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Circular Economy and Sustainable Development: A Systematic Literature Review

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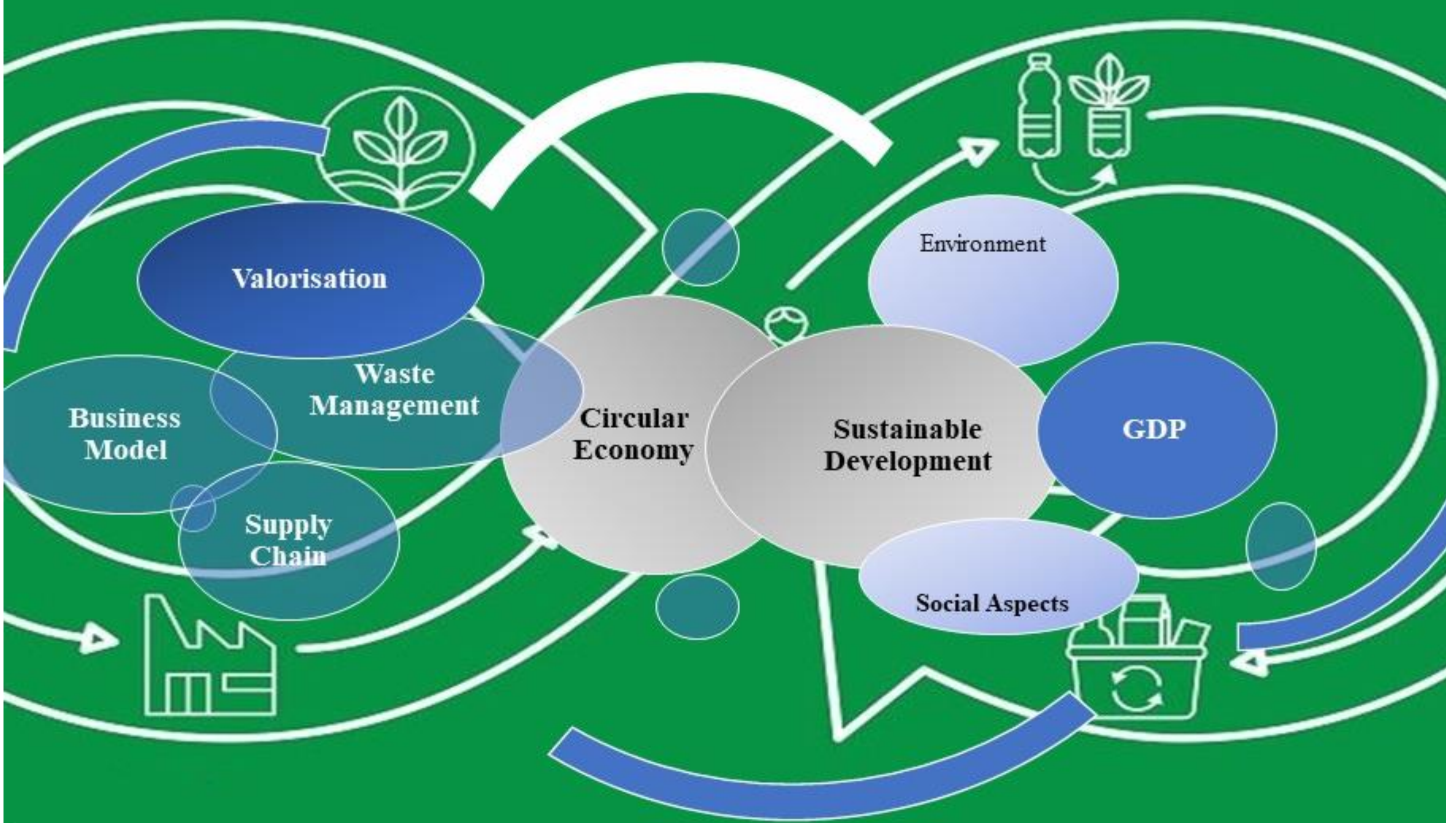

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UNIVERSITY OF STAVANGER

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MASTER THESIS

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Summary

Graphical Abstract:

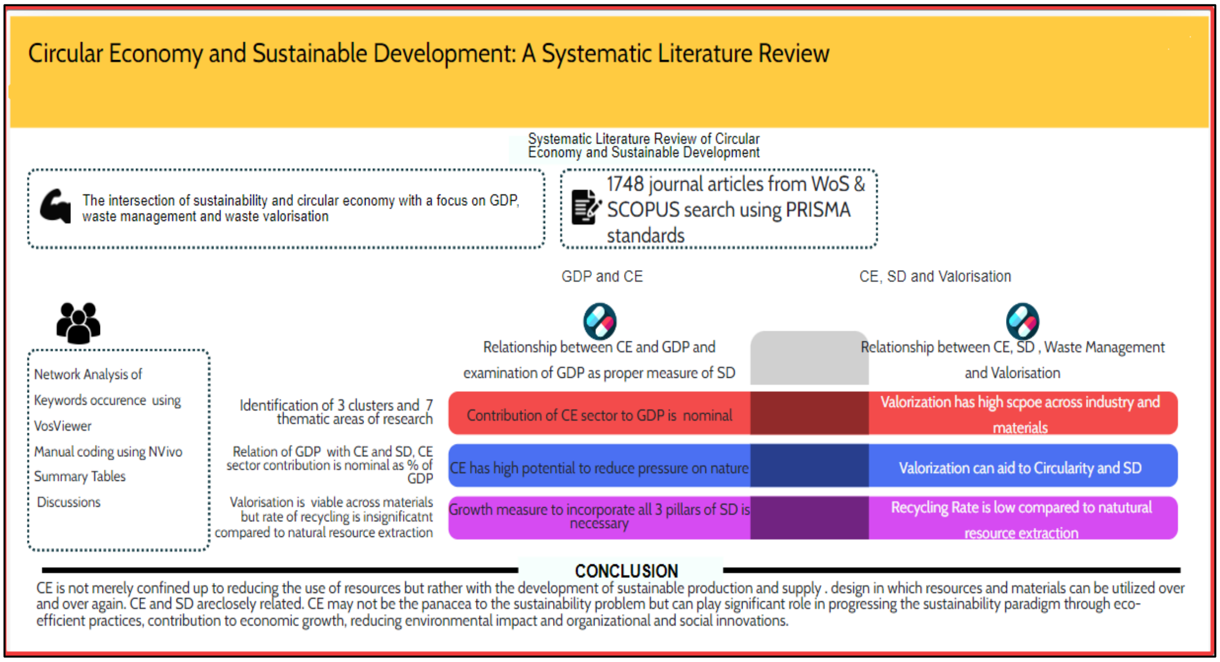

Figure 1: Graphical Abstract of the Review

Circular Economy put forth as an alternative to traditional linear model of extract-use-dispose along with the concept of Sustainable Development encompassing economic, environmental, and social aspects have garnered tremendous impetus among academics, practitioners and policymakers alike. The UN Sustainable Development Goals embraced by the member nations in 2015 based on the preceding Millenium Development Goals have been placed as the targets to be achieved as a part of holistic human development. In this backdrop, this paper examines the intersection of sustainability and circular economy with a focus on the three aspects of sustainable development, first the economic aspect by examining the relationship between GDP and circular economy, second the social economic aspect within the interaction of Circular Economy with Sustainable development and third the environmental-economical aspect by examining circularity and sustainability in waste management and waste valorisation. This paper achieves its objective through a systematic literature review of 1748 journal articles collected from Web of Science and SCOPUS database following PRISMA standards, network analysis of keywords, and manual review of texts. Four Research Questions are formulated:

RQ1: What are the major emergent topics in Circular Economy and Sustainable Development and how are they related?

