

Article

Envisioning a Circular Economy: The Journey of One Mid-Sized Midwestern City

Jennifer Petoskey ^{1,*}, Missy Stults ², Eileen Naples ¹, Galen Hardy ², Alicia Quilici ¹, Cassie Byerly ², Amelia Clark ², Deja Newton ², Elizabeth Santiago ² and Jack Teener ²

¹ Department of Public Works, Ann Arbor, MI 48108, USA; enaples@a2gov.org (E.N.); aquilici@a2gov.org (A.Q.)

² Office of Sustainability and Innovation, Ann Arbor, MI 48104, USA; mstults@a2gov.org (M.S.); ghardy@a2gov.org (G.H.); cbyerly@a2gov.org (C.B.); aclark@a2gov.org (A.C.); dnewton@a2gov.org (D.N.); estantiago@a2gov.org (E.S.); jteener@a2gov.org (J.T.)

* Correspondence: jpetoskey@a2gov.org

Abstract: The City of Ann Arbor has committed to a just and equitable transition to community-wide carbon neutrality by 2030. Our guiding plan, A²ZERO, outlines seven strategies and 44 actions that were chosen by the community to achieve this goal. One of the seven strategies is “Changing the Way We Use, Reuse, and Dispose of Materials”, including the action: “move toward a circular economy”. Many cities are trying to move towards a circular economy, tailoring policies, actions, and outreach towards their unique circumstances. Regardless of context, becoming circular requires an array of actions including collaboration and partnership, policy setting, program development, and education. This paper explores how the concept of the circular economy is discussed in the peer reviewed literature and in practitioner circles, exploring similarities and differences. Following this, we undertake a critical instance case study on the City of Ann Arbor’s materials management programs and efforts towards achieving a more circular local economy. We conclude by offering pathways that Ann Arbor and other cities across the U.S. can pursue to advance a circular economy.

Keywords: circular economy; materials management; zero waste; solid waste; environment; life cycle thinking; sustainability; system change



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1. Introduction

Climate change. Growing economic disparity. Overconsumption. Resource extraction. Systemic and institutional racism. Looming planetary boundaries. At first glance, these major global crises have little to do with one another. When viewed closely, they are firmly linked to our global extractive economy and the continued push toward greater consumption. These crises are intersecting in tangible ways in communities across the world, making communities ideal testbeds to explore solutions to these wicked challenges [1–3].

One solution set addressing many of these intersecting challenges currently gaining traction in the literature and the political sphere is the concept of a circular economy [1,4–9]. The definition of a circular economy remains contested [5], but the concept is nested within the larger study and research of sustainable development, which was initially defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [4,10].

For the purposes of this paper, we use the Ellen MacArthur Foundation’s definition of a circular economy:

“A circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails decoupling economic activity from the consumption of finite resources and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital”. [11]

Put simply, a circular economy is a system designed to reuse materials continuously. It is modeled after natural systems where nothing ‘goes away’ or is wasted. Perfectly envisioned, a circular economy promotes sustainable development and job creation, reduces costs and stabilizes price volatility, and positively contributes to environmental health [8,12–14]. By combining sustainable consumption and sustainable production, a circular economy strives to minimize environmental and social impacts across the entire lifecycle of material use (and reuse) [4,15].

To date, most of the research on a circular economy has looked at one or a few elements in the material production to use cycle [16]. Pomponi et al. [17] note that this field’s research focuses on either the macro-scale, like eco-parks, or the micro-scale, by examining individually manufactured products. Korhonen et al. [4] believe the scientific research to be largely unexplored, with research being largely unorganized and a vague collection of ideas from several fields. In an attempt to provide some structure, a literature review by Kalmykova et al. [16] explored a variety of theoretical approaches to advance a circular economy, culminating in a database of 45 strategies and over 100 case studies of entities working across distinct phases of a circular economy. Similarly, Friant et al. classified 72 different circular economy-related concepts into a 4-part circularity typology to better conceptualize the various theoretical and practical ways to advance the concept: reformist circular society, technocentric circular economy, transformational circular society, and fortress circular economy [18].

From an applied perspective, the organization and categorization of these strategies can provide a useful framework to craft a local circular economy strategy and begin working upstream and downstream to influence necessary changes. However, as noted by Kalmykova et al. [16], few examples exist of a comprehensive and holistic approach to fostering a circular economy, leaving practitioners with the responsibility of piecing together a strategy. As further illustration, case study research by Marin et al. specifically looking at work in Leuven, Belgium found that a disconnect between theory and practice continues to lead to “messy” transitions from theory to public policy and program implementation, particularly in tracking data and monitoring outcomes [19].

Other research on the circular economy has looked at how the concept is used as a boundary-spanning term [5,20], uniting approaches such as zero waste [21], sustainable development [22,23], and environmental and natural resource protection [21]. In this way, a circular economy creates space for people from various backgrounds to come together and co-create unique definitions and pathways for action [24]. Yet, others argue that the term is too broad to be useful, making it challenging, if not impossible, to operationalize [9,25–27].

As a whole, the peer-reviewed literature on the circular economy continues to wrestle with the definition(s) and constructs that compose a circular economy, with little attention being paid to operationalization of the concept [9,23,28,29]. Put another way, gaps remain in how local and regional practitioners, especially those at public authorities, can practically and realistically craft and implement holistic circular economy strategies [30]. Without more literature that explicitly discusses the marriage of theory and practice and is more responsive to contextual realities, there is little likelihood that research contributions will inform practical work, or that practical activities will inform theory development. Given that society is faced with increasing demand for resources at the precise time recognition of resource finiteness has emerged, failing to solve these problems has and will continue to have negative impacts on our natural, built, cultural, economic, and social systems [31].

This paper aims to contribute to the practical knowledge of one proposed solution: the circular economy. To do this we begin by exploring the gray literature as it relates to local applications of a circular economy. Next, we use a critical instance case study methodology to explore historical materials management in one midwestern community, Ann Arbor, Michigan, highlighting how this history has laid the foundation for a more recent commitment towards creating a circular economy. We conclude with recommendations on how the City of Ann Arbor can move forward with achieving its goal around a circular

economy and achieving a just transition to community-wide carbon neutrality by the year 2030 (known as A²ZERO) [32].

