduction and employee engagement.

The model includes specific indicators for measuring the social and economic impacts of different CE strategies, an area that is currently underdeveloped (Elia et al., 2017; Murray et al., 2017). When partnering with entrepreneurial businesses, companies can request measures of the social impacts of product reuse or donation, which could strengthen the business case for such actions, compared to recycling or waste-to-energy, as most large corporations have goals around social responsibility and community support. Such indicators could also help entrepreneurs develop a stronger value proposition and thus grow their business (Ghisellini et al., 2016). The adoption of environmental impact indicators such as GHG emissions prevented, water saved, hazardous emissions prevented, improved worker health and safety, also helps better communicate internally and externally the importance of higher hierarchy waste reduction options. Measuring waste generation intensity (tons per capita) and reduction in key raw materials (per unit of sale) promotes shifting attention to source reduction and waste prevention rather than end-of-pipe measures for waste minimization.

Another innovative aspect of the model is that it incorporates employee engagement as key element of a “zero waste”/CE strategy. As discussed in this paper, despite the strong business benefits of employee engagement, many companies have not implemented effective strategies for better communication and empowerment of employees (Towers Perrin, 2007; Kim et al., 2010). The Biogen survey revealed that two third of participating employees want to play a “significant” or “very significant role” in reducing waste in the future. The key is to identify the best approach for implementing an effective engagement strategy as employees have many other responsibilities. A *relational approach* could help make the connection between employee, employer and society and thus further increase



Environmental, Social and Economic Outcome and Impact Indicators for Each Level:

a) GHG emissions avoided (or generated, e.g. through incineration); b) energy saved; c) water saved; d) jobs created (direct & indirect); e) other social impacts (e.g., scientists supported, students benefitted, NGOs served); f) dollar savings, g) % and number of customers attracted as result of strategy (increase in market share, revenues); h) fair market value (FMV) of repurposed equipment/waste; i) RoI from employee zero waste training ($ invested/total savings from identified solutions); j) improved company resilience or competitiveness (e.g., preparedness for new regulations, reduced reliance on imports, fluctuating commodity prices, access to resources); k) long term ROI of upgraded equipment/systems.

Employee Engagement Indicators: Inform – Educate – Empower – Reward/Recognize

- % of employees aware of company's waste reduction goals
- % of employees who participated in training (eLearning, brown bag lunch lectures) on zero waste/circular economy
- % of employees reporting "significant" or "very significant' contribution to waste reduction goals
- % and # of employees recognized for their innovative waste prevention/reduction ideas
- % increase in employee engagement and job satisfaction as result of involvement in zero waste practices

Fig. 4. Model of "Expanded Zero Waste" practice.

engagement. A *developmental approach* could go even further to help educate and empower employees to take action in their personal lives to reduce consumption, reuse, compost, and recycle (Mirvis, 2012). With any approach, however, ongoing communication should be top priority, as it is the basis for building greater employee engagement (Markos and Sridevi, 2010). The proposed model provides specific indicators to measure employee engagement in four key areas: awareness, education, empowerment and recognition/reward. Such indicators can demonstrate the business value of the CE initiatives and further strengthen support for the program (Veleva et al., 2012).

When comparing indicators found in the GRI G4 the proposed model seeks to link economic, environmental and social indicators, whereas GRI G4 tends to decouple the relationship between categories, which are often interrelated. For example, indicator G4 – EC1 asks for the economic costs distributed amongst cash flows such as operating costs, employee wages and benefits, etc. G4 – EN1 asks for non-renewable materials used and renewable materials used. The cost savings from renewable materials used is an example of integration between categories that attributes value to environmental indicators, which could help to expand adoption of zero waste/CE practices. The Expanded Zero Waste Model offers an integrated approach to sustainability reporting that also includes socio-environmental couplings. On average, organizations with higher levels of engagement receive up to 22% higher levels of production and significantly lower turnover rates (Baldoni, 2013). The proposed model aims to relate economic, environmental and social indicators and identify positive feedback loops to help better understand interdependent components and help galvanize the movement towards zero waste/the circular economy.