RQ2: What is the relationship among CE and GDP in the CE and Sustainability?

RQ3: What are the relationships between CE and Sustainability?

RQ4: What are different use cases of valorisation of waste as CE tool, and can valorisation be sustainable?

RQ1 is answered by presenting hotspot of research on Circular Economy and Sustainable Development through keywords occurrence network analysis using VosViewer. This study identifies three clusters and seven thematic areas of research, along with 25 most used keywords. RQ2 is attended through review of the relationship between economic growth (Gross Domestic Product) and Circular Economy and proposes based on the review that CE is still at its infancy. The paper also discusses the appropriateness of using GDP as a measure of sustainable development. This paper addresses RQ3 by examining the relationship between Circular Economy and Sustainable Development through review of literatures. The indicators used to measure CE and SD are also discussed and summarised. This review finds that achieving SDGs require greater effort, and that the present status of achievement is a bleak picture. Further, the role of waste management and potentiality of waste valorisation to aid in circular economy and sustainable development is analysed to answer RQ4. Though there are ample potential, however the recycle rate is very minimal to quench the required level of circularity. While CE and SD are related, CE cannot be a universal panacea to global challenges like emissions reduction, energy consumption, climate change, gender equality, poverty, well-being, environmental protection etc. even though the impact of CE to achieve SD can be substantial. The paper recommends avenues for future research and presents the conclusion of the study.

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List of Abbreviations

AEV	Additional Economic Value of Agriculture	GRD	Grey Relational Degree
ARDL	Autoregressive Distributed Lag	IEA	International Energy Agency
ASEAN	Association Of Southeast Asian Nations	IPCC	Inter-Governmental Panel On Climate Change
CBM	Circular Business Model	LCA	Life Cycle Analysis
CE	Circular Economy	MrRRM	Market Rate of Recyclable Raw Materials
CE_INV	Ce-Related Investment	MSW	Municipal Solid Waste
CEI	Circular Economy Indicators	MSWG	Municipal Solid Waste Generation
CF	Capital Formation	MWRr / RMW	Municipal Waste Recycling Rate
CI	Circularity Index	MWRr / RMW	Recycling Rate of Municipal Waste
CMR	Circular Material Use Rate	Pat	Number Of Patents Related to Recycling And Secondary Raw Materials
CUR	Circularity Rate	PFW	Produced Food Waste
DMC	Domestic Material Consumption	PMRr	Production Material Reuse Rate
EE	Environmental Economics	PMW	Produced Municipal Waste
Emp %	Employed In Contributors To Circular Economy Percentage Of Total Employed Persons	PPS	Purchasing Power Standards
ER p.c. .	Energy Recovery In Kilograms Per Capita	RE	Renewable Energy
EU	European Union	REC p.c	Recycling Material in Kilograms Per Capita
EU	European Union	SDG	Sustainable Development Goals
GDP	Gross Domestic Product	SEM	Structural Equation Modelling
GDP	Gross Domestic Product	TB	Trade Balance
GDPpc	GDP Per Capita	TMR	Trade In Recyclable Raw Materials
GHG	Greenhouse Gases	UN	United Nations
GI % .	GDP Gross Investment In Tangible Goods, Percentage Of GDP	YCG	Per Capita GDP Growth
GMWp	Municipal Waste Generation Per Capita	WtE	Waste to energy

Table of Content

1. Introduction

The earth when viewed as a spaceship with limited resources necessitates economic concepts distinct from reckless and exploitative behaviour of the past and build an ecological system capable of continuous regeneration of material form (K. E. Boulding, 1966).

Rethinking how the modern economy functions is essential. The Circular Economy (CE) model has drawn a lot of attention as a viable strategy for addressing the pressing Sustainability and climate change challenges (Marco-Fondevila et al., 2021). The circular economy model offers an alternative strategy to the linear production processes and the existing take-make-use-dispose society in order to balance the increasing thirst for resources and growing problem of e-waste etc. with help of innovative ideas and evolving technology (Cheng & Chou, 2018). The renewables need to be used at a rate lower than its replenishment or regeneration rate, and non-renewables with higher efficiency. Stahel (2020) emphasizes that the CE is characterized in the saturated markets of industrialized world as a conscious choice to cope with abundance by reducing waste whereas the circular economy of scarcity and poverty prevails the developing world, and such discontinuity can be addressed by strategies enabling societies and countries to transition from CE of scarcity to that of abundance without going through a wasteful consumer culture. The quest for innovative methods of producing and consuming, respecting and maintaining natural resources and the environment is compelled by global concerns including climate change, land degradation, and ecosystem degradation within a contest of scarce resources (Bartolacci et al., 2020). Circular Economy (CE) is gaining popularity as a viable paradigm for transitioning our existing economy to a more resource-efficient and sustainable one (Garcia-Saravia Ortiz-de-Montellano & Van Der Meer, 2022).

Based on the observation that individual research are constrained in the generalizability of knowledge they produce about concepts and frequently illuminate single piece of a larger puzzle (T. D. Cook et al., 1992) , the goal of research integration is to uncover similarities and variability in identical-appearing studies thereby allowing generalizability while seeking limits and modifiers of generalization (Hedges & Cooper, 1994) . As such, research reviews need to pay attention to relevant theories, and critically analyse the covered topics, attempt to resolve conflicts in the literature, and try to identify central issues for further research (Hedges &

Cooper, 1994), this paper aims to study the interaction between Circular Economy and Sustainability with a focus on the three aspects of sustainable development, (i) the economic aspect by examining the relationship between GDP and circular economy, (ii) the social economic aspect within the interaction of Circular Economy with Sustainable development and (iii) the environmental-economical aspect by examining circularity and sustainability in waste management and waste valorisation. This paper achieves the above stated objectives by examining and systematically reviewing the growing number of literatures in the fields of circular economy strategies and sustainable development. The paper first discusses the concepts of Circular Economy and Sustainable Development, along with their taxonomy and operational definition. This paper then discusses the methods used for the review; the third part highlights the results of this review regarding the relationship among circular economy and components of sustainable development. The paper answers the research question in the findings and discussion section by presenting a qualitative synthesis which, as Mulrow (1994) defines is a set of techniques for summarizing, integrating, and, to the extent possible, combining the results of many investigations on a research issue.

2. Background

The first harbingers of impending calamity due to population outburst coupled with resource depletion were the 1948 publications of "Our Plundered Planet" authored by Fairfield Osborne accompanied by the "Road to survival" by William Vogt (Osborn, 1949; Vogt et al., 1948). Many significant books were published between 1965 and 1975 inspired by the challenges posed by sustainability (Rome, 2015). Boulding in The Meaning of the Twentieth Century highlighted the need to create "a stable, closed cycle, high-level technology" which would not pollute or exhaust resources and that a sustainable future would require numerous social inventions (K. Boulding, 1964). In his 1971 book "The Closing Circle: Nature, Man and Technology", Barry Commoner defined the four laws of ecology as (i)"Everything is connected to everything else", (ii) "Everything must go somewhere", (iii)"Nature knows best", and (iv)"There is no such thing as free lunch" while demanding the private enterprises to be accountable for "biological capital" and bear the cost of pollution (Commoner, 1971). Furthermore, influenced by the Economics of the Coming Spaceship Earth (K. E. Boulding, 1966), the study of circular economy and sustainable development started getting traction

(Geissdoerfer et al., 2017). Pearce & Turner (1989) furthered it through suggestion of working definition of sustainable development as maximizing the net benefit of economic growth while conserving natural resource services and its quality throughout time. The “1972 United Nations Conference on the Human Environment” and the book “Only One Earth by Ward and Dubos” (Dubos et al., 1972) gave the sustainability debate a global perspective (Rome, 2015).

