Circular Economy towards Sustainable Development: A Review of U.S., E.U., and China's Polices

Abstract

The "circular economy" is a concept embraced by policymakers in the European Union and China. It represents a recognition of growing global environmental challenges, including climate change, and the externalities costs of waste. In this review paper, the authors compare the nascent policy efforts to define and operationalize the circular economy in the EU, China, and the United States (US), the major global economies. We begin by comparing how each entity defines circular economy, finding widely varying and ambiguous concepts, then turn to macro-level or economy-wide policies. Here we find notable efforts to spread principles. In the EU, such efforts are taking the form of new global standards and regulations, while in China they are in the form of goals for industrial waste reduction at the provincial level. The US is notable for its lack of action at the national level. The real activity in the US around circular economy transformation appears to be happening at the meso - or industry-level. The authors compared policies and strategies of circular economy and challenges, we find out that the E.U. has adopted the circular economy since 1950 and are way ahead the U.S. and China. I therefore, suggest recommendations for international cooperation among U.S, E.U. and China to promote circular economy in these regions and; spreading circular concepts to ensure adequate societal support to accept the consumption changes required.

Keywords: Circular economy, sustainable development, United States, China, European Union, policy analysis, green economy

1.0 Introduction

Large volumes of trash are produced worldwide by the current (linear) production and consumption methods, indicating the need for new, more circular ones. The EU has funded a CREEA (Compiling and Refining Environmental and Economic Accounts) initiative, which includes the EXIOBASE, which aims to quantify worldwide waste, despite the fact that there are few reliable global measurements (Tisserant et al.,

2017)calculated that homes in the North produce 1-2 tons of solid trash annually based on this data. An estimated 3.2 gigatons (1 billion metric tons, or Gt) of trash were produced worldwide in 2007. Of that amount, only 1 Gt was recycled or reused, 0.7 Gt was burned, gasified, composted, or used as aggregates, and 1.5 Gt was landfilled. The primary sources in terms of volume are construction, waste metal, inert material, and paper/wood, while plastics have received the most attention lately because of their persistence in the environment (Pacini & Golbeck, 2020). Just 37% of materials are thought to be circular at the moment, primarily through recycling and reuse as energy sources, according to (Haas et al., 2015), but they point out that even this estimate is probably exaggerated. According to a more current estimate, only 15% of solid waste is recycled; the remainder is going to landfills (Pietzsch et al., 2017).

These unpalatable realities have given rise to a broad movement in favor of using fewer and sustainable resources. This movement's "circular economy" (CE) idea serves as one of its main focal points. In order to better understand these changes, this review compares the policies of the US, China, and the EU, the three biggest economies in the world. As a next step beyond climate change adaptations, which are solely energy-focused, we are concentrating on planning surrounding the material flows indicated in the transition to a CE. Nobody now knows how to balance social, economic, and environmental needs or what a truly zero-waste economy looks like.

As a "club good" for international policy, we look to the CE and argue that the biggest economies should set the standard. The US has just acknowledged the CE's idea thus far; it has not implemented it into policy. In contrast, the EU and China's more extensive experiments with CE policies are significant because they act as models for upcoming global sustainability regulations and standards. The EU has actively promoted CE initiatives around the world, holding discussions and most recently signing a memorandum with China (Kern et al., 2020).

According to (Suárez-Eiroa et al., 2019), the CE can be analyzed at three different important levels. Individual businesses decide how to use and dispose of materials on a micro level. Meso-level networks are those that involve several firms, including industrial parks that aim to foster industrial symbiosis or the sharing and coordinating of waste, energy, and resources. Social and policy approaches to the CE are considered to be at the macro-level. To investigate the micro-level, a different focus and degree of investigation would be required.

1.1 What Does the Circular Economy Mean?

The circular economy was first proposed in seminal 1996 article (Boulding, 2013). The economist discussed closed and open economy systems in the piece, comparing the linear economy to "the cowboy economy" of a fresh frontier and the CE to a "spaceship economy" that acknowledged the limiting nature of natural resources and the significance of waste management. The 1989 study on natural resources and environmental economics by (Pearce & Turner, 1989) is frequently credited with popularizing the CE idea. They contributed to the introduction of the concept of a "bioeconomy," in which the Earth's natural resource endowments are a component of a system that supplies resources for all kinds of living things in addition to valuable products. Therefore, the cost of disposing of waste materials is one of the many long-term effects of resource efficiency. The challenge lies in accurately valuing waste materials, which are not factored into the initial production expenses. By highlighting the importance of reusing industrial waste products and acknowledging that the manufacturing process affects wider natural systems, this connects with the long-standing ideas of "industrial ecology," the bioeconomy, and ecosystems. It also connects with the more contemporary notions of a "green economy," which highlight changes to low carbon emission.

The definition of the circular economy provided by (Becque et al., 2016) is arguably the most comprehensive. It is based on three principles:

(a) To preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows;

(b) To optimize resource yields by circulating products, components, and materials at the highest utility at all times; and

(c) To foster system effectiveness by designing out negative externalities. It is implicit that using renewable energy and energy in the most productive way is part of this.

According to (Ghisellini et al., 2016), the CE separates environmental pressure from economic expansion. The use of renewable technologies and materials (wherever possible), the adoption of appropriate, transparent, and stable policies and tools, as well as the adoption of cleaner production patterns at the corporate level are all implied by the statement "CE implies." The steadily growing rejection of earlier production and consumption habits, which represents general "resource use inefficiency," may be just as significant.

On its website, the Ellen MacArthur Foundation, a prominent proponent of circular economy based in the United Kingdom, presents three fundamental principles: reducing waste and pollution; reusing resources and goods at their maximum potential; and recycling garbage. Although many people agree with these ideas, it can be difficult to turn them into specific policy recommendations or concrete steps (Solkvint & Madsen, 2023).

The concept of a circular economy has evolved through three phases. The first phase, from the 1970s to 1990s, focused on waste reduction and management, with "polluter pays" principles and end-of-pipe policies. The second phase, from 1990 to 2010, emphasized preventive measures and business-environmental harmony. The third phase, from 2010 to 2020, reflected concerns about population growth, resource depletion, and climate change, with the three Rs (reuse, recycling, and reduction) emerging (Reike et al., 2018).

In response, (Korhonen, Honkasalo, et al., 2018) propose that "the material flows released from economy to nature should be in a form in which nature can utilize them in their functions" be the central tenet of the CE. They give instances of how to grow trees that can serve as carbon sinks by utilizing biomass as fertilizer and how to turn biowastes into fertilizer by using anaerobic digesters. But they also concede that if population growth-driven global consumption keeps rising, even these changes could not be sufficient to maintain natural resource balance. Similarly, (Korhonen, Nuur, et al., 2018) make the helpful argument that in order to realize a true circular economy, there are four essential components:

1. Industrial ecology, which emphasizes natural material and energy flows.
2. Industrial symbiosis, which aims to arrange networks of companies and consumers.
3. Cradle-to-cradle design, which takes a product's whole life cycle into account.
4. The sharing economy lessens the requirement for private property.