The model, however has some limitations. First, measuring impacts is often more complex and data is not readily available which can be a significant barrier for adoption. Second, measuring employee engagement requires getting buy-in from the HR department, which could be challenging considering the numerous surveys that each company already conducts. While the model is applicable to any company, there is a need to add some sector-specific indicators to better describe and measure “zero waste”/CE practices by a specific industry. In addition, proposed indicators must be pilot tested to determine feasibility and refine further. Finally, models and indicators are just tools and moving towards CE requires strong commitment by top management, clear vision, as well as specific goals, strategies, and targets for implementation.

6. Conclusion

Companies are a key player in fostering the transition towards a “zero waste”/CE society. They have the responsibility and the capabilities to implement innovative strategies and business models for designing-out waste, repurposing products and materials and separating biological from technical nutrients for continuous reuse. Despite the lack of policies to support such a transition within the U.S., a growing number of large companies are establishing goals around waste reduction and “zero waste-to-landfill” as part of their CSR commitments. Measuring waste reduction efforts typically includes “output” indicators that track reuse, recycling, composting, energy recovery, incineration, and landfill.

The present study calls for more research in an area which has received limited attention, suggesting that despite the significant progress reported by many companies, current efforts are inadequate in supporting a transition toward “zero waste” and CE. The authors examine three present challenges. First, when companies establish “zero waste-to-landfill” goals, they are focused on diverting the generated waste from going to landfill rather than aiming to prevent waste generation in the first place. As a result, they rely primarily on recycling and waste-to-energy methods for waste reduction instead of source reduction through changes in manufacturing and supply chain practices. This confirms previous research, which has raised concerns with the “zero waste-to-landfill” goals (Krausz, 2012). There is a need to establish robust goals for advancing adoption of waste hierarchy strategies to create impactful waste reduction programs.

Second, the study demonstrates that even within the same sector, companies' reporting of waste data is inconsistent and often lacks effective indicators for source reduction and reuse. While the GRI guidelines provide standardized indicators for measuring waste reduction through different methods, majority of these are focused on the environmental *outputs* and not the social, environmental and economic *outcomes* and *impacts* of such actions. In addition, some companies report the *percent of waste recycled, reused and composted* as one number, making it impossible to effectively measure and advance source reduction, reuse and remanufacturing. Others include waste-to-energy and incineration under recycling. Such practices do not provide critical feedback to employees and other stakeholders about progress made and opportunities to increase reuse and composting. Effective indicators must also communicate the greater significance of sustainable methods for waste reduction by measuring the social and economic impacts of such actions.

Third, while research has demonstrated that employees are companies' most important ambassadors for sustainability initiatives, their awareness and engagement for advancing “zero waste”/CE practices remains low even among sustainability leaders such as Biogen. Effective communication and employee empowerment are critical for identifying and implementing innovative approaches and initiatives.

The study has several limitations. First, it only focuses on non-hazardous waste. Future research should include hazardous waste and examine the role of green chemistry and toxics use reduction in reducing overall waste and transitioning to safer materials and processes. Secondly, due to the limited time and resources, the study of employee engagement at Biogen was based on a small sample of 102 employees. Future research should consider conducting a population study for a large company to allow for more extensive statistical analysis and hypothesis testing. Thirdly, the research involved only eight companies in the benchmarking of waste management practices. Future studies should expand this sample and conduct a survey including multiple companies to examine waste reduction strategies across different sectors and identify best practices.