2.1. Circular Economy

One tagline describes the idea of a circular economy as "regenerative by design" (Webster, 2020) while Raworth (2017) adds the idea of the economy to be “regenerative and distributive by design”. By gathering and analysing written definitions of the circular economy concepts, Kirchherr et al. (2017) present an overwhelming 114 operational definitions of CE concepts used in varying contexts by different people and organizations. These concepts are built around (a) core principles of 4R (Reduce, Reuse, Recycle, Recover); (b) core principles of waste hierarchy (c) core principles of system perspectives (micro, meso , and macro) (d) Business model as enabler (e) Consumers as enablers; (f) sustainable development as the aim; (g) Environmental quality as the aim; (h) Economic Prosperity as the aim (i) Social equity as the aim, and (j) future generations or the long term perspectives. Among the definitions investigated by (Kirchherr et al., 2017), recycling was the most frequent component (79% of definitions), followed by reuse (74%–75% of definitions) and reduce (54%–55%). The circular economy can be taken as a paradigm in which waste management, upstream product design, and service development are all aimed at extending product life and reducing natural resource usage while simultaneously creating jobs and contributing in poverty reduction (United Nations, 2019). The term CE is used in this paper in its broadest sense captured historically and in contemporary use in scientific literatures and policy papers.

2.2. Sustainable Development and Sustainable Development Goals

According to (WCED, 1987), sustainable development seeks to meet present needs without impairing the capacity of future generations to fulfil their needs. WCED (1987) introduces the three aspects of sustainability viz: an economic growth, which is socially and environmentally sustainable and that the sustainable development incorporates a growth which is less material-and-energy-intensive and more equitable.

The "2030 Agenda for Sustainable Development" was introduced by the UN General Assembly in September 2015 (United Nations, 2015), based on preceding Millenium Goals (Geissdoerfer et al., 2018). The 17 outlined Sustainable Development Goals are intended to address the problems facing the global economy, society, and environment. These objectives are to be used by all UN members in creating national development agenda. Table (1) summarizes the Sustainable Development Goals and its achievement status:

SDG#	**Goal**	**Status**
SDG-1	No Poverty	Forecasts that SDG 1 would be accomplished by 2030 have been proven incorrect (United Nations, 2023a; World Bank, 2022). Owing to consequences of Covid and ongoing crises, 75 million to 95 million more people are bound to live in extreme poverty (Daniel Gerszon Mahler et al., 2022; United Nations, 2023d). In 2030, almost 575 million people will be under the line of extreme povery (World Bank, 2022).
SDG-2	Zero Hunger	Globally, the percentage of individuals who experience hunger rose from 8.0 to 9.3 percent between 2019 and 2020, and to 9.8 percent in 2021 (FAO, 2022a). Covid and the Ukraine-Russia situation has exacerbated the situation, as these two nations produce one-third of the world's traded calories (FAO, 2020).
SDG-3	Good Health and Well Being	There are 6.7 million deaths annually from exposure to ambient and household air pollution, and 99 percent breathe air with pollution level higher than WHO guideline limits. Between 2019 and 2021, the world's life expectancy, which had been rising, fell from 72.8 to 71.0 years (United Nations, 2022c).
SDG-4	Quality education	The goal of equal education for girls around the world is being approached (UNESCO, 2022). Another 100 million kids won't be reading at the required proficiency, putting over a billion kids at risk of falling behind in their academics (UNESCO, 2021).
SDG-5	Gender equality	The emergency hotlines for violence against women received a significantly increased number of calls in 2020. Around 10 million additional girls will be at risk of underage marriage (UNICEF, 2021). More than two million women have quit the labour market as a result of the increased pressures of unpaid care (United Nations, 2022a), employment for women declined by 4.2%, compared to 3% for males (ILO, 2021). Globally, 70% of first responders and the majority of frontline employees are women, putting them at a high risk of infection all the time. However, they are less likely to be in charge: women held only 24% of the seats on COVID-19 taskforces in 2020 (UN Women; UNDP, 2021). Despite significant increases in the percentage of seats held by women in municipal and national governments, just 26.5% of seats in lower and single chambers of parliament were held by women in 2023 (UNSTATS, 2023a). Legal limitations, current social pushback, and vulnerabilities brought on by violent conflict and climate change have all had an impact on women's sexual and reproductive health (United Nations, 2023a).

SDG#	Goal	Status
SDG-6	Clean water and sanitation	Between 2000 and 2020, The percentage of the world’s population with access to safe drinking water increased from 62% in 2000 to 74 % in 2020, meaning safer water for two billion more people (WHO, 2023).Nevertheless, there are vast inequalities among and within countries, and 2.2 billion people are deprived of safe drinking water (WHO, 2023). Progress is also threatened by climate change, and by competing agricultural, ecological, and financial priorities, along with multiple threats to water quality (WHO, 2023). Over one hundred and seven countries are not on-track to have sustainably managed water resources by 2030 which is vital for balancing competing water demands from across society and the economy (UN-Water, 2021).
SDG-7	Affordable and clean energy	The percentage of people who have access to electricity worldwide has risen to 91% in 2021, but the rate of growth has slowed recently, leaving 675 million people mostly in LDCs and sub-Saharan Africa without it (United Nations, 2023a). Green energy, with a rapid transition, is viewed as a developing sector that can boost employment, stimulate economic growth, and offer long-term benefits. For the first time ever, investments in renewable energy surpassed the investment in fossil fuels in 2022. The cost of wind energy, lithium-ion battery technology, and solar energy has reduced by more than 85%, around 50% (IEA, 2022b), and more than 50%, respectively, since 2010(Wiser et al., 2021) (IEA, 2022b).
SDG-8	Decent work and economic growth	Economic expansion has historically been associated with increases in greenhouse gas emissions, causing global warming and harm to biodiversity. Decoupling economic growth from environmental degradation and ensuring that growth is more inclusive in the upcoming years are necessary to meet the 2030 objective. An opportunity for employment and job creation in green sectors can arise during a green transition generating 18 million employments globally (ILO, 2018).
SDG-9	Industry, innovation, and infrastructure	Achieving each of the SDG requires a suitable and reliable infrastructures. However, the infrastructures are inadequate. One billion people need to travel a mile to access a road, and broadband signal remain out of reach for 450 million people. Given the tighter budget and the end of cheap borrowing rates, improvements and investments in infrastructure are likely to fall short of the requirement (Riccardo Puliti, 2022).
SDG-10	Reduced inequalities	While 99 percent of humanity saw their standard of living decline, the top 10 richest people in the world saw their incomes double during pandemic (Ahmed et al., 2022). The productivity gap between developed and developing nations increased further between 2020 and 2021, increasing from 17.5:1 to 18:1, the largest gap since 2005 (ILO, 2021). Recovery in emerging markets and developing economies has been slow and worsened by inflation which can further the inequality globally (United Nations, 2023a).
SDG-11	Sustainable cities and communities	Urban areas experience a slower decline in the poverty rate than rural ones. More than 80% of the world's GDP is contributed by cities and at the same time 70% of greenhouse gas emissions (UNSTATS, 2023b). Rapid urbanization can result in significant inequalities to the housing, transportation, and accessibility of essentials. The one billion people who live in slums will need to be the focus of the "Leaving no one behind" projects (UNSTATS, 2023b).