To put it briefly, the goal of the CE principles is to move civilization away from recycling and reducing carbon emissions and toward a zero waste society that uses only closed-loop resources for production. This calls for actions that go much beyond waste minimization and disposal, encompassing a variety of sectors such as energy, packaging, re-use, re-manufacturing, and re-purposing, as well as Eco-design, packaging, and production process efficiency. The duties involved in disposing of legacy garbage, which includes plastic that is everywhere, are even further off.

The core principles of sustainable development economic, social, and environmental sustainability had to be rewritten in 2015 with the goal of harmonizing standards among UN member states in order to incorporate and advance the circular economy. The United Nations 2020 designated these as the Sustainable Development Goals (SDGs). As a result, the circular economy is now a tool used by businesses, government agencies, and the general public to support the sustainable development principles (Kirchherr et al., 2017). Five of the 17 Sustainable Development Goals have something to do with the circular economy, according to an analysis of the goals. The following are the five SDGs that were mentioned:

• SDG 6: Sanitation and clean water.

• SDG7: Accessible and sustainable energy.

• SDG 8: Economic growth and decent work.

• SDG 12: Conscientious Consumption and Production

• SDG 15: Life on land.

When planning such a strategy, we must take into account the activities proposed by the circular economy, such as:

• Recycling and reuse of water (Targets 6.1, 6.2, 6.3, 6.4 and 14.1).

• Industrial symbiosis and the creation of industrial clusters, where all businesses take advantage of the energy and waste discarded by others, to use them in various functions, thus extending their useful life (Goals 3.9, 6.3, 7.3, 8.2, 12.4, 9.4 and 17.7).

• Reduction of waste (Targets 12.3 and 12.5).

• Reducing wasteful consumption and production (Targets 8.4 and 9.4).

• Sustainable food production systems (Targets 2.4 and 2.5).

• Favour and care for the environment and the natural ecosystem, reducing human impact on the environment and facilitating its expansion (Targets 15.1, 15.2 and 15.5).

• Transition to renewable energy sources (Targets 7.2 and 7.3) and provide energy for all, including small developing countries (Targets 7.1 and 7.b).

• The implementation of the 7Rs model, preserving the capabilities and functions of materials, allowing to preserve and even improve product quality (Targets 8.4 and 12.4).

• Creating sustainable cities and merging industry with the natural environment (mutual benefit) (Targets 9.2 and 11.6).

• Conservation and restoration of natural resources (Target 12.2).

This paper reviews the policies and strategies implemented by the United States (U.S.), the European Union (E.U.), and China in promoting a circular economy and provides recommendations for enhancing these policies towards sustainable development.

2.0 LITERATURE REVIEW

2.1 The current state of circular economy literature

The idea of the Circular Economy (CE) is becoming increasingly popular among a wide range of academics and practitioners (Wiesmeth, 2021),as evidenced by the 112% rise in scholarly publications from 2014 to 2017 (Ruiz-Real et al., 2018). In places like China and Europe, where CE ideas have been incorporated into mainstream public policy on sustainable development, this increase is partly linked to the implementation of CE policies (Schöggl et al., 2020). According to Ghisellini et al. , CE is an economic system that has no connection to environmental effects (Ghisellini et al., 2016); yet, it is still a concept that is being developed and discussed in the scientific community (Korhonen, Honkasalo, et al., 2018; Velenturf & Purnell, 2021). There is a lack of a cohesive conceptual framework and a significant fragmentation in the CE literature, despite increased academic interest, according to recent bibliometric and scientometric studies (Alnajem et al., 2021; Anaruma et al., 2022; Homrich et al., 2018; Majiwala & Kant, 2022; Merli et al., 2018; Ruiz-Real et al., 2018; Türkeli et al., 2018).

2.1.1 Defining Sustainable Development

According to the 1987 report of the Brundtland Commission, the "ability to make development sustainable to ensure that it meets the needs of the present without compromising the capacity of future generations to meet their own needs" is a concise definition of SD. SD can be explained in terms of the natural problems brought on by global resource overconsumption. The amount of materials mined has grown significantly since 1980, reaching 72 gigatons (Gt) in 2010 and is predicted to reach 100 Gt by 2030, according to global measurements (OECD, 2015a). The industry has implemented many waste and environmental measures to reduce pollution, increase energy efficiency, and produce cleaner products (EC COM, 2015). Businesses who care about human welfare and sanitation in underdeveloped countries now have more opportunities thanks to SD objectives (Schroeder et al., 2019). In developing nations,

innovative and sustainable methods can help address hygiene issues. For example, human waste can be used to create bacteria that can be fed to fish farms and other animal generation systems (Schroeder et al., 2019), increasing horticultural productivity and sustainable nutrition creation systems (UN, 2015). Closed-loop wastewater recycling and reuse frameworks (Fonseca et al., 2018)will be essential to achieving UN agenda 2030 (UN, 2015).

Governments have implemented clean energy programs (nuclear renewable) in accordance with the Sustainable Development Goals (SDGs) in order to counteract the aforementioned environmental challenges. The goal of decarbonizing the energy sector has led nations to prioritize the use of nuclear and renewable energy sources (Pata & Samour, 2022). According to Yang et al., renewable energy is a crucial clean energy source that comes from naturally regenerated sources (Yang et al., 2016). According to Nathaniel et al., renewable sources have the ability to regenerate rapidly (Nathaniel et al., 2020), and their use offers energy security (Hao et al., 2021). According to Rahman et al., renewable energy sources are incredibly dependable, sustainable, and enhance environmental quality without interfering with the process of economic progress (Rahman et al., 2022). In this way, fossil fuels are replaced by renewable energy sources, which also lessen the need for contaminated resources and enhance the biocapacity of the planet (Pata, 2021).

Due to high installation costs and technological obstacles, the use of renewable energy is still restricted in many nations despite this growing trend (Nguyen & Kakinaka, 2019). Global trends in renewable energy sources show that, in particular, UN Agenda 2030 member nations have focused their efforts on renewable energy to meet the SDGs. Using renewable energy widely is probably going to help meet Sustainable Development Goals 7, 11, 12, 13, 14, and 15. In 2020 and 2021, respectively, renewable energy contributed for 28.5% and 28.3% of worldwide electricity generation due to the strong interest in achieving these six SDGs.

According to (Nathaniel, 2021), human consumption has surpassed nature's potential for regeneration, and 1.6 Earths are currently needed to meet humanity's ecological service needs. Therefore, the issue of environmental sustainability and the requirement for a sufficient energy supply to fulfill their increasing energy consumption are problems that many countries are confronting. There have been numerous international gatherings and initiatives to reduce environmental deterioration, including the Paris Agreement (COP-21). Balancing economic and

environmental activities was at the forefront of international initiatives (Abbasi & Choukolaei, 2023). Accordingly, green growth has been acknowledged as a crucial worldwide approach to reduce environmental contamination in all spheres of economic activity (Abbasi et al., 2023) and to encourage economic growth (Abbasi et al., 2022).