As practitioners, we face an intersecting and urgent array of environmental and social crises that will remain intractable problems unless we implement practices that are both informed by and help inform theory. Through our paper we argue that perpetuating the current paradigm of theory informing theory, and practice informing practice is, at best, insufficient and, at worse, obfuscates our responsibility to meaningfully and immediately address crises such as climate change, inequality, and environmental degradation. The goal of this article is to identify an opportunity to strengthen the connection between theory and practice in the expectation that the integration of the two fields will result in a more effective adoption of circular economy principles and practices in cities like Ann Arbor, MI. As such, our research question is simply: what lessons from theory and practice can inform the City of Ann Arbor as it moves forward in advancing a circular economy?

2. Materials and Methods

Two primary analysis methods were utilized in this paper: (1) a review of proposed activities to advance a circular economy as highlighted in the gray literature; and (2) a critical case study analysis of the City of Ann Arbor's materials management initiatives. In coding analysis, authors analyzed the peer reviewed and practitioner literature (including gray literature, conference reports, urban sustainability practitioner forums) to identify common themes and discrepancies. After an initial review of the peer reviewed and gray literature, the authors developed a coding protocol similar to that administered by Woodruff and Stults [33] and used that to analyze the various types of circular economy-related actions being proposed or advanced in practice. The coding protocol consisted of 12 predetermined categories: capacity building; collaboration/partnerships; funding; infrastructure; law; outreach/education; planning; policy; programs; social equity/inclusion; study/assessment/research/monitoring; and technology (Table 1). The intent of the 12 metrics was to help cognitively group and associate related actions—it was not to prioritize one type of action over another. The key words “local”, “circular economy”, and “sustainable materials management” were used to identify peer-reviewed and gray literature to inform code development. Articles written in 2010 or after were selected for review, with an emphasis on examples from U.S. and European communities. Each article was then reviewed to see if it included recommended actions to advance a circular economy. If yes, then the article was coded by one of three reviewers, following recommended practices on content analysis [34]. Following the initial coding, the reviewers met to compare codes and gauge intercoder reliability. A final, reconciled set of codes was then used to assess the most and least prominent types of actions proposed or taking place in local practitioner circles.

Table 1. Classification system used to organize the various types of actions taking place in practice related to a circular economy.

Code Type	Definition of Code
Capacity Building	Activities to develop human resources, institutions, and communities, equipping them with the capacity to undertake circular economy-focused actions
Collaboration/Partnerships	Activities focused on leveraging external entities to advance a circular economy
Funding	Activities focused on securing capital to implement circular economy-related actions
Infrastructure	Activities to create new physical infrastructure, remove physical infrastructure, or modify how physical infrastructure is built
Law	Legal activities or ordinances that impact movement towards a circular economy
Outreach/Education	Activities focused on increasing public knowledge
Planning	Activities that incorporate circular economy science, impacts, principles, or actions into government and institutional planning processes, efforts, or existing initiatives

Table 1. Cont.

Code Type	Definition of Code
Policy	Activities to create new or revise existing regulations and legislation
Programs	Activities to modify or expand on the-the-ground behavior, operations, management, or programs that effect progress towards a circular economy
Social Equity/Inclusion	Activities that center social equity, inclusion, and justice in the work towards achievement of a circular economy
Study/Assessment/Research/Monitoring	Activities that focus on gathering information and creating reports, maps, or models; monitoring includes observation or repeated measurements over time
Technology	Activities to develop or expand circular economy technologies

For the critical instance case study analysis, City of Ann Arbor historical records were analyzed, and current and historical staff were interviewed. As the authors are all staff or interns at the City of Ann Arbor, access to historical records, including previous materials management plans, staff notes, and records were readily available. This material was analyzed and coded using the methodology described above to both create a more holistic understanding of the history of materials management in Ann Arbor and to place that history within a comparable framework to what is discussed in the peer-reviewed and gray literature.

3. A Circular Economy in Practice: Lessons from Urban Practitioners

In the last several years, the circular economy concept has gained traction in policy, sustainability, and materials management practitioner communities. Celebrated as a technique to minimize environmental burdens, stimulate the economy, and sustainably manage materials, a circular economy is viewed as a versatile and essential tool in sustainability offices [1,6–9].

Networks such as the Urban Sustainability Directors Network (USDN) and ICLEI-Local Governments for Sustainability have stood up learning groups to more fully explore concepts related to the circular economy. ICLEI recently partnered with Circle Economy and ten local governments to help identify and prioritize circular opportunities in their community or region [35]. Figure 1 illustrates how USDN thinks about sustainable consumption, grouping approaches into four categories: consuming more efficiently, consuming differently, sufficient consuming, and moving beyond consuming or thriving [35].

Another prominent player in the practitioner space is the Ellen MacArthur Foundation, which has helped elevate the concept, made investments in research and practice, and contributed to a significant body of literature around the circular economy [11]. The Foundation's online platform provides outlines, visions, and plans to help guide circular economy work in cities. According to the Foundation, a circular economy will allow us to rethink how we make and use things while ensuring long-term prosperity in cities [11].

Generally speaking, urban practitioners appear to use the terms circular economy and sustainable resource management interchangeably. This may be due to the reality that practitioners are often forced to unite what may be perceived as disparate concepts into a tangible and implementable work plan. In such a situation, theoretical and conceptual distinctions fall away, and the practical realities and constraints take center stage.

In addition to nonprofit and philanthropic support for a circular economy, a great deal of informal collaboration helps inform the practical application and understanding of the concept. This type of informal sharing takes place through networks, personal affiliations, and conferences. To help provide a succinct overview of some of the promising practices related to a circular economy discussed within practitioner communities, we developed a classification system based on that used by Woodruff and Stults [33], informed by Kalmykova et al. database [16] (Table 1).