SDG#	Goal	Status
SDG-12	Responsible consumption and production	Overconsumption, wasteful and inefficient use of natural resources causes the triple global catastrophe of pollution, climate change, and loss of biodiversity. Material footprint consumption per person increased substantially between 2000 and 2019, reaching 95.1 billion metric tons (United Nations, 2022b). The Global North has a greater consumption footprint. Around 14% of food is lost during production and 17% is lost during retail and domestic sales globally (FAO, 2019). Chemical and electronic waste also contributes to the prominent levels of global waste. Plastic pollution has grown tremendously in recent decades, reaching over four hundred (400) million tons per year, and is anticipated to double by 2040. (UNEP, 2021).
SDG-13	Climate action	The planet is 1.1°C warmer compared to pre-industrialization and average global temperatures are expected to surpass by 1.5°C within 2030s (Mukherji et al., 2023). With the current Nationally Determined (NDC) commitments, warming is projected to be 2°C to 3°C towards the end of century (UNEP, 2022). Hurricanes, wildfires, flooding, and heat stress are already wreaking havoc on agricultural productivity, fisheries, forests, and ecosystems on which people all over the world rely. Clean energy innovation, adequate finance for scale-up, and measures to decarbonize the world's economies provide promising grounds for responding to climate change (Griscom et al., 2017).
SDG-14	Life below water	There has been a global reduction in 14 of the 18 categories that evaluate nature's ability to "sustain contributions to good quality of life" since 1970 (J. Liu et al., 2019). In 1974, 10% of stocks were fished at "biologically unsustainable" levels; by 2019, that figure had risen to 35.4 percent (FAO, 2022b). Climate change, pollution, overfishing, loss of habitat, public sector support for destructive ocean economic activities, continue to endanger and weaken oceans' capacity to control climate and support livelihood (Sumaila et al., 2019).
SDG-15	Life on land	Five SDG 15 objectives were supposed to be accomplished by 2020, however time has passed with little progress. One of SDG 15 targets is to reduce global food waste in half by 2030, reduce at least $500 billion per year in subsidies that harm biodiversity, and increase positive incentives for biodiversity conservation and sustainable use (Ainsworth, 2022).
SDG-16	Peace, justice, and strong institutions	Rising levels of violence, war, and instability jeopardize progress on SDG 16 which is dependent on peaceful and inclusive communities with equal access to justice and institutions that are effective, accountable, and inclusive. Under stress, they frequently degrade, exacerbating existing socioeconomic instability and inequality, worsening violence and illegal activities, and undermining rights and protection institutions, with serious consequences for disadvantaged people (Soergel et al., 2021).
SDG-17	Partnerships for the Goals	SDG 17 encourages collaboration and access to science, technology, and innovation, notably through the establishment of a global technology facilitation framework. In the context of several crises with global ramifications, effective institutions for collaboration and knowledge partnerships are even more critical. Partnerships and integrated operations to create synergies between knowledge and resources in various areas and institutions would allow for more efficient and fair SDG achievement (Leal Filho et al., 2022).

Table 1: Summary of SDG and Achievement Status, summarized by author from (United Nations, 2023a)

2.3. Link among Sustainable Development Goals and their Relationship with Circular Economy

Numerous literature (Anderson et al., 2022; Asadikia et al., 2021; Barbier & Burgess, 2019; Cernev & Fenner, 2020; Dawes, 2022; European Union, 2019; Kroll et al., 2019; Lusseau & Mancini, 2019; Myriam Pham-Truffert et al., 2020; Randers et al., 2019; Warchold et al., 2021) point out the interlinkages among SDGs identifying trade-offs and synergies among the 17 Goals and 169 targets (United Nations, 2023a). For instance, peace (SDG 16) should be viewed as a complement to the other SDGs; it is a necessary condition towards realising sustainable development (O'Neill et al., 2020). Moving toward gender equality (SDG 5) can unleash enormous potential and have a multiplier effect on all SDGs (United Nations, 2023a). Partnership (SDG 17) is focused with expanding the means of implementation in order to achieve all of the SDGs and Targets, by facilitating access to science and technology, financial resources, capacity to effectuate change, and fair and equitable trade. (United Nations, 2023a). Education (SDG 4), water (SDG 6), sustainable production and consumption (SDG 12), oceans (SDG 14), ecosystems (SDG 15), peace (SDG 16), and partnerships (SDG 17) are examples of co-benefits multipliers and trade-off buffers, yet they are negatively impacted by other SDGs (Myriam Pham-Truffert et al., 2020). Improving access to clean water (SDG 6) in households, healthcare facilities, and schools, for example, would directly assist several targets in nutrition and health (SDG 2), education (SDG 4), and gender equality (SDG 5) (Warchold et al., 2021). Women and girls' lives are greatly enhanced (SDG 5) by better drinking water services (SDG 6) since it saves them time from fetching water from remote sources, resulting in less time spent on unpaid care and domestic labour (SDG 5) (UN-Water, 2021).

As all the SDGs are shown to be interlinked, the ambiguity prevails as to which SDGs are impacted by the Circular Economy. Nonetheless, United Nations (2019) identifies six entry points for sustainable development transformation, viz (i) Urban and peri-urban development (ii) Sustainable and just economies, (iii) Energy decarbonization and universal access, (iv) Food systems and nutrition patterns, (v) Human well-being and capabilities,, and (vi) Global environmental commons, in which Circular Economy has been presented as a key agent for the said transformation.

CE is usually seen as a way to put the hotly contested idea of sustainable development into practice. However, the explicit elaboration of the relationships between the concepts cannot be found in the literature (Geissdoerfer et al., 2017). Kirchherr et al. (2017) point that only 12% of the CE definitions specifically include sustainable development. Geissdoerfer et al. (2017) highlights the lack of an overview of the environment quality, economic prosperity, and social equity in Circular Economy discourse (WBCSD, 2017; Elkington, 1997). Kirchherr et al. (2017) explored that only 13% of definitions mentioned all three dimensions of sustainable development therefore suggesting that all CE Implementation may not be sustainable such as those that do not take social considerations into account. There are numerous papers that aim to consolidate the research in the field of circular economy and sustainable development e.g. (Agyabeng-Mensah et al., 2021; Budi Sutomo et al., 2023; Candan & Toklu, 2022; De Keyser & Mathijs, 2023; Dinda, 2020; Karuppiah et al., 2021; Kazancoglu et al., 2020; Kolling et al., 2022; Kylili et al., n.d.; Sherwood et al., 2022; Silvestri et al., 2021; Stillitano et al., 2022; Xie et al., 2023; Yadav et al., 2020). However, there are very few papers that have comprehensively assimilated the relationship between circular economy and sustainable development addressing all the aspects arising in the domain. Cortés et al. (2021) revealed investigative biases in CE research which limited contribution towards solving the Sustainable Development Goals (SDGs) challenges faced by regulation and political instrumentation. There prevails ambiguity in the conceptual relationship between Circular Economy and Sustainability in spite of its importance for academia, governments, and corporations (Geissdoerfer et al., 2017).

In this context and given background, this paper aims to provide a holistic review of the interlinkages among CE and SD by examining the relationship between economic, social and environmental components of SD with GDP, sustainability of CE, and waste management along with valorisation.

3. Theoretical Framework

The two most widely used conceptualization of CE (Garcia-Saravia Ortiz-de-Montellano & Van Der Meer, 2022, 2022) given by (Ellen MacArthur Foundation, 2013; Kirchherr et al., 2017) puts forth the CE as “an economic system that is restorative and regenerative by intent and design which encourages and is based on business models that pursues the idea of reduction, reuse, recycling, and resource recovery instead of the linear design of “end of life" in production/distribution and consumption activities. CE enables the switching of economies to renewable energy, avoiding toxic chemicals and waste through superior design in order to achieve sustainable development, environmental quality, economic success and social equity for present and future generations.

