"Zero Waste"—Myth or Reality?
Overview of the Concept, Its Current Application, Limitations, and Future Opportunities

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The movement toward zero waste (ZW) has been growing in developed countries in recent years as an alternative to the dominant "take-make-waste" model of production and a key approach for addressing climate change. A growing number of cities and companies are establishing "zero waste" goals, and consumers are discovering "zero waste" stores. But what does "zero waste" really mean? Is zero waste truly possible in the current economic system? This article aims to provide an overview of the concept, the main frameworks guiding its implementation, key limitations, and potential future opportunities in preventing waste and reducing environmental impacts by companies, cities, and individuals.

Every organization and individual generates some waste. There are different types of waste, such as municipal (what we typically put on the curb as "trash"), agricultural, construction, mining, and hazardous, among others (United States Environmental Protection Agency [US EPA], 2021a). The zero-waste movement, which began more than twenty years ago as a grassroots initiative (Seldman, 2016), has focused primarily on nonhazardous (municipal) waste. In 2018, the world generated 2.01 billion metric tons of solid waste, of which 13.5 percent was recycled and 5.5 percent was composted (Ellis, 2018). According to a recent World Bank study (Ellis, 2018), developed countries—which made up 16 percent of the global population—generated 34 percent of the global waste in 2018. The average person in North America generated 4.87 pounds of waste each day (Ellis, 2018), and total municipal solid waste increased more than three times between 1960 and 2018 (see Figure 1). While developing countries often generate less waste per capita, due to their large populations their waste generation is projected to grow significantly in the future (see Figure 2). Overall, waste generation globally is projected to reach 3.4 billion metric tons by 2050 (a 70 percent increase from 2018). The COVID-19 pandemic further exacerbated the problem due to the increased use of disposable products, online shopping (and related packaging), and stockpiling of food and other products (Sarkodie & Owusu, 2021). Besides endangering human health and the environment, waste contributes to climate change and demonstrates inefficient production processes. For instance, the US EPA has estimated that 40 percent of US greenhouse gas (GHG) emissions in 2009 came from the production, transportation, use, and dis-

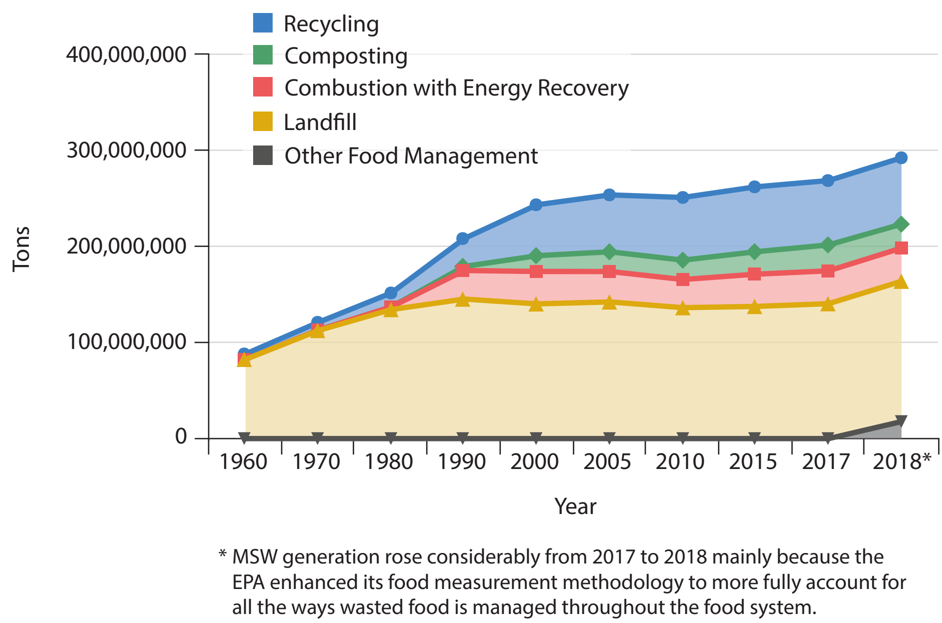

Figure 1: US municipal solid waste management by stream, 1960–2018.
Adapted from US EPA (2021, July 14).

posal of material goods (US EPA, 2009). Thus, preventing waste can help address environmental pollution and climate change, reduce the cost of production and waste management (by improving manufacturing efficiency, reducing the costs for raw materials, disposal of waste, and potential liability), and improve human health (by reducing air pollution from waste incineration, and water and waste pollution from landfill and accidental releases).