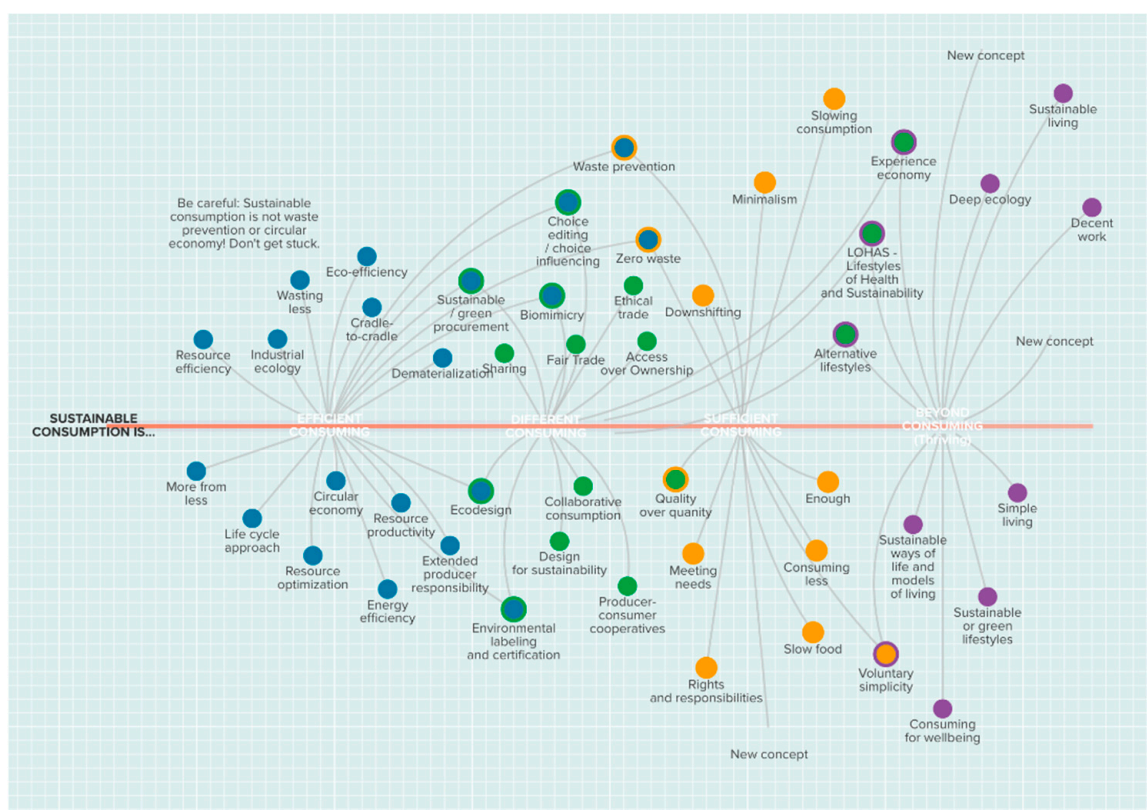


Figure 1. Conceptualization of Sustainability Consumption per the Urban Sustainability Directors Network [35].

Using this classification system, we find that the majority of promising activities actively discussed in practitioner circles relate to: collaboration and partnerships, laws, planning, policies, and programs, and infrastructure. The least common types relate to: funding and social equity and inclusion. The remainder of this section explores some of these actions, primarily focusing on those development at the sub-national level in U.S. and European communities.

Often touted as a leader in the circular economy space, the City of Amsterdam's circular economy strategy includes eight (8) of the 12 coded actions [36]. Their approach to circular economy closely aligns with the technological concepts of the smart city and sharing economy, which reflect the Dutch commitment to environmentalism, ecological modernization, and a Green Economy [37]. The city continually embraces collaboration, including a project with the local water utility and waste and energy company on policy to reframe three regimes (waste, energy, and construction materials) to one more focused on circularity improvements, specifically the goals of reducing greenhouse gas emissions and material consumption with the opportunity of simultaneously spurring economic growth and employment opportunities. Additionally, Amsterdam is working on localizing infrastructure and promoting decentralization to make systems more robust and circular [37]. A disconnect between consumption and production patterns remains, however, with little detail within the Amsterdam's circular economy strategy provided in support of changing consumption patterns. While the city affirms its commitment to a sharing economy which encourages "activities . . . that will benefit innovation, social inclusiveness, entrepreneurship and sustainability", this is largely framed as an independent process from municipal intervention [37]. In fact, the Netherlands approach as a nation to achieving a circular economy largely focuses on incentivizing a steady market supply for more sustainable services and products by removing legal and regulatory burdens rather than influencing consumer demands [37].

Barcelona's circular economy strategy aligns with nine (9) of the 12 coded actions [38]. The city has an ambitious goal to become a self-sufficient region by 2050, which will be

achieved by large scale implementation of energy initiatives, redesigning the transport system, and installing intelligent heating and cooling systems [39]. Barcelona is also part of the Fab City initiative, a concept designed by Tomas Diez which presents a new model for self-sufficient cities through “locally productive and globally connected” means. This experimental approach focuses on sharing information as opposed to resources to harness the benefits of digital technologies to create goods [39].

The city of Glasgow’s circular economy strategy touches on 10 of the 12 coded actions [40]. The City’s comprehensive strategy focuses on policy changes, programmatic initiatives, education, and engagement [39]. The strategy is founded on many policies including the first Scottish government’s 2002 sustainability strategy, and the Climate Change Act, which was passed in 2010 and helped create the nation’s Zero Waste Plan. Glasgow places an emphasis on businesses as part of the circular economy work, which is why they created the Green Business Network. One of the challenges they are facing with implementing a circular economy is making it simple and understandable so that people can easily be involved and contribute.

Paris’ circular economy strategy touches on eight (8) of the 12 coded actions [41]. To identify and implement strategies, it collaborated with a General Assembly of government authorities, businesses, scientific institutions, non-profit organizations, and citizens. Its strategy built upon laws already in place in France around energy and food waste reduction as well as European Commission initiatives to achieve zero waste and resource efficiency by 2050. Paris’ policy centers the circular economy as “the first stage in the fight against climate change” in both its municipal programs and its work to legitimize Greater Paris as the administrative institution for the region and symbolic embodiment of the Paris Climate Agreement [37]. Paris frames the circular economy as a “collective and unifying political horizon”, which includes a focus on social cohesion and a social and solidarity economy supporting vulnerable groups [37].

London’s circular economy strategy identifies 10 of the 12 coded actions [42]. Inspired by the Ellen MacArthur Foundation’s framework and network, London is implementing the goal of achieving a circular economy for Greater London by 2036. Faced with a rapidly growing population, London is particularly concerned with waste reduction and resource exploitation, with an emphasis on impacts like price volatility, resource degradation, and disruptive socio-technical innovations [37]. London’s circular economy plan identifies outreach through media and digital venues as well as finance, government, and higher education as enabling factors to support efforts to change business models in high impact sectors such as: buildings, food, textiles, electronics, and plastics. The plan proposes funding through venture capital and tax reform laws, as well as training and knowledge-sharing opportunities to scale new business models. The proposes tracking five (5) metrics to assess effectiveness, including: the number of circular business start-ups and of traditional businesses transitioning to a circular business model; the number of circular economy demonstration projects; the rate of product recycling, sharing, re-use and remanufacture in the specific focus areas; the number of GLA (Greater London Authority) group procurements that use circular economy principles; and the contribution to the greenhouse gas emissions reduction targets in London” [37].