3.1. Trends in Literature

The concept of CE and sustainability covers a wide array of topics with multiple stakeholders, business practices, business models, technologies, actors in value chain, and demands for varied alternative approaches, models, and tools. This has also led to production of myriad of scientific literatures in the arena of Sustainable development and Circular Economy. This brings to the first research question this paper aims to address:

RQ1: What are the major emergent topics in Circular Economy and Sustainable Development and how are they related?

The findings and discussion pertaining to RQ1 have been presented in section (5.1) with a reporting on current state of research and knowledge in domain of Circular Economy and Sustainable Development.

3.2. GDP, Circular Economy, and Sustainability

As defined by Eurostat (Eurostat., 2013; Eurostat, 2023b), "Gross domestic product (GDP) is an aggregate measure of production that is equal to the sum of the gross value added of all resident institutional units engaged in production, with taxes on products added and subsidies subtracted. GDP in national accounting is a basic measure of the overall size of a country's economy" (Eurostat., 2013; Eurostat, 2023b).

Though the use of GDP as a measure has its limitations, for e.g. (Costanza et al., 2009; Giannetti et al., 2015; McCulla & Smith, 2007; Stiglitz et al., 2009) identify the limitations of GDP as an performance and social progress indicator, in that the pursuing economic activity may not always benefit the society and environment, Gross Domestic Product has been traditionally viewed as a measure of economic growth and viewed as default indicator of well-being and standard of living (Costanza et al., 2009; Giannetti et al., 2015). While Gross Domestic Product (GDP) is taken as a measure of the performance of economy, a general question arises about the performance of circularity in the economy with respect to GDP. Does the Circular Economy consider the economic growth as well as the social and environmental aspects of growth ? What are the literatures viewpoint into the measurement of circular economy performance?

GDP is expressed as $Y = C + I + G + (X - M)$, where C is total of consumer spending, I the business investment, G being government spending and (X-M) the net of export (X) and import (M). Can a framework for GDP exist where circularity indicators have causal relationship, such as :

$$GDP_{it} = \omega_0 + \omega_1\, CE1_{it} + \omega_2\, CE2_{it} + \omega_3\, CE3_{it} + \omega_4\, CE4_{it} + \omega_5\, CE4_{it} + \ldots + \varepsilon_{it},$$

where CE1, CE2, CE3…. are measures of circularity. This review addresses these queries through the second research question:

RQ2: What is the relationship among CE and GDP in the CE and Sustainability?

The findings and discussions addressing RQ2 has been presented in section (5.2).

3.3. CE and Sustainability

The link between the Circular Economy and sustainability conceptually remains unclear, despite the concept's significance for academia, governments, and businesses (Geissdoerfer et al., 2017). A myriad of papers has conducted systematic literature review on the topic. (Bartolacci et al., 2020) conducted a bibliometric literature review on sustainability and financial performance of SMEs, Johnson & Schaltegger (2016) outline significant implementation barriers and easing requirements for sustainable management tools in SMEs and public policies, Klewitz & Hansen (2014) through an interdisciplinary systematic literature review evaluated strategic sustainability behaviours among firms with focus on sustainability oriented innovation. (Orsini & Marrone, 2019) conducted a systematic review studying methods for production of low carbon building materials within the nexus of international policies and CE principles. Geissdoerfer et al. (2017) presents relationship, similarities and contrasts between Circular economy and sustainability. Based on clustering of subcategories and parameters, Garcia-Saravia Ortiz-de-Montellano & Van Der Meer (2022) draws the distinction between circular processes and circular impacts presented in Figure (2).

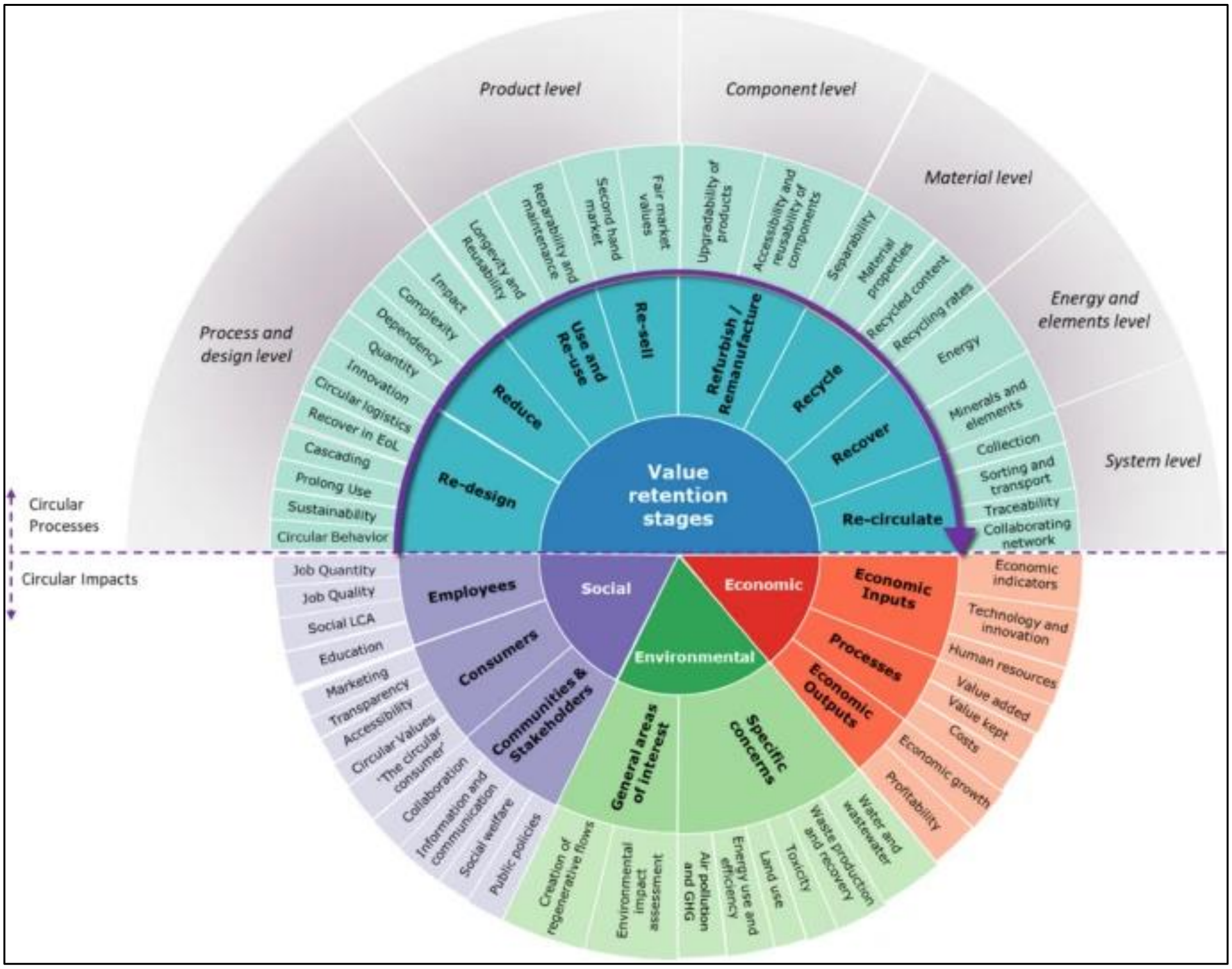

Figure 2: Categories and Subcategories of CE Framework presented by (Garcia-Saravia Ortiz-de-Montellano & Van Der Meer, 2022)

Sustainable Development has social, environmental and economic pillars that are impacted by circular economy. The third research question in this review tries to evaluate avenues where such relationships exist and what those relationship are.

RQ3: What are the relationships between CE and Sustainability?