While waste prevention strategies have been used for millennia, the modern concept of zero waste was first introduced in 1995 by Daniel Knapp and his company Urban Ore, which focused on "total recycling" and thus preventing waste from going to a landfill (Seldman, 2016). The term has gained greater popularity over the last two decades with the growing environmental and sustainability movement. Despite its long use, however, the understanding and practice of the term still varies greatly as a waste reduction goal, aspirational statement, a tool for resource management, and a solution to pollution and global climate change (Veleva et al., 2017). The most widely used definition of zero waste was developed by the Zero Waste International Alliance ([ZWIA] 2018):

> The conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health.

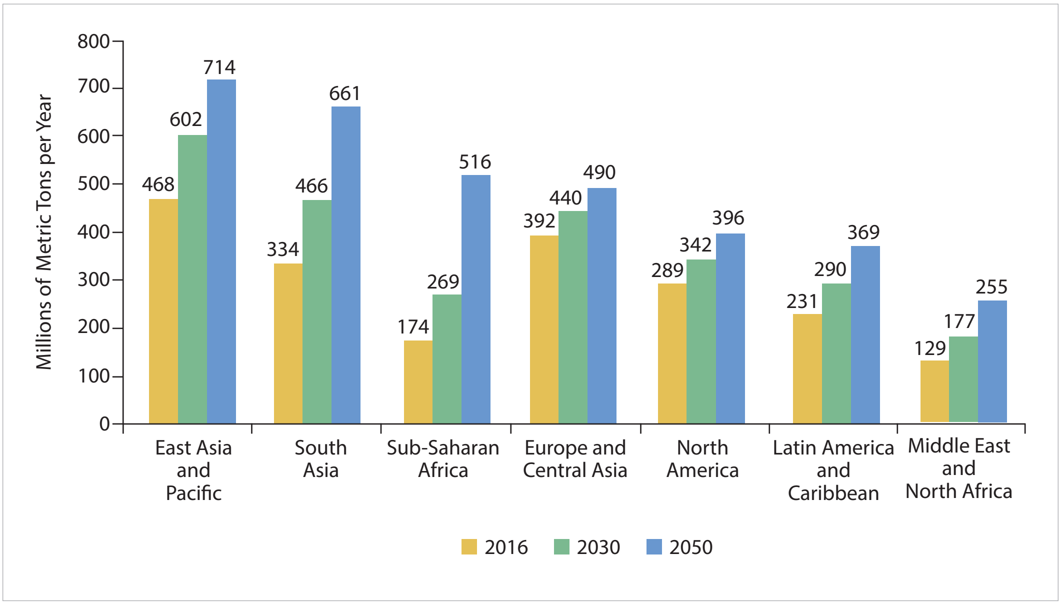

Figure 2: Predicted waste generation at 2030 and 2050 in millions of metric tons per year.

Data source: Kaza et al. (2018).

Zero Waste Frameworks

To guide the ZW transition, policymakers and nongovernmental organizations (NGOs) have developed different frameworks based on a *hierarchy of waste reduction methods* (see Figure 3). These frameworks typically include waste prevention, reuse, recycling, composting, incineration, and landfill. The US EPA has issued voluntary guidelines for a four-step hierarchy of waste management, including (1) source reduction and reuse, (2) recycling/composting, (3) energy recovery, and (4) treatment and disposal (US EPA, 2021b). In 1998, the EPA launched the Waste Reduction Model (WARM), an online tool that allows organizations to measure and track the GHG emissions associated with different waste management practices (US EPA, 2021c). For instance, research has found that landfilling generates the most GHG emissions, 400 kg/ton of carbon dioxide equivalent (CO2e), compared to composting, which generates 41 kg of CO2e per ton of waste (Nordahl et al., 2020). When we buy less or reuse products, we prevent the use of energy for the extraction, transportation, and processing of materials to manufacture products, thus greatly reducing resulting GHG emissions.