The main contribution of this study is that it opens a new research area suggesting why current efforts to achieve “zero waste” might be inadequate to foster a transition to a circular economy. While a growing number of socially responsible companies have made commitments to support “zero waste” manufacturing, they lack effective indicators to measure progress, identify opportunities, and engage employees. Greater development, transparency and reporting of such indicators could help to advance information flows and pressure companies to shift from less sustainable waste disposal options to more preferred options of prevention and reuse. To address the identified challenges, this study proposes a new model for “expanded zero waste” practice, which integrates employee engagement and more robust measures for circular economic business practices. However, indicators are only tools and there is a need for effective goals and progressive regulations that introduce new incentives for private-sector leaders. Scaling up innovative partnerships and practices for advancing the circular economy will require the collaboration of many stakeholders such as large companies, entrepreneurs, government, NGOs, and academic institutions. Finally, there is a need for government leadership in shifting its procurement policies and helping decouple economic prosperity from resource consumption in order to advance the circular economy.

Acknowledgments

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Appendix A. Employee perception of Biogen sustainability performance based on length of service (0–2 years compared to over 2 years)

Q1 versus Q8: "*What is your perception of Biogen's current sustainability performance?*"

Statistically insignificant.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.833[a]	1	0.176		
Continuity Correction[b]	1.106	1	0.293		
Likelihood Ratio	1.825	1	0.177		
Fisher's Exact Test				0.230	0.147
N of Valid Cases	88				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.76.
b. Computed only for a 2 × 2 table ("above average" and "average and below").

Appendix B. Biogen employee knowledge about the company "zero waste-to-landfill" based on length of service (0–2 years compared to over 2 years)

Q2 versus Q8: "Do you know that Biogen has a "zero-waste-to-landfill" goal?"

Statistically insignificant.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	0.532[a]	1	0.466		
Continuity Correction[b]	0.266	1	0.606		
Likelihood Ratio	0.534	1	0.465		
Fisher's Exact Test				0.524	0.304
N of Valid Cases	91				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.70.
b. Computed only for a 2 × 2 table ("No" and "Yes").

Appendix C. Biogen Waste Management/Recycling Questionnaire

Biogen, March 17, 2016; conducted by UMass Boston & E.L. Harvey

Purpose: To assess employee awareness of Biogen waste reduction initiatives and identify future opportunities

1. On the scale of 1 to 5, what is your **perception of current Biogen sustainability performance**: (1-Don't know/not sure, 2-below average, 3-average, 4-above average, 5-sustainability leader)
2. Do you know that Biogen has a **zero-waste-to-landfill goal**? (Yes/No)
3. On the scale of 1 to 5 **how clear do you find the waste signage/ training/awareness** about separating recycling, compost and trash? (1-not clear at all, 2-somewhat clear, 4-clear, 5-extremely clear); *What type of training/signage/awareness would you like to see?*
4. Do you know if the **desk recycling bins** are for paper or all recycling? (Yes/No)
5. Which of the **following initiatives** would you consider **most important for reducing waste** at Biogen **(please select the top 3)**?
   a. Use compostable utensils and carry out materials……………………………..
   b. Transition from personal waste bins to centralized waste bins …………………
   c. Eliminate plastic water bottles (e.g., switch to water machines) ……………….
   d. Expand K-Cup recycling program ……………………………………………….
   e. Expand green purchasing……………………………………………………….
   f. Improve recycling in labs (e.g., non-hazardous plastic ware) …………………..
   g. Offer educational events (e.g. brown bag lunch presentations) ………………..
   h. Utilize the "follow you printing" program …………………………………………..
   i. Engage in team/interdepartmental activities (e.g. competitions) ……………….
   j. Other (please specify) ………………………………………………………………….
6. How would you **rate your current contribution** to Biogen's waste reduction goal? (1-not contributing; 2-small, 3-average, 4-significant, 5 –very significant)
7. On the scale of 1 to 5 (1-not significant, 5-very significant), **what role would you like to play in the future** to help Biogen further reduce waste?

Length of service:	Department/Function:
1–2 years	
3–5 years	
6–10 years	
11–15 years	
Over 15 years	

Thank you for taking the time to respond! If you'd like to be entered in the raffle, please provide your email address…………………………………………………………………………………………

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