Seattle, Washington’s approach to a circular economy aligns with eight (8) of the 12 coded actions [43]. The city is a technological and manufacturing hub, with growing levels of air pollution, energy demand, waste generation, population growth, and water usage as a result of continued urbanization trends and changing climate conditions [44]. As a part of its 2013 Climate Action Plan, the City committed to a goal of becoming carbon neutral by 2050, which includes 2030 midpoint goals of increasing waste diversion above 70% and reducing energy use by 20% [45]. After an initial decrease in all emissions following the plan’s adoption, the most recent years of available data show setbacks in every measured sector, which include buildings, transportation, and waste, putting 2018 levels on par with those measured in 2008 [46]. The most progress has been seen in waste

diversion as the city continues their educational initiatives and embraces policies and programs targeting both supply changes and shifts in consumer demand [44].

Boulder, Colorado's circular economy strategy identifies 10 of the 12 coded actions [47]. As part of their Climate Mobilization Action Plan (CMAP), the City worked with a sustainability consultant to create Circular Boulder, a plan to create a zero-waste and climate neutral city. Three themes Boulder is focusing on are: environment and resilience; society and economy; and equity. The city has committed to becoming zero-waste by 2025 and created strategies that will decrease per capita waste generation [47]. These strategies are informed by the city's urban metabolism analysis, which was an assessment of the material flow in and out of Boulder. For example, through this analysis they found that \$2.3 million dollars of valuable materials are being sent to landfills; 28% of which is packaging material. They used this information to create a roadmap that included but is not limited to engaging the public and working with city departments to reduce packaging.

Other prominent examples include the City of Phoenix, Arizona's Reimagine Phoenix Initiative: an initiative that invests in new programs and public-private partnerships like the Resource Innovation Campus, a re-manufacturing hub. Or Orlando, Florida whose waste reduction goals brought into focus the need for a food waste diversion program that repurposes unused packaged food from after-school programs to local food pantries. Similarly, Alameda County, California has mandatory composting and recycling programs at all public schools. Washington, D.C. requires that businesses that serve food or alcohol impose a \$0.05 fee for each paper and plastic bag distributed with any purchase, generating more than \$19 million in revenue for other materials management programs since its inception in 2010. The City of San Diego, California has a recycling mandate for residential, commercial, and special events and has a construction and demolition ordinance that uses a permitting deposit that is proportionally refunded to the amount of waste diverted during the construction or demolition process.

While the aforementioned are merely examples of laws, planning, policies, and programs that support the movement towards a circular economy, they are demonstrative of the types of activities local practitioners are discussing, exploring, and looking to replicate. Largely missing in practice are actions related to funding and advancing social equity and inclusion. Most of the funding that does exist comes from higher levels of government (state or national offices) and focuses on one or two specific components of advancing a circular economy strategy. The lack of funding support available is fairly traditional, although not desirable, in practitioner communities where a history of idea generation predates financial investments necessary to support the implementation of ideas.

In terms of social equity, few actors have concrete pathways for integrating the equity considerations into their actions. The United Nations Environment Programme (UNEP) Life Cycle Initiative includes Social Life Cycle Assessment (S-LCA) as a method to assess the social and sociological aspects of products, as well as their potential positive and negative impacts along a product's life cycle. The few examples found of work at the intersection of the circular economy and social equity focus on requiring waste to be managed near the point of generation (European Union) and work coming out of the Social and Solidarity Economy pushing practitioners to consider people over profit when making decisions. For example, in the United States, the City of Oakland, California's 2030 Equitable Climate Action Plan identifies actions, including targeted measures to reduce material consumption and waste, to combat climate change while ensuring that those impacted by environmental injustices will benefit from action. Overall, work related to the intersection of the circular economy and social equity remains nascent. The lack of explicit discussion about social equity may be due to how the circular economy has been framed as a technocratic issue, with discussions rarely focusing on concepts such as differential impacts or historic and systemic racism and how that intersects with visions of a circular economy. Given the prominence of racial and social equity in sustainability practitioner circles, we anticipate much more attention being paid in the near future as to how a circular economy intersects

with social and institutional systems and how these interactions affect different portions of the community.

Understanding the state of circular economy planning and action in practice can help inform not only the collective body of knowledge around the operationalization of the concept, but this knowledge can also help other communities, such as the City of Ann Arbor, Michigan, create more holistic approaches towards creation of a circular economy.

4. A History of Materials Management in the City of Ann Arbor, Michigan

Originally settled by Ojibwe, Odawa, Potawatomi, and Wyandot tribes, Ann Arbor is a medium-sized (pop. ~120,000) city in Michigan that sits along the banks of the Huron River. Dubbed “Tree Town”, Ann Arbor is home to more than 50,000 trees. The city is also home to the University of Michigan, constantly ranked as one of the top public universities for research and education in the United States. Named a “recycling pioneer” by the Environmental Protection Agency, Ann Arbor has a long and rich history of environmental activism. As illustration, in March 1970, students the University of Michigan and community members held the nation’s first “Environmental Teach-In”, which drew more than 15,000 participants and earned the attention of the *New York Times* who called the event “one of the most extraordinary happenings ever to hit the great American heartland: four solid days soul-searching, by thousands of people, young and old, about ecological exigencies confronting the human race” [45]. Today, Ann Arbor’s commitment to tackling environmental crises remains strong as evidenced by the City Council unanimously adopting the A²ZERO Decarbonization Plan—a plan that lays out a path to a just transition to community-wide decarbonization by the year 2030 [32].

The following sections provide a historical and current look at materials management activities in Ann Arbor in order to inform how the City may move forward with reaching the goals outlined in A²ZERO. These activities are organized around the twelve types of actions outlined in our coding protocol.