2.2 Working Definitions of the CE in the US, EU, and China

Though many states and towns have pushed the idea most notably San Francisco with its zero waste program the US does not yet have federal legislation pertaining to the establishment of CEs. The CE idea is supported by US government organizations such as NIST and USAID. Their CE efforts are, nevertheless, typically restricted in scope. On its webpage on strategy, for instance, the EPA merely covers recycling; on the other hand, it offers a brief definition of a CE. Green energy is used by USAID (n.d.) to advance circularity. The options for supporting waste measurement are mentioned by NIST (n.d.); for a link, view the bibliography. All things considered, when it comes to endorsing and advocating for a CE, the US lags well behind China and the EU. We address US CE activities in the meso-section below since there are no national-level policies in place.

A definition provided by the EU Action Plan for the Circular Economy(Commission, 2011) states that an economy is one in which "a sustainable, low carbon, resource efficient, and competitive economy is achieved" by "maintaining the value of products, materials, and resources for as long as possible and the generation of waste is minimised."

CE is defined as "general reduction, reuse, and resource utilization [ziyuan hua] activities in the process of production, distribution, and consumption" in China's Circular Economy Promotion Law(2008, art. 2). This definition of resource utilization, which goes beyond the conventional definition of recycling, is given to "the direct use of waste as raw materials or the recycling of waste." Reduced resource consumption and waste generation during manufacturing, distribution, and consumption are the additional definition of reduction given in the article.(Timoteo, 2017).

Reuse is defined by legislation as "the use of waste as a product directly or after repair, refurbishment, and re-manufacturing, or the use of all or part of the waste as part of other products." The three Rs that direct Beijing's use of the CE idea are resource utilization, reuse, and reduction (of consumption).

The National Development and Reform Commission (NDRC 2010, 1) adds another level to the Chinese definition of the circular economy concept in its Guidelines for Compiling Circular Economy Development Plans. It states that the circular economy "is an economic development model that maximizes resource conservation and environmental protection and is a fundamental change to the traditional growth model of 'mass production, mass consumption, and mass waste'."(Hira & Au-Yeung, 2023).

Though prevention or reduction of use in the first place was prioritized in China's Circular Economy Promotion Law (2008, art. 4), the Guidelines for Compiling Circular Economy Development Plans (NDRC 2010, 3), the Notice on Printing and Distributing the National Environmental Protection 12th Five-Year Plan (State Council 2011) (Hira & Au-Yeung, 2023), and the Announcements on Circular Economy Development Strategy and Near-Term Action Plan (State Council, 2013) (Hira & Au-Yeung, 2023), the emphasis has since shifted with the country's 13th Five-Year Plan (2016–2020). According to(Hira & Au-Yeung, 2023), in fact, the 14th Five-Year Plan on Circular Economy (NDRC 2021, 3) and the Medium and Long-Term Plan for the Construction of Renewable Resources and Recycling Systems (2015–2020); both changed the direction, with the former placing more emphasis on recycling and sorting and the latter on reuse and resource utilization.(Westmore, 2015).

In other words, similar to the lack of agreement surrounding CE among scholars (Kirchherr et al. 2017), each country in our study interprets the term differently, resulting in a variety of guiding principles. Furthermore, even within the same country, the concept can change over time, as we have seen in the case of China.

2.2.1 Principles of Circular Economy

2.2.1.1 Elimination of waste and pollution: The circular economy's main premise is the removal of waste and pollution. A take-make-waste economy cannot endure in the long run due to the finite resources on our planet. Natural cycles and scientific principles are combined in the circular economy paradigm. Modern technology makes it possible to recycle waste that is generated. Waste that is produced should be integrated into next manufacturing cycles rather than being left to accumulate. Thanks to technological developments in design and recovery processes, businesses were able

to create workable circular economy plans within the industrial ecology framework (Hobson 2016).

This promoted a reduction in the use of raw materials and the creation of trash, which benefits companies both financially and environmentally (Andersen, 2007).

2.2.1.2 Movement of finished goods and raw materials at maximum capacity: The second pillar of the circular economy is the circulation of materials and things at the peak of their useful lives. Keeping materials in use means using them as raw materials or components when they can no longer be used as a product. In this way, nothing is wasted and the intrinsic value of the resources and products is preserved.

The flow of products and resources can be preserved in a variety of ways, but it can be helpful to think about the two main cycles the biological and the technical cycles. While biodegradable materials are returned to the earth through processes like composting and anaerobic digestion in the biological cycle, items are reused, repaired, re-manufactured, and recycled in the technological cycle.

One way to increase an item's lifespan while it is owned is to prolong its replacement. Numerous factors, including as situational circumstances and client attitudes, can impact replacement behavior (Van Nes 2016). Product development techniques (such as layout for upgrades and repairs) or a strong product relationship could be to blame for this. Businesses can derive value from old products by allowing components, resources, or products to be recirculated when a customer returns them (Wilson et al. 2017).

2.2.1.3 There is room for nature to flourish because of the increased resource usage that is taxing the ecosystem and reducing its natural resources. Due to human actions that negatively impact biodiversity and ecosystem services (e.g., reducing soil erosion, enhancing soil fertility, reducing the effects of climate change, and degrading contaminants), ecosystems are under stress. Additionally, adopting inappropriate resource residue disposal practices during the trash phase of a product's life might have detrimental effects on the environment. In response to the increasing environmental stress brought on by various anthropogenic activities like the extraction of mineral resources, land use and degradation, and waste disposal, a circular economy that promotes resource efficiency and avoids the production of problematic residue is being adopted. (Breure et al. 2018).

Instead of trashing nature endlessly, we have to learn to create natural capital. Thus, the third main objective of the circular economy is the renewal of nature. Unlike the linear economy's "take-make-waste" approach, a circular economy fosters natural processes and increases the amount of space available for the growth of the natural world (Fig.1). We may reallocate resources from extraction to renewal by embracing a more circular economic paradigm. The circular economy aims to reduce waste by recycling and reusing as much as possible. An important aspect of the circular economy is the long-term, efficient (re)use of resources. Accordingly, it is thought that using (renewable) bio-based resources as manufacturing inputs is essential to the circular economy (De Baan et al. 2013).