The findings on this research question are discussed in section (5.3)

3.4. Waste Management and Valorisation

One key aspect of circular economy and sustainability is closing the loop, where waste of one is food for the other, that the waste is recycled, reused, or remanufactured. The butterfly diagram depicted in Figure (3) represents a circular economy system with two major cycles, viz the technical and biological; the technical cycle keeps the materials in circulation through reuse, repair, remanufacture and recycling, and the biodegradable materials is returned back to the earth as nutrients to regenerate nature by the biological cycle (Ellen MacArthur Foundation, 2013, 2019).

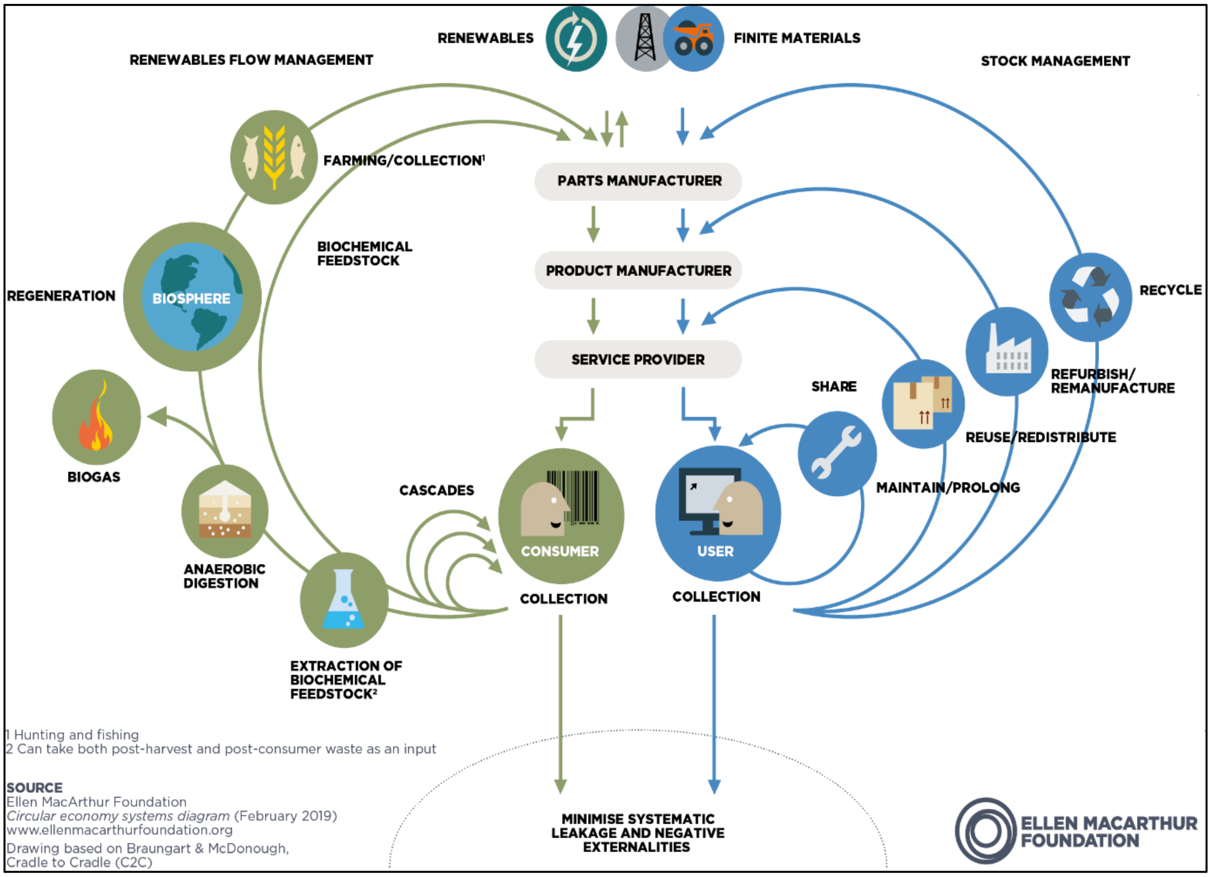

Figure 3: Butterfly Diagram: Circular Economy Systems based on Cradle-to-Cradle adopted from (Ellen MacArthur Foundation, 2019)

For both the technical and biological cycle to close the loop requires an economical incentive. The economic, environmental, and social benefits determines the implementation of these cycles. The fourth research question examines if waste management and valorisation of waste are economically, socially, and environmentally viable as follows:

RQ4: What are different use cases of valorisation of waste as CE tool, and can valorisation be sustainable?

The next section discusses the method used to compile and classify the papers for this review. The results and discussion section supplies a detailed relationship summarized in tables while addressing the research questions. The avenues for future research, other finding and critiques are included in the finding and discussion section followed by conclusion derived from this review.

4. Methodology and Research Design

A research literature review is systematic, explicit, and reproducible approach for identifying, evaluating, and synthesizing body of knowledge produced by researchers, academics and practitioners (Fink, 2014) to address research queries or determine the current state of knowledge on a certain subject (D. J. Cook, 1997), limiting systematic errors (Popay et al., 2006). Mulrow (1994) argues systematic review to be the most efficient scientific technique that allows large body of information to be broken down into smaller comprehendible blocks, and establish generalizability, consistency or inconsistency of scientific research. The systematic literature review functions to identify gaps, provide unbiased evidence for interventions, policy and practice for policy makers, and act as powerful evidence-based source collect information (Davies, 2000; Green et al., 2006; Pickering et al., 2015). Tranfield et al. (2003) suggests that all pertinent citations found during search should be reviewed, complete texts be obtained, and the number of sources included and excluded at each level of review be recorded along with justification for exclusions.

4.1. Methods and Materials

To systematically find, screen, and choose pertinent articles from the target literature, a search protocol based on the PRISMA statement (Page et al., 2021) was devised. In keeping with this, the research was conducted using the global citation databases, Web of Science (WoS) and SCOPUS. This paper has used the steps depicted in Figure (4) suggested by Fink (2014) in the literature review along with modifications by the author. Review was done by studying the content of the articles and manual categorization was done. VOSviewer was used for key words, NViVo was used for coding and for qualitative analysis.