As part of the European Green Deal, the EU adopted a new Circular Economy Action Plan in March 2020 (European Commission, 2021). The circular economy is an emerging economic model seen as an alternative to the extractive (linear) industrial model of production used in developed countries. This model is based on several main principles, including (1) "designing out" waste, (2) separating biological from technical nutrients whereby the former are returned to the biosphere, and the latter are reused indefinitely, and (3) using renewable energy to reduce dependence

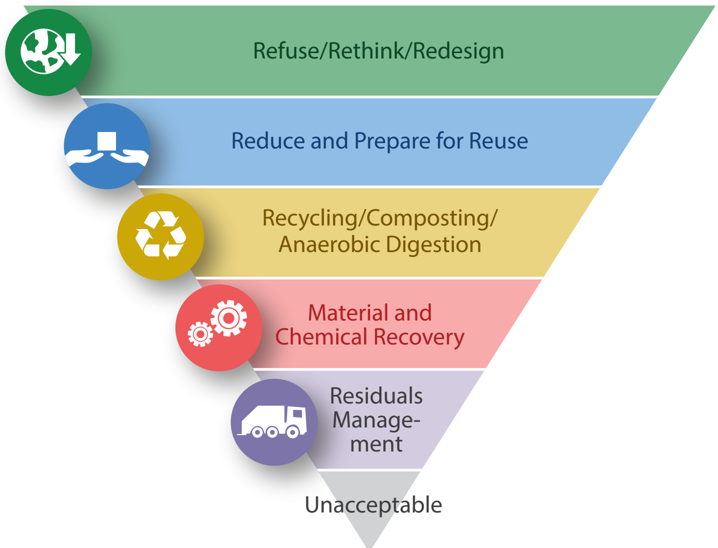

Figure 3: Zero-waste hierarchy.

Adapted from Zero Waste Europe (2019).

on finite resources and develop sustainable systems (see Figure 4). To advance waste reduction and circular economy, the EU has adopted a range of policies in recent years, such as bans on single-use packaging, mandates for increased recycling and composting, and a Zero Waste Hierarchy for Europe, prioritizing source reduction and prevention versus recycling and waste-to-energy (see Figure 3; Zero Waste Europe, 2019). The most desirable strategy for achieving zero waste, according to the US EPA materials management hierarchy and the EU Zero Waste Hierarchy, is source reduction and reuse, which requires addressing the system of production and consumption.

"Zero Waste" Strategies by Cities and Companies

In developed countries, municipal solid waste (MSW) is typically managed by towns and cities, which in recent years have faced challenges with waste disposal due to public opposition to constructing new landfills and incinerators. As a result, a growing number of towns and states have begun promoting alternative waste management strategies by using both incentives and mandates. For example, many cities have invested in recycling and composting infrastructure to make it easier for individuals and companies to divert waste. Some have bans on the disposal of commercial food waste (e.g., the 2014 Massachusetts Organic Waste Ban), matrices, electronics, and textiles. Many towns have also banned single-use plastic products such as plastic bags and straws. All these strategies, however, are primarily focused on recycling and continue to support the linear system of production. An increasing num-