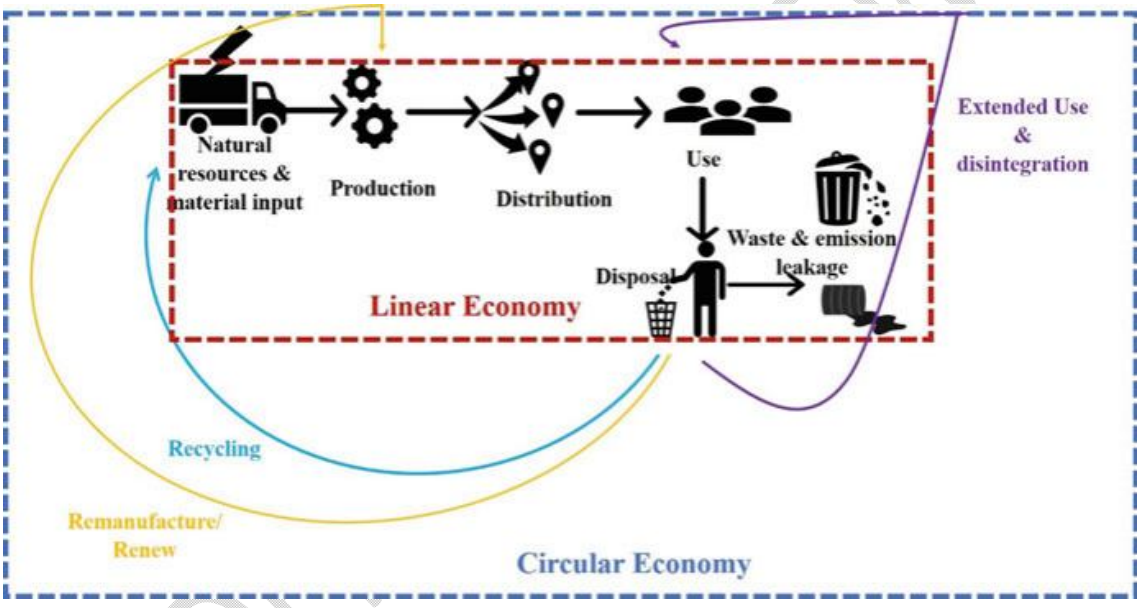

Fig. 1 Linear v/s Circular economy

Source: Arzoo Shahzabeen, Annesha Ghosh, Bhanu Pandey, and Sameer Shekhar. ‘‘Circular Economy and Sustainable Production and Consumption’’(2023)

2.3 The CE from a Policy Perspective

According to Reike et al. (2018), there have been three general historical periods in the US and EU when it comes to circular economy strategies. This approach is consistent with the work of other scholars, such as Blomsma and Brennan (2017).

• From the 1970s to the 1990s (CE 1.0), waste management, including "polluter pays" and "end-of-pipe" approaches, predominated, with the main methods of dealing with waste being landfills, incineration, and later recycling. During this time, business was a passive partner.

• Following the Brundtland Report in 1987, a stronger focus on preventative measures was placed in the second phase (CE 2.0), with the aim of encouraging enterprises to enhance their overall reputation and efficiency. Ideas like life cycle thinking and industrial ecology gained popularity as attention moved from production processes to the effects on ecosystems. The authors believe that during this time, the concepts of the closed-loop or circular economies are beginning to take hold.

• The authors claim that starting in 2010 CE 3.0, the constraints on growth such as population pressures and resource depletion were being acknowledged more and more. There was a hesitant recognition of the boundaries of consumption.

Five primary areas are proposed for CE policy interventions by Becque et al. (2016, 5), including public procurement; sharing economy/collaboration platforms; technical business support; fiscal policy, especially taxation; education, information, and awareness; and regulation, especially material-related. Additionally, they point out something most writers overlook that the move to the CE will hurt businesses that are focused on linear growth even as they add additional lines.

The market is hindered by a lack of successful business models centered around circular economy (CE); technological obstacles include the inability to create practical re-manufacturing processes; cultural barriers include a lack of awareness and motivation at the company and consumer levels; and regulatory barriers include a lack of policies, including appropriate taxation and procurement. (Kircherr et al. 2018). Lack of information and data across the factors can be added to these.

In reality, recycling takes precedence over reuse in global CE policy initiatives. Institutional support for the CE appears to be lacking, according to Ranta et al. (2018). The three aspects of institutional that they analyze regulatory, normative, which includes business certification and accreditation programs, and culture-cognitive, which reflects common values and beliefs are shown to be unsupported. For instance, there is little legislation governing material disposal or encouraging reuse.

Businesses who wish to brand their products as eco-friendly are not encouraged by insufficient transparency or certification processes. Additionally, buyers typically favor new products. The pressures they experience are erratic and random when it comes to business activities. For instance, Huawei started an e-cycling initiative after receiving pressure from private parties. The California statute requiring Dell to make arrangements for recycling end-of-life equipment and the expected cost savings from recycling served as the impetus for the company's recycling program.

2.3.1 EU's CE Policy

Since the EU is a federation of nation states, it is unique, so we will confine our observations to the EU level of strategy here. Every country state has a unique CE strategy, which is outside the purview of this study. The large level of differentiation among EU countries is even more worrisome (Mazur-Wierzbicka 2021).

The EU promoted resource efficiency, which included circular economy principles, under the Europe 2020 Strategy (European Commission, 2011). A number of initiatives are recommended for advancement in the E.U's 2015 Action Plan for the Circular Economy, including eco-design, product labeling, government procurement, waste management, enhanced standards for secondary materials, innovation, investment, and R&D, as well as progress monitoring. Regarding these ideas, the literature emphasizes the significance of four key documents: the REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals) regulation (EC 1907/2006), which establishes rules for the use of chemicals; the Waste Directive; the Eco-Design Directive; and the Circular Economy Package (2015), which establishes the conceptual foundation.

Domenech and Bahn-Walkowiak (2019) provide descriptions of several papers that expand on the momentum of CE. These consist of the Europe 2020 Strategy, the Circular Economy Action Plan (COM 2020 98), and the Resource Efficiency Road map (2011). The primary policy instruments that they identify are water regulation, which encompasses the principles of polluter pays, extended producer responsibility, and the acceptance of waste hierarchy and life cycle analysis. The Eco-Design Directive additionally aims to increase energy efficiency. The refusal to appropriately employ the tax policy to reflect actual resource costs is the primary criticism leveled at the authors. Additionally, they draw attention to the disparities in national policies, especially in Central and Eastern Europe. The creation of industry-specific efforts in electronics and IT, batteries and automobiles, packaging, plastics, textiles, and construction is mentioned in the Circular Economy Action Plan. Wilts et al. (2016) outline three broadly applicable CE policy instruments from EU policies:

(1) Establishing waste/recycling targets;

(2) Establishing mandatory design standards for recycling, reuse, and repairability.

(3) Assigning responsibility to individual producers, meaning that producers would be responsible for the costs associated with a product's entire life cycle. Despite their attractiveness, each concept is difficult to implement due to a lack of ready indicators.

Extended producer responsibility, or EPR, is a significant EU effort, according to Joltreau (2022). EPR requires manufacturers to pay for the products' recycling and trash disposal. The upfront disposal fee, which is assessed at the point of sale, is the most often used policy instrument for EPR. Establishing a producer responsibility organization (PRO) to handle waste management, recycling, and collection is another obligation. The author notes that there are significant differences in the EU member states' EPR laws.

According to Den Hollander et al. (2017), the European Waste Framework Directive of 2009 introduced the idea of the "waste hierarchy," which establishes a hierarchy of importance for waste management. The priorities align with CE concepts: minimizing waste is the first choice, followed by reuse, recycling, and other forms of recovery, and disposal is the final choice. They point out the drawbacks of this strategy, including the notion that improvement can only go in one direction up the hierarchy and that it ignores dematerialization, or the reduction of inputs, and decoupling, or the reduction of consumption. In response to worries about the disposal of trash in the South, the EU also established the trash Frame Directive, which forbids the shipment of hazardous material outside of the OECD region. To further encourage reuse, the EU has implemented a landfill tax (Gregson et al. 2015, 227).