4.1. Collaboration and Partnerships

Ann Arbor began recycling and composting services in the 1970s and now contracts with WeCare Denali to manage a City compost facility. The City also contracts with Recycle Ann Arbor, a 501(c)(3) nonprofit that has been in operation for more than 40 years, to help manage the City’s recycling. In 2020 the City entered into a new service agreement with Recycle Ann Arbor for a Materials Recovery Facility, which helps process recyclables locally. Additionally, Ann Arbor participates in regional coalitions, including as a non-voting member of the Washtenaw Regional Resource Management Authority, a waste authority comprised of seven municipalities in Washtenaw County formed in 2019 to improve local and regional recycling streams. The City also participates in the Washtenaw County Home Toxics Center, which provides education to reduce the manufacturing and purchase of home toxics and offers a safe way for residents to dispose of toxic materials. Since its inception in 1995, the Center has collected and properly disposed of over 3.6 million pounds of toxic materials. The City also provides funding for County annual clean up days for proper disposal of household hazardous waste. The City is an active member on the County’s Plan Implementation Advisory Committee for its Solid Waste Plan. Finally, the City also supports and helps facilitate other partnerships through its Sustaining Ann Arbor Together grant program, a small grant program to help advance local sustainability initiatives in the public sphere. In 2018, the grant program awarded funding to the Ann Arbor Area Elders Climate Action Chapter and the Interfaith Council for Peace & Justice to raise awareness about the City’s food scrap composting program through a cart stickering event.

4.2. Infrastructure

Like many local governments, the City’s infrastructure primarily focuses on end of life disposal. Specifically, the City has a compost facility for organic materials and a

drop-off station for materials not collected curbside. The City is also in the process of refurbishing its Materials Recovery Facility with an expected operational date of late 2021. Weights of materials into each of these facilities is also tracked with the City's own scale. Washtenaw County, in which Ann Arbor is located, also has a strong collection program for household hazardous waste. Finally, there are many businesses and non-profits within the City and County that offer repair, reuse, and rental services, but these are not coordinated by the City.

4.3. Plans

Ann Arbor has implemented multiple strategic plans to improve community and environmental sustainability. Underlying most of Ann Arbor's strategic plans is a bedrock of partnership, collaboration, and coalition building. In June of 2020 the City adopted A²ZERO: A Living Carbon Neutrality Plan [32] that outlines a comprehensive and ambitious goal to achieve a just transition to community-wide carbon neutrality by 2030. The plan includes seven overarching strategies and 44 actions identified by members of the public, technical advisors, the peer-reviewed and gray literature, and staff. One of the seven overarching strategies is "Change the way we use, reuse, and dispose of materials" [32] with a sub-action of "move towards a circular economy". Under this action, the plan outlines the importance of working with other municipalities to create tools to track and understand the full life cycle impacts of materials, goods, and services and begin intervening across this life cycle to lower environmental, social, and economic impacts. This action is highly connected to the City's Solid Waste Resource Management Plan (SWRMP), which outlines recommendations to achieve responsible resource use [48].

Ann Arbor's SWRMP was developed in accordance with the City's Sustainability Framework [49] and the City's 2013 Waste Less: Solid Waste Resource Plan Update. The SWRMP incorporates the Sustainability Framework [50] goal of responsible resource use to "produce zero waste and optimize the use and reuse of resources in our community". Specifically, the SWRMP calls for actions to increase diversion rates city-wide, expand and increase opportunities for composting and recycling, implement educational and stakeholder outreach, and implement a plan which mandates recycling at all non-residential locations in the City. This plan built on the 2016 *Comprehensive Organics Management Plan*, which contains strategies to reduce and divert organic wastes, including all food scraps.

These most recent plans build on a long tradition of strategic planning and coordination within the City of Ann Arbor (Figure 2).

4.4. Outreach and Education

Like many cities (e.g., London and Glasgow) Ann Arbor emphasizes outreach as a significant element of its waste prevention and diversion strategies. The City contracts with a local non-profit, The Ecology Center, to provide outreach activities to local schools. This outreach consists of in-school presentations from kindergarten through high school about recycling and composting. The City also offers recycling outreach materials, training, and materials audits to local businesses. Finally, information about the circular economy and the City's recycling and composting programs is provided at three annual community fairs and in multiple resident newsletters.

Ann Arbor also runs an A²ZERO Ambassadors program which brings together and trains interested community members on A²ZERO and ways they can work with their family, peers, and neighborhoods to address climate change and help achieve the City's decarbonization goals. Ambassadors go through a 9-week training program and are asked to undertake at least 40 h of community service related to sustainability. This type of outreach, where the community is empowered to create change through outreach, is distinct from the types of outreach and education identified in our review of other city initiatives.