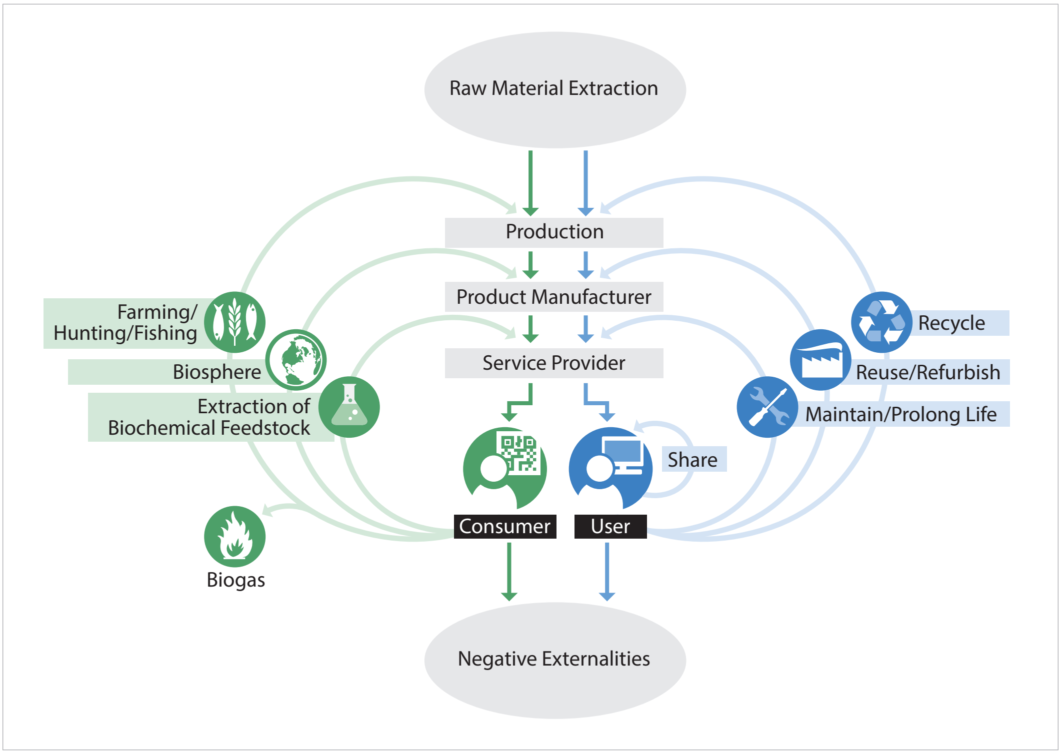

Figure 4: The circular economy reduces waste in the lifecycle of consumer goods. It can also apply to biochemical feedstocks, providing inputs for biogas or agriculture.

Adapted from Ellen MacArthur Foundation (2019).

ber of cities globally have established zero waste goals. For instance, in 2002, San Francisco was the first US city to pledge to become a zero waste city by 2020 ("10 Cities," 2019). It adopted a series of policies, such as the mandatory recovery of construction and demolition waste, mandatory recycling and composting, innovative three-stream residential and commercial waste collection, and surcharges and bans on some single-use products such as plastic bags and polystyrene foam packaging (US EPA, 2022). While it had to push back this commitment to 2030, it has made significant progress in diverting 80 percent of its waste from landfills in 2021. New York City established a goal to become a "zero waste to landfill" city by 2030 under a plan called OneNYC (OneNYC, 2021). Some of the strategies that New York City has already implemented include the collection of organic material for composting or anaerobic digestion, increasing the recycling of textiles and electronics, and reducing the use of nonrecyclable materials. In 2018, Boston adopted a zero-waste plan with the goal of reducing its waste by 80 percent to 90 percent by using waste prevention, recycling, and composting. The plan is aligned with the city's goal to become carbon neutral by 2050 (Zero Waste, 2021). It emphasizes repair, reuse, and recycling/composting and includes some bans, such as on single-use plastic bags (City of Boston, 2022). Globally, at least twenty-five cities have committed to zero waste goals, including Auckland (New Zealand), Ljubljana (Slovenia), Kamikatsu (Japan), Copenhagen (Denmark), and Pune (India), among others ("10 Cities," 2019). C40, a network of mayors from one hundred of the largest cities globally committed to fighting climate change, developed a declaration to advance zero waste, which as of January 2022, was signed by twenty-seven cities (C40 Cities, 2022).

Cities with zero-waste goals are turning to anaerobic digesters, textile recycling, electronics recycling, and public composting to increase the circularity of their waste management.

Photos courtesy Getty Images.

Besides cities, a growing number of companies have recognized the business benefits of reducing waste, such as reduced disposal costs and risks, improved efficiency and brand reputation, increased employee engagement, and diversified revenue streams (e.g., when companies sell unwanted products or waste) (Hermes, 2014). Reducing waste also helps decrease a company's carbon footprint, an important commitment for many multinational corporations.

Unilever was a first mover in the area of zero waste, requiring suppliers to take back packaging and containers, switching to reusable containers, recycling, composting, and waste-to-energy to prevent landfill disposal (Burton, 2020). Biogen, a biotech company based in Cambridge, Massachusetts, established a "zero waste to landfill" goal more than a decade ago and, since 2012, has achieved "virtual zero waste to landfill" in all of its owned operations (defined as diversion rate of 98 percent to 99 percent). In 2015 it diverted 98.9 percent of its waste from landfills; however, 14 percent was incinerated, and 23 percent was sent for energy recovery (Veleva et al., 2017).

To avoid being accused of "greenwashing" or misleading consumers about their practices and pretending to be "greener" than they actually are, a growing number of companies have begun using *zero waste certifications*. For example, Raytheon established a goal to achieve zero waste certification for twenty facilities by 2020, and as of 2019 had certified fifteen of its facilities (Danicelis, 2019). Google has succeeded in sending no waste to landfills in six of its data centers globally. Fetzer Vineyard became the first in its industry to achieve zero waste certification (Burton, 2020).