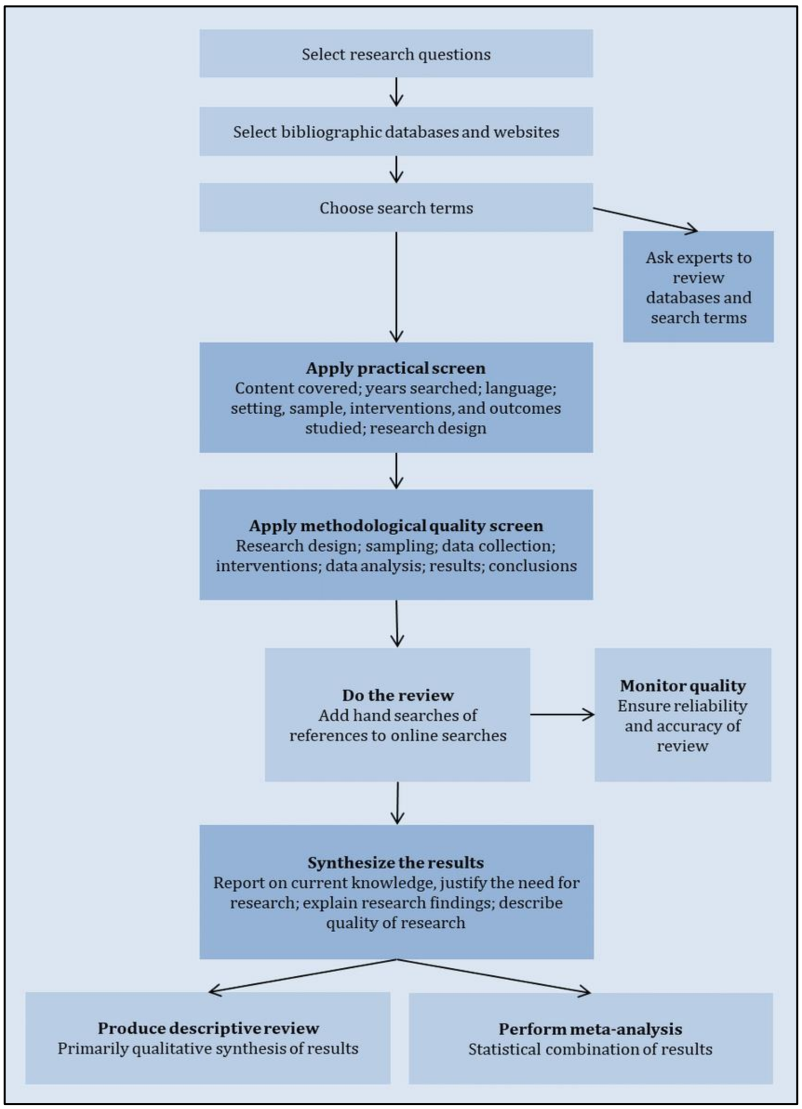

Figure 4: Systematic Literature Review Process adopted form (Fink 2014)

4.1.1. Eligibility Criteria:

This literature includes articles published in the journals listed at level 1 and level 2 in the Norwegian Register for Scientific Publication Channels (https://kanalregister.hkdir.no/publiseringskanaler/Forside). The articles published in journals listed as Level 0 or not listed in the register were excluded from the study. Only the articles published in English language were studied. This study includes only the papers published from the year 2010 onwards, so that literatures published in the years leading to UN SDG resolution could also be included as UN SDG goals were declared in 2015. Both qualitative, quantitative, empirical research papers as well as research review papers were included.

4.1.2. Database and query

The following queries were used to search articles in the web of science and SCOPUS databases.

Query used in Web of Science (WoS)

((((TI=("Circular Economy" AND "Sustainable Development" AND ((policy) OR (practice) OR (implement*) OR (measure) OR (goal*) OR (challenge) OR (decouple) OR (degrowth) OR (sdg) OR (intervention) OR (un) OR ("United Nation") OR (strateg*) OR (frame*))) OR AB=(("Circular Economy" AND "Sustainable Development" AND ((policy) OR (practice) OR (implement*) OR (measure) OR (goal*) OR (challenge) OR (decouple) OR (degrowth) OR (sdg) OR (intervention) OR (un) OR ("United Nation") OR (strateg*) OR (frame*)))) OR KP=(("Circular Economy" AND "Sustainable Development" AND ((policy) OR (practice) OR (implement*) OR (measure) OR (goal*) OR (challenge) OR (decouple) OR (degrowth) OR (sdg) OR (intervention) OR (un) OR ("United Nation") OR (strateg*) OR (frame*)))) AND LA=(English)) AND DT=(Article)))) Publication Date: 2010-01-01 to 2023-5-31

Query used in SCOPUS Database

TITLE-ABS-KEY (("Circular Economy") AND ("Sustainable Development") AND ((policy) OR (practice) OR (implement*) OR (measure) OR (goal*) OR (challenge) OR (decouple) OR (degrowth) OR (sdg) OR (intervention) OR (un) OR ("United Nation") OR (strateg*) OR (frame*))) AND PUBYEAR > 2009 AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (EXCLUDE (EXACTSRCTITLE , "Sustainability Switzerland")) AND (LIMIT-TO (LANGUAGE , "English")) Publication Date: 2010-01-01 to 2023-5-31

The representation of the research framework developed for this study has been presented below in Figure (5).

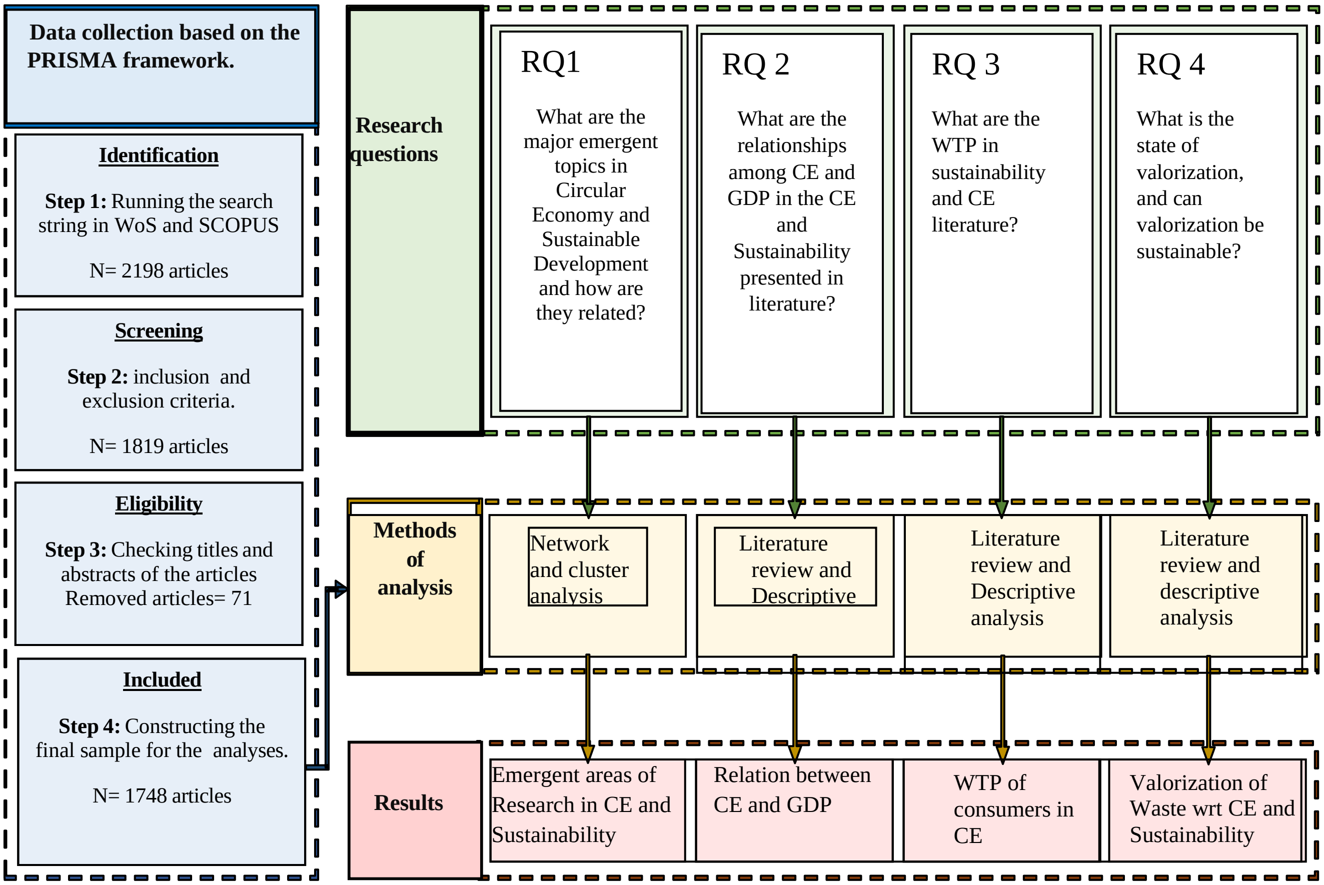

Figure 5: Representation of the Research Framework

5. Findings and Discussions

The adoption of CE strategies, principles and models has positive as well as adverse effects on several domains covered by the Sustainable Development Goals. Businesses can contribute to sustainable development, as for instance, by creating direct and indirect employment, investment in community for long-term prosperity, improving environmental protection, conditions of human rights, enhancing health and safety, and mitigating the impact of their activities in the course of business. Energy access fosters social and economic progress while producing revenue for government, and encouraging innovation in process, technologies and products.