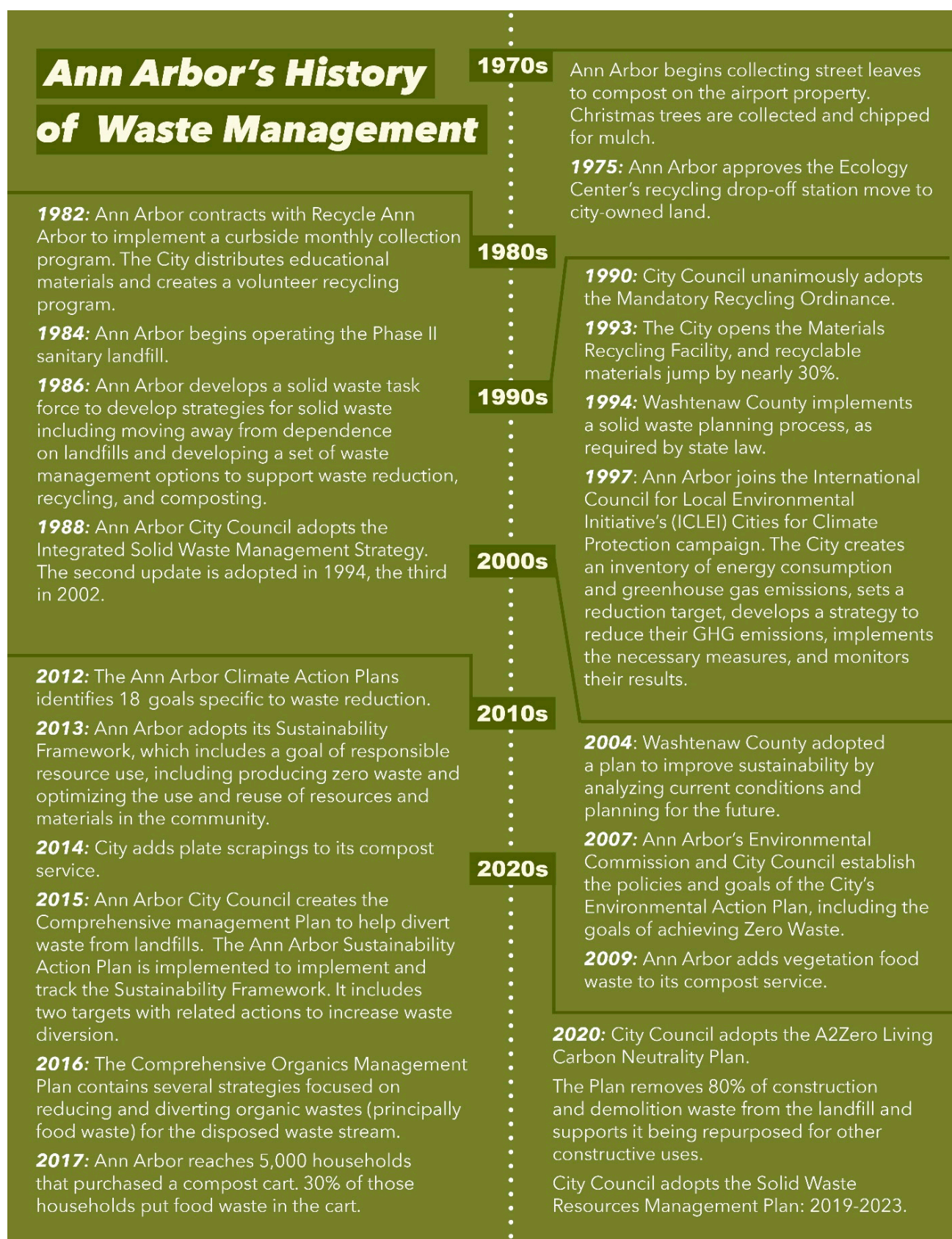


Figure 2. A timeline of waste management activities in Ann Arbor from 1982 to 2020.

4.5. Policies

In 2013 the City adopted a Sustainability Framework [49] to guide City operations and decision making. The Sustainability Framework was subsequently integrated into the City's Master Plan, used to evaluate projects for consideration in the City's Capital Improvements Program and the City's annual budget, and used to generate performance metrics for the various City departments. The Sustainability Framework also informed the creation of an Environmentally Preferred Purchasing Policy that requires the City to prioritize purchasing products that fulfill a range of the City's Sustainability Framework goals, including provisions aimed at reducing waste. This is similar to London's Responsible Procurement policy and Amsterdam's use of procurement to affect the circular economy. In addition, Ann Arbor has a requirement that all new municipal facilities be LEED Silver (although this is being revisited in consideration of a net-zero energy requirement) and the City passed a Green Fleets Policy that requires the City to reduce greenhouse gas emissions from the City fleet by at least 25% from 2000 levels by 2025. In light of the recent adoption of the A²ZERO plan, this goal has been replaced by a goal of zero greenhouse gas emissions from the City fleet by 2030. The City has made a commitment to powering all municipal electricity with renewable energy no later than 2035, but with a soft target of 2025. Finally, staff at the City are currently drafting municipally focused policies related to the procurement of carbon offsets for business travel, facility electrification, and net-zero energy development.

4.6. Programs and Practice

Along with the plans and partnerships detailed above, Ann Arbor offers curbside residential and commercial recycling and single-family home composting. The composting facility accepts all food scraps—including meat. Ann Arbor also allows residents to: drop off one (1) yard of free organic materials per day at the compost facility; collect free mulch in the spring; and collect compost directly from the composting facility. Additionally, local organizations that maintain a local park or playground can get wood chips delivered for free to their facilities. In addition, the City administers a program where contractors can drop off leaves in the fall at the compost facility for free, while Christmas trees are collected and chipped and the wood chips are offered to residents for use. Another significant City program is seasonal material diversion services for university students.

In addition to these programs, City departments prioritize sharing, refurbishing, and recycling equipment and other resources. For instance, Parks and Recreation shares equipment between golf courses, mulches clippings and leaves on site, and uses excess asphalt from road projects to pave its cart paths. Forestry uses wood chips from its own tree maintenance for mulch and paths and has a strict maintenance program to extend its tools' lives. Multiple departments keep broken and outdated equipment to use as parts in repairs of other equipment or devices. Public Works uses recycled content products in its water utility infrastructure, has electric leaf blowers, and uses a recycled water feature for its vector truck. The City also maintains a process for obsolete products to be sold into the private market.

4.7. Social Equity and Inclusion

Ann Arbor's A²ZERO plan specifically addresses equity and inclusion through the establishment of three (3) core values that guide the plan: equity, sustainability, and transformation. Equity is also centered in Ann Arbor's engagement toolkit, which is designed to identify and effectively engage with all relevant stakeholders before starting a project, plan, or policy. The City's work management software, CityWorks, also provides transparency around response and service levels. Additionally, over the last three (3) years the City has hosted racial equity trainings for City staff in various departments, helping staff explore how their actions and decisions influence social, economic, and racial disparities within the community.

4.8. Study/Assessment/Research/Monitoring

Unlike many of the cities noted above, Ann Arbor has not completed a materials flow assessment to determine sectors with the biggest opportunity to impact the circular economy. Instead, the City focuses on end of life analyses for which it has access to data. Specifically, the City's contract for curbside recycling includes semi-annual waste audits that determine materials present as well as the residual rate. It also calculates its diversion rate as the percentage of materials kept out of the landfill. The City is able to complete this analysis through the use of its own scale at its Materials Recovery Facility, trash transfer station, and compost facility.

4.9. Technology

Ann Arbor uses comprehensive work order management software called CityWorks to maximize the longevity of its assets. CityWorks, in conjunction with other asset management tools ensures appropriate preventive and predictive maintenance of the water distribution system, storm and sanitary sewers, streets, dumpsters, and Parks infrastructure. It is also used to track and manage incoming customer service requests to ensure fair and equitable service response time. Ann Arbor uses 15 solar compacting trash and recycle stations. These stations are branded with State of Michigan outreach information and wireless technology that communicates when they are full, thus reducing service requirements. They are also able to act as platforms for other technology including 5G infrastructure, hot spots, and lighting.

5. The Future of Sustainable Materials Management and a Circular Economy in Ann Arbor

Ann Arbor is committed to creating a more just, equitable, sustainable, resilient, and carbon neutral future. Just like the three core principles of A²ZERO (sustainable, equitable, and transformative), the City is committed to putting people at the center of its work to create a circular economy. As outlined in A²ZERO, moving toward a circular economy locally can help increase the local production of energy, create jobs, improve local resiliency, improve public health outcomes, support the local economy, support biodiversity preservation, provide solutions that are scalable or transferable to other communities, and provide direct benefits to the most vulnerable of the community. The goal of changing consumer habits is ambitious; the A²Zero Plan makes it clear that there are communal and personal incentives in doing so.