The most widely used ZW certifications in the US currently are offered by UL Environment, TRUE, and SCS Global Services.

- UL Environment's certification was launched in 2013 by UL (formerly known as Underwriter Laboratories), a nonprofit company best known globally for its product safety testing and certification (UL, 2022). The UL Environment initially offered three levels of zero waste validation: Zero Waste to Landfill (based on 100 percent diversion from landfill), Virtually Zero Waste to Landfill (requiring at least 98 percent diversion from landfill), and Landfill Waste Diversion (requiring at least 80 percent diversion from landfill). More recently, it has begun offering a Silver (90–94 percent diversion), Gold (95–99 percent), and Platinum (100 percent diversion) certification for landfill diversion, where at least 90 percent of the material is diverted using other methods than waste-to-energy (UL, 2022).
- TRUE (Total Resource Use and Efficiency) was launched in 2013 by the Green Business Certification Inc. (GBCI), formerly part of the Green Building Council, which is best known for launching the Leadership in Energy and Environmental Design (LEED) certification for buildings. TRUE is a point-based system where facilities earn points in fifteen categories, including redesign, reuse, recycle, compost, reporting, leadership, and training, among others (TRUE, 2020). To be certified, a project must achieve "an average of 90 percent or greater overall diversion from landfill, incineration (waste-to-energy) and the environment for solid, non-hazardous wastes for the most recent 12 months" (TRUE, 2020).
- SCS Global Services (SCS) launched a zero-waste certification in 2021 (SCS, 2021). Its certification offers recognition for waste diversion of 50 percent or greater, and facilities that have achieved 99 percent diversion are certified as "Zero Waste." The standard hazardous waste to be included toward overall waste diversion and requires that "no more than 25 percent of all waste is managed using waste-to-energy production" (SCS, 2021).

Leveraging the growing consumer awareness of waste and its environmental and social impacts, a growing number of ZW stores are emerging around the world and in the US. These stores represent an alternative to the traditional retail stores and typically offer reusable packaging (e.g., reusable bags, refillable containers), organic food, ethically sourced and fair-trade products, and local sourcing (Beitzen-Heineke et al., 2017). For instance, Boston's first ZW store, Uvida, was opened in 2020 by Maria Vasco, a young entrepreneur and graduate of UMass Boston School for the Environment, who was passionate about eliminating plastics and wanted to offer customers packaging-free and plastic-free options (Bremer, 2022). A study in Europe, however, revealed that consumers must sacrifice convenience and accept limited product variety and higher prices, thus making ZW stores a niche market rather than the mainstream. According to Beitzen-Heineke et al. (2017), changing current shopping practices requires "influencing consumer behavior, convincing suppliers to change their packaging practices, and solving the dependency of food logistics on packaging. To achieve wide-ranging, significant environmental and social benefits, zero-packaging stores will ultimately have to offer service levels that are comparable to conventional supermarkets" (p. 1528).

A young woman refills body wash into a reusable glass bottle in a zero-waste (ZW) store in London, England. ZW stores promote the preferred waste-management options of source reduction and reuse.

Photo courtesy Getty Images.

Current Limitations and Future Opportunities in Advancing Zero Waste

Despite the progress in advancing ZW over the past two decades, the concept has several key limitations. First, achieving ZW is not possible due to the first law of thermodynamics (according to the law of thermodynamics, there are always losses when energy and materials are converted from one form to another). Even when collected and recycled, most materials are "downcycled" or turned into inferior products that cannot be reused continuously. The widely adopted "single-stream recycling" (where all recyclables are placed together in one recycling bin), while convenient for consumers, leads to high levels of contamination that prevent continuous reuse and recycling. A study of 223 provincial municipalities in Canada over a ten-year period found that while single-stream recycling programs collected more material, they were most costly due to the higher materials management costs (Lakhan, 2015). Single-stream recycling leads to higher levels of contamination, requires more advanced separation technology by the recyclers, and leads to a higher percentage of recyclables being sent to disposal (via landfill or incineration). These costs increased further with the adoption of the Chinese National Sword in 2017, which banned exports of recyclables with high levels of contamination to China. Therefore, the EU Zero Waste Hierarchy calls for "high quality material recovery from separately collected waste streams" (see Figure 1). Second, the current ZW movement is primarily addressing nonhazardous (municipal) waste, thus largely ignoring the problem of hazardous, construction, mining, and other types of waste.