A key conceptual foundation for the CE is the EU waste hierarchy. It was established in 2008 and ranks the following in order of importance: prevention, reuse preparation, recycling, recovery, and disposal (EC n.d.-a, b, c, d, e). Maitre-Ekern (2021) highlights that the European Union's waste policy primarily focuses on decreasing impact and preventing waste, such as through extended producer responsibility (EPR), rather than emphasizing eco-design, re-use, and recycling through secondary market development. One problem is the scarcity of spare components and the inability to reuse them. Customers also don't have easy access to information regarding the waste composition of products and subsequent products. The need shift, according to her, is from EPR to PPR (pre-market producer responsibility).

As of now, eco-design is more of an idea than an actual practice. The EU's 2005/32/EC Directive mandated that businesses that manufacture specific energy-consuming goods incorporate environmental considerations into their design. General

language resolutions regarding eco norms for a variety of products, including computers, dishwashers, and vacuum cleaners, are available on the EC website. Additionally, the notion of requiring energy use labeling to educate consumers is suggested (EC, Sustainable product). Nevertheless, according to Grote et al. (2007), businesses do not yet have a defined process in place for redesigning consumer goods to make them more circular.

Regarding REACH, the 2006 EU law aims to adopt the precautionary principle, which states that industry should guarantee the safety of chemicals before registering and licensing them with the appropriate authorities. The pursuit of regulatory harmonization throughout member states was the other objective, which may encourage innovation (Williams et al. 2009).

Alaranta and Turunen (2021) propose that REACH and the waste directive be combined, doing away with the separation between the waste and chemicals regulations. The primary problems stem from the fact that once chemicals are included in a product, they can no longer be tracked, especially when they end up in a waste stream. Moreover, legacy waste is not sufficiently taken into account by new design principles.

As in the EU, there is likewise a sub-federal, state level of safety regulation. If a chemical is deemed risky based on evidence, the Environmental Protection Agency (EPA) can limit or ban its use, after requiring testing. Botos et al. (2019) point out that "the US has taken a very different approach to hazardous chemicals from the EU REACH approach in rejecting the precautionary principle. The main federal law is the Toxic Substances Control Act (TSCA) of 1976. Rather the approach is more common law, allowing for legal action against chemical-induced harm rather than pushing industry to prove safety".

Due to the strategy's recent implementation, there haven't been many assessments conducted at the supranational level. Friant et al. (2021a, b) draw the conclusion as do others that the EU's "words" and "actions" fall short of each other. The EU's holistic language is not matched by policies that prioritize "end of pipe" fixes over the entire manufacturing process. They worry about the absence of mandated goals, the disregard for creating eco-design and secondary reuse markets, the insufficiency of financial incentives, and the meager amount of awareness-raising.

Kirchherr et al. (2018) find that a lack of market incentives and corporate culture are the main obstacles in the EU to CE transition, based on a series of stakeholder

interviews. They discover that these crucial elements have not been the focus of EU rules. EU policies are criticized more harshly by Calisto Friant et al. (2021a, b), who claim that they are merely rhetorical and that in reality they mostly concentrate on improving waste management and recycling rather than making the fundamental changes required to create a CE. A review of the most recent EC Resource Efficiency Scorecard (2016), which was released in 2015, indicates a dependence on relatively broad metrics, such as the total amount of resources (land, water, and carbon) consumed in relation to production (GDP).

2.3.2 Chinese CE Policies

China developed its economy's circularity rather late. However, the nation has had great success developing CE thus far. Beijing's resource intensity, waste intensity, recycling, and contaminant disposal rates improved by 34.7%, 46.5%, 8.2%, and 74.6%, respectively, between 2005 and 2013, according to the National Bureau of Statistics (2015). This translated into a 37.6% increase in Beijing's CE index. Further research has revealed a strong trend of decoupling economic growth from the mass use of natural resources (Bleischwitz et al. 2022; Matthews and Tan 2011), in addition to subnational-level regional differences (Fan and Fang 2020). Improvements have also been found in end-of-life waste recycling (Wang et al., 2020), the utilization of plastic wastes (Jiang et al. 2020), and overall circularity (Wang et al., 2020).

Beijing's drive for CE development can be attributed to its internalization and full realization of the negative externalities associated with the linear economic growth model of mass production, mass consumption, and mass waste, as in China's climate change adjustments (Hira and Au-Yeung, 2023). The People's Republic urgently needs to develop a circular economic growth model because, according to official documents from state agencies, resource depletion and environmental concerns resulting from rapid industrialization and urbanization (State Council 2005, 2013; NDRC 2010), as well as supply chain and resource security issues owing to an overreliance on foreign resources (NDRC, 2021). According to the State Council (2013), the CE is the answer to “the conflict between economic growth and resources and the environment” and the “fundamental measure necessary to eliminate China's environmental and resource constraints” (NDRC 2010, 1).

Beijing made the circular economy (CE) a national goal in 2005 with the publication of Opinions on Accelerating the Development of Circular Economy (State Council

2005). This was done by taking a top-down, central government-driven approach to policy implementation, as seen in the cases of resource depletion in the linear economic development model (Bleischwitz et al. 2022; Matthews and Tan 2016). According to Article 5 of the Circular Economy Promotion Law (2008), higher governments are mandated to "make regular assessments of the work of the lower authorities... against major indicators" and "make sub-national governments above the county level... responsible for organizing, coordinating, and regulating affairs about circular economy promotion in their respective jurisdictions" (Article 14). These clauses collectively provide the framework for the "target responsibility" enforcement model, according to which subnational officials' career development is dependent on how much their jurisdictions contribute to the national CE targets (McDowall et al. 2017; Bleischwitz et al. 2022).

Sub-national governments are evidently well-motivated to participate in inter-jurisdictional competitions to contribute to national CE targets, given the direct and immediate responsibilities and incentives tied to local authorities under this model. As Fig. 1 illustrates, during China's 14th Five-Year Plan period (2021–2025), 19 out of 31 provincial jurisdictions (apart from Hong Kong, Macau, and Taiwan) have adopted more ambitious targets than that of the central government, in terms of energy consumption reduction (as per unit of GDP). Only three provinces Guangxi, Yunnan, and Gansu have chosen an energy consumption reduction target below the national standard. Although the national goal is to reduce energy consumption (as a percentage of GDP) by 13.5% from 2020 levels, the average goal across provincial jurisdictions is about 14%, which is a far greater goal given the size of China's economy overall (NDRC 2021, 4).

In addition to the momentum created by inter-jurisdictional competitions, the social responsibility model has created a "catch-up" effect whereby sub national governments with lower performance levels are inclined to adopt similarly ambitious goals. Notably, as Fig. 1 shows, during the 14th Five-Year Plan era, all five of the least performing jurisdictions in Fan and Fang's (2020) analysis Liaoning, Shanxi, Xinjiang, Hebei, and Inner Mongolia adopted energy consumption reduction targets of 13.5% or higher. Of China's 31 province jurisdictions, Inner Mongolia and Hebei have one of the highest ambitions.