The A²ZERO Plan does not include a goal of zero waste, like other municipalities. Ann Arbor focuses on resource recovery rather than waste diversion, although several of the aforementioned actions will divert many materials from local landfills and prioritize proper disposal and recycling. As the City works to achieve the goals outlined in A²ZERO, actions will be needed across all of the 12 activity types identified above. The remainder of this section explores the activities the City of Ann Arbor could undertake, building upon practices in other communities and the City's long history of materials management, to advance its goals around a truly circular economy.

5.1. Capacity Building

To build the capacity of staff and the community around implementing a circular economy, the City should set a clear definition of what the term means and how it can be measured. In a similar fashion to Paris' General Assembly, this definition should be created in partnership with community members and local institutions and center the needs and opportunities of frontline populations. Once a definition has been created, Ann Arbor should work with partners to develop a series of trainings on how to operationalize the definition. Any trainings created should be living so they can be adjusted over time to incorporate learning and feedback.

5.2. Collaboration/Partnerships

Ann Arbor is rich with local institutions working on and dedicated to sustainability. Just as Paris convened a General Assembly of multiple, diverse stakeholders to create its circular economy strategy, Ann Arbor can leverage local expertise, through the A²ZERO Partners Network, a network of over 70 local and regional organizations, to begin mapping out who wants to engage in implementing a circular economy and how. One possibility is working with the Ann Arbor 2030 District to create building waste accounting standards and integrate them into the City's current energy benchmarking and disclosure efforts. Having this information will allow the City and the 2030 District, along with other partners, to be more strategic and surgical in helping building owners (residential, commercial, multi-family, and institutional) with making improvements that save energy, money, and improve indoor comfort.

The City can also work with the Michigan Department of Energy, Great Lakes, and Environment (EGLE) on the NextCycle initiative and in the Michigan Materials Marketplace. NextCycle Michigan is a state initiative that uses approaches including grants, technical support, and mentorship to improve materials recovery and create a circular economy within Michigan. Both of these forums bring together industry experts, businesses, researchers, and state and local practitioners to find ways to close material loops. These forums present novel opportunities to learn from and deeply engage with industry experts to understand how to meaningfully collaborate and achieve shared objectives.

The City could also work with industry leaders to advance data collection, design specifications, funding, and advocacy. For instance, the Association of Plastic Recyclers has created programs to expand demand for post-consumer recycled (PCR) plastic. These include PCR certification and Recycling Demand Champions programs as well as making data available for legislators. The Flexible Packaging Association is partnering with the Product Steward Institute on extended producer responsibility for certain materials. Partnering with institutions such as these presents an opportunity for the City to both learn, share, and begin testing new approaches.

5.3. Funding

To support and generate more funding, the City should advertise and promote its Sustaining Ann Arbor Together grant program to organizations working to implement circular economy strategies. Additionally, the City can work with state and federal agencies to advocate for more funding support in public, private, nonprofit, and research sectors to support the operationalization of a circular economy. Just as London is using venture capital funding to spur other private investment in the circular economy, the NextCycle initiative noted in the section above is using state funding to spur private, county, and city funding. More immediately, however, the City could work with the University of Michigan to conduct a holistic assessment of the funding landscape to more fully understand funding opportunities.

5.4. Infrastructure

The City is currently making investments to reopen its Materials Recovery Facility and is in discussions with other partners about rebuilding an expanded regional drop-off station. The City could additionally enhance its sharing, repairing, and refurbishing economy by establishing repair cafes, FixIt clinics, and expand the current infrastructure supporting lending libraries, tool sheds, and material and equipment loans from the public library system.

5.5. Laws and Policies

While the City does have an ordinance stating that recyclables shall be separated from refuse and compost and put into recycling containers (Chapter 26, Solid Waste Regulations, Part 2:5—Solid Waste Containers), there are many other levers that could be put into place. Some promising policies and laws the City could explore include a

construction and demolition ordinance (recommended in the SWRMP), a food waste ban, rescinding/revising garbage scavenger laws, creation of energy disclosure and performance standards for all buildings, support for community gardens with neighborhood composting opportunities, and a requirement that all vendors to the City report their greenhouse gas emissions along with relevant equity and justice indicators.

European circular economies are strongly nested within provincial, regional, national, and European laws. It could benefit the City to become more active in developing and working to get supportive state and federal laws adopted. Some potential opportunities include extending producer responsibilities; requiring that waste is handled near its point of generation; extending minimum legal product warranties and shifting the burden of proof from the consumer to the producer; expanding bottle deposit laws and mandatory minimum recycled content requirements; establishing a legal requirement for traceability of materials and products; stronger sanctions for misleading environmental claims and poor labor practices; resource efficiency laws and policies; eco-design laws and policies; greater protections for workers in the sharing economy; and laws that support the social and solidarity economy. The City should also advocate for the repeal of the state ban on regulating single use items, which prevents municipalities like Ann Arbor from implementing material bans or taxes.

Internally, the City could expand its Environmentally Preferable Purchasing Policy to require that all municipal vendors disclose their greenhouse gas emissions. This would send a strong market signal that the City is concerned about and factoring climate change and the circular economy considerations into all decision making. Additionally, the City could create a policy requiring the use of compost materials in all infrastructure projects, parks and playground maintenance, and community gardens.

5.6. Outreach/Education

A great number of opportunities exist to enhance education around a circular economy. The City operates a robust safety management training program. Modules on sustainable procurement, a circular economy, and A²ZERO more broadly could all be integrated into that curriculum. Once developed, this training could be refined for sharing with the broader public.

The City should also leverage the A²ZERO Ambassadors program to help advance public understanding as it relates to a circular economy, using the program as a vehicle to collect feedback on what changes are needed to better support residents and businesses in their carbon neutrality and circular economy work. Finally, as the City continues to explore new ways to connect with residents, educators, non-profits, businesses, visitors, and industry professionals on its sustainability initiatives, it could:

- Work with the University of Michigan and local professional chapters (i.e., AIA, APA, IBEW) to incorporate circular economy education into their curriculum.
- Provide courses to schools, businesses, and communities on Ann Arbor's approach, goals, and actions to achieving a circular economy.
- Incorporate circular economy education into existing outreach efforts, like the Green Business Challenge.
- Work with local schools to create vocational programs around repair and refurbishment.
- Implement an awareness campaign on how much greenhouse gas emissions result from product production.
- Work with local businesses to identify regulatory barriers to sustainability and correct them through public policy.
- Share knowledge and promising practices with other municipalities.
- Showcase sustainable projects and businesses, including at the annual A²ZERO Summit.
- Explore regional approaches to resource management.