Third, most companies and municipalities 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; Veleva et al., 2017). Veleva et al. (2017) examined eight biotech and pharmaceutical companies' waste reporting and found that despite the use of standardized guidelines such as the Global Reporting Initiative (GRI), reporting of waste data differed greatly, which made it impossible to effectively compare companies' waste reduction practices and identify opportunities for improvement. 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. 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?* (Veleva et al., 2017) This finding is in line with previous research reporting that "zero waste to landfill" goals are problematic as they do not address the problem of overconsumption (Krausz, 2012). To effectively address the problem of waste, "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, p. 208). Pollans (2017) examined the case of municipal solid waste in Boston, Massachusetts, and found that the main barriers to waste *prevention* included "limited enforcement of existing policy, institutional and physical fragmentation, financial incentives, and the vested interests of the private sector to protect the disposal mode of governing" (p. 2300). The stakeholders who were most interested in moving beyond recycling and waste-to-energy, such as NGOs and citizen organizations, "lack access to decision-making processes and daily operations, limiting their ability to influence policy and practice" (Pollans, 2017, p. 2300).

Finally, a growing number of researchers are sounding an alarm that ZW is incompatible with the current growth-focused economy and related policies. Sattlegger (2019) argues that from a consumer perspective, ZW is challenging due to a range of social, cultural, and sociotechnical trends, such as "to-go culture," convenience, and online shopping. In addition, policymakers' current focus on growth and consumption goes directly against waste avoidance and prevention, thus making such transition politically challenging. "Although the throw-away society is increasingly criticized, it is hardly possible to renounce packaging. We are not free in our consumer actions. … Packaging and waste are firmly anchored in the capitalist logic of our society," argues Sattlegger (2019, p. 4). Thus, "packaging-free purchasing and avoidance of surplus and waste can only be a niche solution in such a system and by no means the basis of a growth-based economy" (Sattlegger, 2019, p. 3). Bartl (2011) also argues that the EU Zero Waste Hierarchy and related regulations are "little more than a paper army, and in practice no decoupling of Gross Domestic Product (GDP) and waste production has been obtained to date" (p. 2370). Sattlegger (2019) believes that "a sustainable-garbage-free society therefore has no choice but to abandon the growth-based economic model" for a steady-state economy (p. 4). The latter is characterized by a stable population, stable use of materials, and energy at sustainable levels (Daly, 1991). Making this shift, however, requires bold policy actions.

According to Cohen et al. (2017), in the current capitalist economy, where consumption is seen as key to economic success, changing the dominant "regime" is challenging and therefore more likely to happen gradually over time, in market niches that do not represent a threat to the dominant players. The literature on sustainability transitions, degrowth, and steady-state economy has called for national-level policies to overhaul our current economic system to ensure more sustainable production and consumption (Jackson, 2009; Cosme et al., 2017; Cohen et al., 2017).

Conclusion

Despite the growing commitments by cities and companies, making the transition to zero waste is challenging due to the economic stakes and complexity of the current production system, outdated policies that tax labor rather than resources, a lack of effective measurement and awareness about the significance of different ZW strategies, and most importantly, a growth-based economy that promotes consumption and thus waste generation. As Daly (1991) argues, we continue to operate our economies as we did in the early twentieth century, when labor was scarce and resources plentiful. We must change our policies to tax the scarcer resource currently (e.g., natural resources) in order to protect it. In terms of measurement, we continue to use the GDP as the key indicator for a variety of government policies when studies have demonstrated that it promotes endless consumption and does not adequately reflect many activities that are important for society (e.g., protecting the environment, promoting volunteering) (Costanza et al., 2009). Achieving ZW requires all stakeholders to take responsibility—manufacturers to design their products and production systems differently, consumers to be responsible in their consumption and product end-of-life management, and governments to offer the political and economic framework to support such transition (Boguzs et al., 2021). In order to make this shift, we must overhaul our capital markets, which are focused on short-term gains, change our tax system to protect scarce resources, promote cultural and social changes that support quality of life versus consumption, and implement new indicators of economic progress as an alternative to the GDP.

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