However, it is important to remember that although the central government controls most aspects of China's top-down approach to CE growth, the model does allow for

some flexibility and the customization of strategies to fit specific local circumstances. For instance, Shanghai continues to place a higher priority on prevention all the way up to its most recent province CE promotion plan, despite the national 14th Five-Year Plan on Circular Economy (NDRC 2021, 3) placing a significant emphasis on reuse and resource usage (Shanghai Government 2022). This could be because the province-level municipality has an extraordinarily high resource utilization rate: during the 13th Five-Year Plan period (2016–2020), the province/city achieved a 99.7% bulk industrial solid waste utilization rate (Shanghai Government 2022).

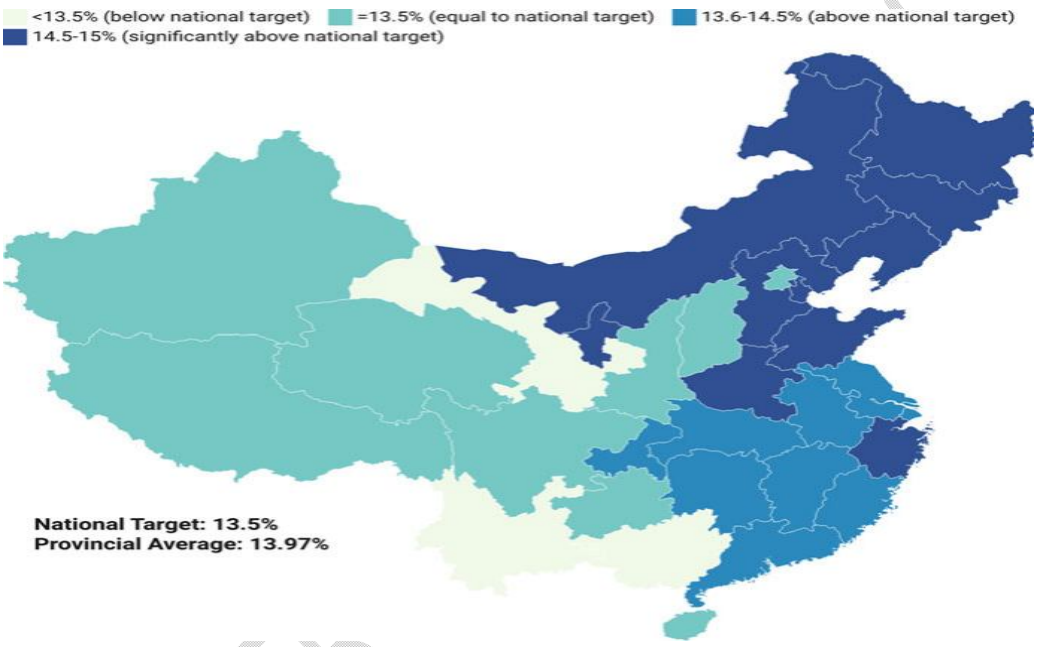

Fig. 2 Provincial 14th Five-Year Plan targets for reducing energy use (per GDP unit). (Source: Au-Yeung's compilation of the provincial 14th Five-Year Plans. Note: Due to problems with data availability for other significant indicators at the subnational level, authors decided to look at the per unit GDP energy consumption objective)

As the authors point out, the fact that the CE is centrally administrated by the NDRC, as opposed to the Ministry of Ecology and Environment, indicates that economic needs overshadow circularity concerns. In fact, China's Circular Economy Promotion Law (2008, art. 4) makes it explicit, stating that "the circular economy shall be promoted on the premises of being... reasonable in economy..." China's model has a few major flaws. First and foremost, the economy is seen as the central focus of Beijing's CE strategy, implying that circularity follows economic growth (Bleischwitz et al. 2022).

This prioritization is reflected in the official CE progress index of China. Interestingly, weights are applied to three of the five criteria in connection to economic growth.

According to the National Bureau of Statistics (2015), the resource and waste intensity rates are determined by measuring the relative amounts of waste produced and resources consumed per unit GDP. Many of the significant indices, such as resource productivity, energy consumption, water consumption, and land output rates, continue to be weighted in proportion to the overall economic performance, even though the NDRC (2017) published a more comprehensive set of indicators in 2017 that now include 17 different measurements.

Among the "non-per unit GDP" indicators, the solid industrial waste utilization rate is arguably the most important statistic. However, China hasn't made any noticeable strides in recent years to improve it. As illustrated in Fig. 3, China's usage of solid industrial waste has declined. The total tonnage fell by 193 million tons between 2012 and 2017, and the usage rate dropped from 61.49% to 54.71% during that same period. We observe no improvement in solid industrial waste usage up to 2019 (relative to 2012 levels), despite a trend of reserving beyond that.

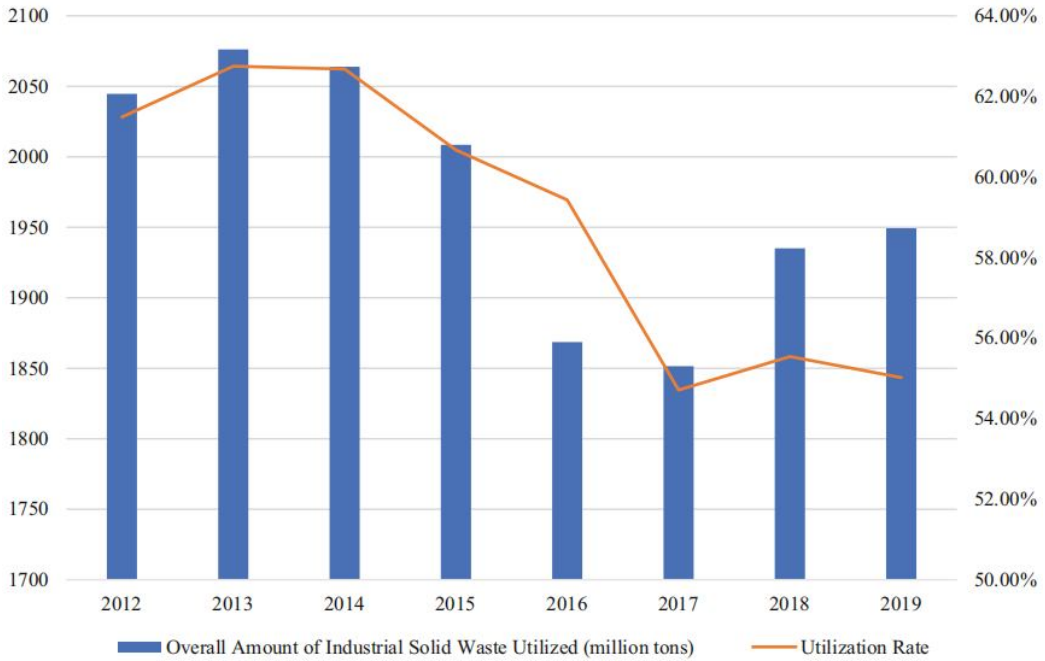

Fig. 3 Solid industrial waste utilization rate, 2012–2019. (Source: National Bureau of Statistics, Ministry of Environment, and Ministry of Environment and Ecology; compiled by Qianzhan Industry Research Institute, 2020)

Maybe this helps to explain why, from the 13th Five Year Plan period, China's CE emphasis has changed from prevention and reduction (of usage) to recycling and resource exploitation. However, the central government is aware of the stark fact that

there is much space for improvement given its low record in resource use (NDRC 2021).