5.7. Planning

The recently adopted A²ZERO plan presents an opportunity for the City to unify its disparate planning initiatives under the framework of justice and carbon neutrality. If this were to happen, the City would be able to ensure that these two concepts were centralized in all future planning and engagement activities. For the purposes of a circular economy, this could mean integrating material usage into permitting, working with local economic development agencies to incentivize recruitment of sustainable manufacturers and refurbishment organizations, working with engagement specialists at the City to foster greater outreach and engagement around operationalizing these topics in homes and neighborhoods, and evaluating zoning, capital improvements, and land use decisions to ensure they support low-carbon and sustainable lifestyles.

5.8. Programs

Programmatically, the City could create initiatives such as the Green Business Challenge, called for in A²ZERO, to educate and incentivize desired behaviors within the commercial sector. Additional strategies such as expanded material collection programs, community solar, neighborhood energy generation and micro-gridding, home efficiency initiatives, and programs to encourage more walking, biking, and use of public transit can all help reduce consumption and lower environmental footprints. Moreover, Ann Arbor and Washtenaw County have many businesses that engage in repair, rental, refurbishment, and reuse. There is an opportunity to work with these businesses to determine if and what sorts of support they need and how best to promote their services to help shift public practice and sentiment toward reuse.

5.9. Social Equity/Inclusion

Overall, work related to the intersection of the circular economy and social equity remains nascent. The lack of explicit discussion about social equity may be due to how the circular economy has been framed as a technocratic issue, with discussions rarely focusing on concepts such as differential impacts or historic and systemic racism and how that intersects with visions of a circular economy. Given the prominence of racial and social equity in sustainability practitioner circles, we anticipate much more attention being paid in the very near future to how a circular economy intersects with social and institutional systems and how these interactions affect different portions of the community. When designing the strategy, policies, and programs to support a circular economy, the City should use the principle of targeted universalism to ensure that the first and greatest benefits of a circular economy go to those who have been most negatively impacted by the extractive nature of our current economy. Doing this would necessitate working directly with fenceline, frontline, and marginalized populations to design the types of activities discussed in this section (i.e., policies, programs, technologies). This will help with the procedural justice aspects of planning for a circular economy and ideally help center distributive justice in solution sets. To help further ground equity and justice, it is recommended that all proposed actions related to a circular economy be evaluated as to their equity and justice implications, including potential impacts on community members who have been subject to environmental injustice.

5.10. Study/Assessment/Research/Monitoring

Currently the City is measuring materials management by calculating and tracking waste diversion, specifically the weight of materials sent to landfill versus the weight sent to the compost facility and Materials Recovery Facility. One weakness of this method is that it tracks the end use of the material; whereas, a circular economy measurement approach, like London's, encourages the reuse of materials or greater work upstream to ensure the material could stay in use longer. Another weakness of this method is that it is not tracked on a per capita basis, which is significant as the City continues to grow. Finally, this measurement approach misses large segments of the waste stream including reuse,

construction and demolition debris, and other potential material flows. This highlights the need to have better circular economy metrics, particularly ones that are standardized.

Going forward, the City should partner with state agencies and researchers at the University of Michigan to identify specific material flows through an urban metabolism assessment [50]. This type of insight can help identify specific opportunities and intervention points to advance our circular economy strategy. Brussels, Charlotte, Glasgow, São Paulo, and Sorsogon have all used urban metabolism tools to inform their circular economy roadmaps" [1]. For Ann Arbor, this flow analysis should explicitly identify greenhouse gas emissions, including embedded carbon, as this is a priority for the City.

5.11. Technology

A very basic technology that could be employed in Ann Arbor is the creation of an interactive map and database to promote the reuse, repair, sharing, renting, and other recycling or reuse initiatives. There are also apps that create searchable databases of materials recovery options based on material type. Another opportunity exists to expand the City's current Bigbelly trash and recycling containers to optimize labor and equipment for servicing public receptacles. These containers can also serve as platforms for other infrastructure including 5G and lighting.

The City can build on recent efforts including the material recovery facility revitalization and invest in infrastructure upgrades that advance circular economy goals. As the City transitions its aging vehicle fleet to electric vehicles, an opportunity exists to ensure those vehicles are powered with clean and renewable energy (i.e., solar, wind, geothermal). Additionally, new solid waste vehicles and dumpsters could have cameras so that reports can be provided to constituents about the composition of their waste stream and what in that stream is divertible. The City can also work with local economic development agencies to recruit sustainability focused businesses into the community, especially those that focus on finding solutions to the climate crisis and building a more just and circular economy.

6. Conclusions

The concept of a circular economy, albeit contested, presents a unique opportunity to make significant progress in addressing systemic societal problems such as climate change, inequality, environmental degradation, and growing economic disparity. While there is a growing body of work in the peer-reviewed literature looking at strategies within European cities; the peer reviewed literature for US cities is limited. Additionally, literature that helps design holistic circular economy strategies, those focused on the twelve action types identified in this paper, are scarce. As more communities look to design and operationalize actions to create a circular economy, greater attention needs to be paid to what is happening in practice and how this informs and is informed by theory. Special attention should be paid to issues related to equity and how communities can embrace solutions to advance a circular economy that respect the need for procedural, distributional, and restorative justice.

The growing body of work in the peer reviewed and practitioner literature is an indication of the potential for the concept of a circular economy to inform the next generation of sustainable materials management thinking and practice. Operationalizing these concepts, however, necessitates the marriage of theory and practice. The City of Ann Arbor is uniquely positioned to usher in this marriage. The City's long history of leadership on materials management and sustainability, the strong political and public support for action, combined with the focusing power of the City's recently adopted carbon neutrality plan, A²ZERO, presents an immediate opportunity for Ann Arbor to adjust and create a support ecosystem for a local, circular economy. There will undoubtedly be stumbles, missteps, and lessons learned along the way. However, the City also has a chance to prove that its stated tenants of being sustainable, equitable, and transformative, are necessary and possible. As the City moves forward with operationalizing these concepts, care must be taken to ensure equity and decarbonization are centered in programs, policies, laws, technologies, and

related actions. The lessons learned from this work should help inform both the theory and the practice of creating more circular, just, and sustainable futures.

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