The Chinese method demonstrates the importance of national goals and progress indicators at a macro level. Even though China is a single nation, the central government's authority over the provinces shouldn't be overstated. Differential levels of progress are therefore exposed, indicating the necessity of customization based on local circumstances, such as the degree of energy generation and use and manufacturing presence, the availability of renewable resources, and the skill of local authorities. We believe that the requirement to consistently demonstrate "progress" may obscure these demands.

Not to mention, economic growth continues to be the top focus throughout the South. It appears that there is still conflict between it and sustainability.

2.4 ECOLOGICAL BENEFITS OF THE CIRCULAR ECONOMY

The problems of environmental pollution and the limitation of natural resources have been addressed over the years using a variety of tactics and approaches. Economic efficiency can be increased, for example, by institutional reform, resource/energy conservation, economic restructuring, technological advancement, and other means (Naidoo et al., 2021; Zvimba et al., 2021). In addition to prevention measures like environmental impact assessments and cleaner production, abatement facilities are also implemented to lower pollution (WHO, 2018). However, the truth shows that in order to properly address the problems of environmental degradation and the limitation of natural resources, more is required than these tactics and measures. Given the foregoing information, the CE states that its objective is to solve problems by reducing material waste and attaining a balance in material flow between the socioeconomic system and the ecosystem (WHO, 2018). By renting, sharing, reusing, repairing, refurbishing, and recycling existing resources and products, the CE is a production and consumption paradigm that reduces waste output (Hamam et al., 2021). According to Hamam et al. (2021), the strategy entails improving resource utilization efficiency and reducing the intensity of emissions. It also entails converting the material flow from linear to circular, that is, from resources to products to wastes, and then further converting the wastes into new resources (Hamam et al., 2021).

The CE is a well-liked paradigm for changing traditional production and consumption patterns into sustainable ones because of this unique characteristic. This and other

factors have led to the adoption of the CE because of its capacity to provide a solid basis for investment and innovation. In 2015, for example, the European Commission approved an action plan to accelerate Europe's transition to a CE, increase global competitiveness, promote sustainable economic growth, and create new jobs (Naidoo et al., 2021). From production and consumption to waste management and the market for recycled raw materials, the action plan outlines 54 measures to "close the loop" on the product life cycle. In order to accelerate the transition along the value chain, the plan has identified five priority industries: bio-based materials, essential raw resources, construction and demolition, plastics, food waste, and biomass (Kalebaila et al., 2024).

2.4.1 The 3r'sprinciple

The unique ecological and economic theoretical underpinnings of the CE surely give it unique concepts, methods, and indicators. An great framework for implementing the CE is the "3Rs" idea, which stands for reduce, reuse, and recycle. With the reduce input technique, the flow of resources into the production and consuming processes is reduced. Reuse is a technical technique that makes a product or service more time-consuming. Recycling is an output technique that requires that materials be put back into renewable resources after being used (Zhao et al., 2012).

In order to minimize the use of resources and energy, efforts are concentrated on the manufacturing and consumption processes (D'Amato, 2021). Reuse makes full use of previously utilized objects as well as any residual usage function. This also applies to any leftover materials from the manufacturing process and components of items that have been used up.

Since recycling turns waste into new resources, it bridges the gap between the production and consumption sectors, making it an essential step in the growth of the CE. The material flow in the socioeconomic system is sometimes likened to the blood circulation system of the human body, and the recycling sector in Japan is sometimes contrasted with the "arterial industry" of production (Zhao et al., 2012). This implies that materials and energy should not be discharged into the environment before being put to use for less important uses (D'Amato, 2021).

3.0 METHODOLOGY

This methodical approach to research takes into account the published literature that is currently available in terms of titles, references, years, and keywords (De Bellis, 2009). "Before the reviews become systematic, the writer is free to pick and choose the paper that supports his or her viewpoint […] a biased approach," (White & Schmidt, 2005). Initially, the information was gathered by searching the databases Web of Science (WOS) (www.webofknowledge.com) and Scopus (www.scopus.com) with the keywords: Circular Economy, Sustainable Development, Policy Analysis, U.S., E.U., and Green Economy. This made it possible to find every pertinent piece of literature at a given moment. The process of identifying the distinctions, parallels, and connections among CE, sustainability, and sustainable development was also initiated, which would help guide the later development of a unified framework for these ideas (Fetscherin & Heinrich, 2015).

4.0 Results and Discussion:

4.1 Relationship Between CE and SD

According to Jain et al., enhancing the financial and environmental performance of enterprises in both developed and developing countries requires circularity in business frameworks for the sustainable creation of goods (Jain et al., 2018). According to impact and value, the United Nations Agenda 2030 outlines 17 sustainable development goals, containing 169 targets (UN, 2015). For example, SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Sustainable Consumption and Production), and SDG 15 (Life on Land) all have direct link relations and cooperative dynamics between CE practices and SDG targets, registering high scores for both direct and circular commitments. SDGs 1 (No Poverty), 2 (Zero Hunger), and 14 (Life Below Water) are all indirectly impacted by CE initiatives. SDG 4 (Quality Education), SDG 9 (Industry, Advancement, and Infrastructure), SDG 10 (Reduced Inequalities), SDG 13 (Climate Action), SDG 16 (Peace, Justice, and Solid Institutions), and SDG 17 (Partnerships for the Goals) are all mentioned in the UN Agenda 2030 concerning CE. These goals have been adopted globally (UN, 2015). However, several targets—such as SDG 3 (Good Health and Well-Being), SDG 5 (Gender Equality), SDG 10 (Decreased Inequities), SDG 11 (Sustainable Cities and Communities), and SDG 16 (Peace, Justice, and Strong Institutions) have only shown a tenuous relationship with CE practices. SDG 5 (Gender Equality), for example, highlights the gender diversity

and the proportion of women in top-level director roles, but it ignores how female activists advance the CE and SD within their organizations through decision-making and operational rethinking. Every goal has objectives pertaining to cooperation in CE practices, with the exception of SDG 9 (Industry, Innovation, and Infrastructure) and SDG 16, especially SDG 17 (Partnerships for the Goals/Means of Implementation). SD has significant positive effects on the economy, ecology, and society, as shown in Table 1. It summarizes the connections, contrasts, and parallels between CE and SD.

From: Systematic Literature Review of Circular Economy and Sustainable Development

Concept	Similarities	Differences	Relationships	Reference
History of concept		✓		Brundtland Report (1987)
Objectives		✓		UN (2015) SDGs Agenda 2030, Green Deal (EU, 2019)
UNO agenda 2030		✓		UN (2015) SDGs Agenda 2030
Targets (Rules and regulations)	✓	✓	✓	UN (2015) SDGs Agenda 2030
Stakeholders	✓	✓	✓	(Kirchherr et al., 2018; Kirchherr et al., 2017)and EMF (2015b)
Circular supply chain management for sustainable development practices	✓		✓	(Geissdoerfer et al., 2018; Linder & Williander, 2017)
Circular sustainable business models enhance sustainable practices	✓		✓	EMF (2015c)
Ecology economics sustainability practices	✓		✓	(Martins, 2016), EMF (2020) and (Mathews & Tan, 2011)
Technology transfer and low-carbon energy technology for sustainability	✓		✓	(Kirchherr et al., 2018; Liu et al., 2017)
Product Service Model	✓		✓	(Linder & Williander, 2017; Tukker, 2015)
3Rs, 6Rs, 10Rs, principles, and sustainable design strategies	✓		✓	(Barnabe & Nazir, 2021; Barnabè & Nazir, 2022; Reike et al., 2018)
Sustainable technology and circular business model innovation	✓		✓	(Drăgoi et al., 2018; Linder & Williander, 2017)
Waste Management Framework (Zero waste)	✓		✓	(Casiano Flores et al., 2018; Kirchherr et al., 2018) and EU, 2019
Plastic Recycling Strategy for Sustainability	✓		✓	EU (2016, 2017)
Eco-Innovation, Ecosystem, Industry Ecology, Eco design	✓		✓	(Kirchherr et al., 2018; Martins, 2016)
Design Thinking, and Education for Sustainability	✓		✓	**(Martins, 2016)**
Industry Symbiosis and GHG	✓		✓	(Liu et al., 2017; Mathews & Tan, 2011)

Table 1-Overview of the similarities, differences, and relationships regarding CE and SD found in the literature

Table 2: Key analysis and comparison of Circular Economy from U.S, E.U, and China

Countries	Policy Frameworks	Implementation and Enforcement	Public Participation	Challenges
European Union	• European Green Deal: Aims to make Europe climate-neutral by 2050. • Circular Economy Action Plan (CEAP): Introduced as part of the Green Deal, focusing on sustainable product design, waste reduction, and increasing recycling. • Waste Framework Directive: Sets the legal framework for waste management and recycling.	• Strong enforcement mechanisms and regular monitoring ensure compliance with CE policies. • Varying degrees of implementation across member states create challenges in achieving uniform outcomes.	• High emphasis on public awareness and participation. • Educational campaigns and community initiatives are widespread, promoting recycling and sustainable practices	• Variation in policy implementation across member states. • Balancing economic growth with stringent environmental regulations. • Ensuring compliance and enforcement.
United States	• Resource Conservation and Recovery Act (RCRA): Governs the disposal of solid and hazardous waste. • National Recycling Strategy: Aims to increase recycling rates and reduce waste. • Sustainable Materials Management (SMM): Focuses on the use and reuse of materials in the most productive and sustainable way across their entire life cycle.	• Inconsistent enforcement due to fragmented policies results in varying effectiveness of CE initiatives. • Federal and state-level discrepancies can hinder nationwide progress.	• Public participation is less emphasized, with lower overall awareness of CE benefits. • Efforts are generally localized and not uniformly adopted nationwide.	• Fragmented policies at federal, state, and local levels. • Lack of a comprehensive national framework for CE. • Limited public awareness and participation.
China	• Circular Economy Promotion Law: Enacted in 2008 to promote the development of a circular economy. • 13th Five-Year Plan: Includes targets for resource efficiency, recycling, and reducing waste. • Extended Producer Responsibility (EPR): Requires manufacturers to take responsibility for the entire life-cycle of their products.	• While policies are ambitious, enforcement is often weak due to rapid development and inadequate regulatory frameworks. • Addressing the informal sector is critical for effective policy implementation.	Public participation is growing, but more efforts are needed to educate and engage the public in CE practices. • Informal recycling efforts are common but need formal recognition and support.	• Rapid industrialization and urbanization leading to increased waste generation. • Need for better enforcement and implementation of policies. • Addressing the informal recycling sector.

5.0 Conclusionand Recommendations

5.2 Conclusion

I have reviewed the embrace of the circular economy concept by both China and the EU. The US does not yet seem ready to accept the idea at the national level. On both the supply and demand side, there are inadequate market mechanisms and incentives to create a consistent transition away from the linear model. Lacking clear conceptualization, measurement of progress is also ambiguous. So far, societies across the globe are not ready to embrace a switch to a CE, which would imply vastly different means of production and consumption. By adopting comprehensive national strategies, enhancing public participation, promoting innovation, and fostering international cooperation, these regions can advance towards a more sustainable and resilient economic system. Implementing these recommendations will require concerted efforts from governments, businesses, and communities to realize the full potential of a circular economy.

Recommendations

1. Develop Comprehensive National Frameworks

United States:

• Establish a unified national circular economy policy to ensure consistency and coherence across federal, state, and local levels.

• Integrate existing fragmented policies into a comprehensive strategy that aligns with national sustainability goals.

China:

• Strengthen enforcement mechanisms for existing laws, such as the Circular Economy Promotion Law.

• Develop detailed guidelines for local governments to implement national policies effectively.

2. Enhance Public Awareness and Participation

United States:

• Launch national educational campaigns highlighting the benefits and importance of a circular economy.

• Support community-based recycling and waste reduction programs, making them more accessible and visible to the public.

China:

• Increase public education on the benefits of CE practices through schools, media, and community programs.

• Formalize and support the informal recycling sector, integrating it into the broader CE framework.

3. Promote Innovation and Collaboration

United States:

• Foster public-private partnerships to drive innovation in sustainable technologies and practices.

• Support startups and businesses that develop CE solutions through grants, tax incentives, and technical assistance.

China:

• Encourage collaboration between government agencies, businesses, and research institutions to develop and implement CE technologies.

• Invest in research and development to improve recycling processes and sustainable material design.

4. Strengthen Enforcement and Compliance

European Union

• Enhance coordination among member states to ensure uniform implementation and enforcement of CE policies.

• Increase funding for monitoring and enforcement agencies to ensure compliance with CE regulations.

United States and China

• Develop robust monitoring and enforcement mechanisms to ensure adherence to CE policies.

• Implement penalties for non-compliance and provide incentives for businesses and individuals adopting circular practices.

5. Support Research and Development

European Union:

• Continue funding research into new materials, recycling technologies, and sustainable product design.

• Support pilot projects and initiatives demonstrating the feasibility and benefits of a circular economy.

United States and China:

• Increase funding for R&D in CE-related fields, focusing on innovative recycling and sustainable materials technologies.

• Encourage collaboration between universities, research institutions, and industries to accelerate the development of CE solutions.

6. International Cooperation

All Regions:

• Promote international agreements and cooperation on circular economy practices to share knowledge and best practices.

• Align national policies with global sustainability goals and frameworks, such as the United Nations Sustainable Development Goals (SDGs).

• Establish global standards for CE practices to facilitate international trade and cooperation in sustainable products and technologies.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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