The Sustainable Development Goals nevertheless emphasize issues that relate to sustainable development. The influence of the resource use by different sectors of the economy that has on biodiversity, ecosystem and planetary boundaries, and the effects of climate change faced by communities are among the most significant to address sustainability.

5.1. Keyword-based analysis: Research Trends

The outcomes of the keyword-based analysis in this section address the first research question RQ 1 as follows:

RQ1. What are the major emergent topics in Circular Economy and Sustainable Development and how are they related?

The authors' keywords were analysed for keyword co-occurrence to discover the main idea and article scope as well as the top research areas that link circular economy principles, practices, indicators and models with sustainable development, sustainable development goals and related concepts of sustainability. On data cleaning, of 12455 keywords identified, 193 keywords had more than twenty (20) occurrences. These 193 keywords served as the keystone for both the cluster identification depicted in Figure (6). The network analysis provides three distinctive and interrelated research topics grouped in three different clusters.

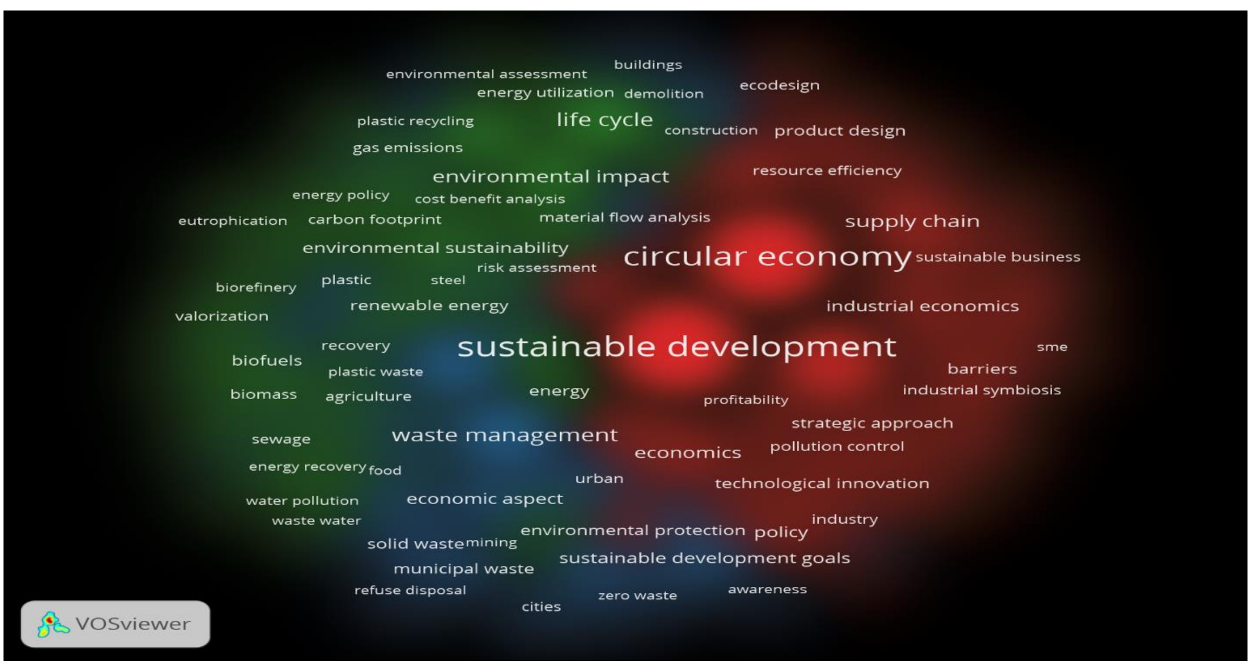

Figure 6: Density Visualization of Clusters identified from Keyword analysis

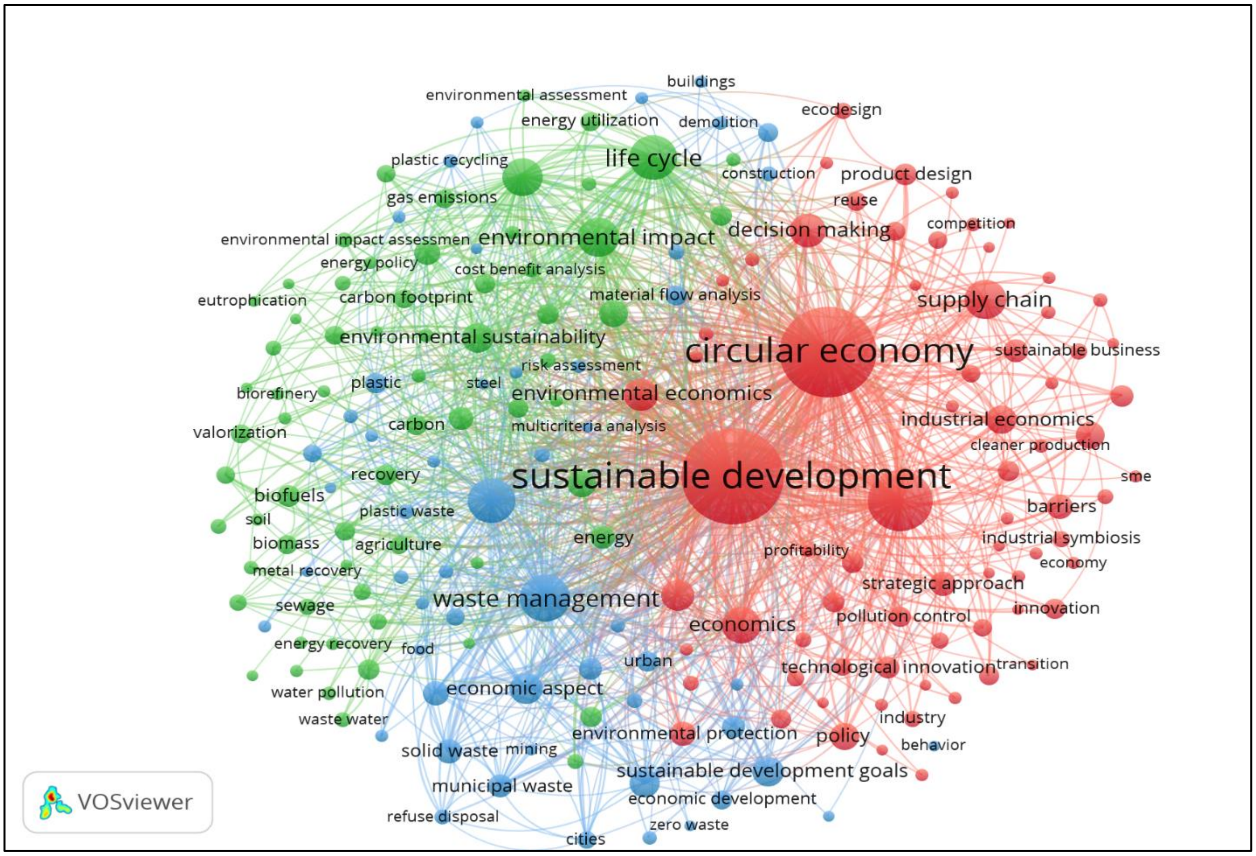

Figure 7: Network Visualization from keyword and abstract analysis

A total of three clusters were identified as presented in the density visualization diagram in Figure (6):

Cluster 1 (red): Sustainable development and Circular Economy conceptualisation, which consists of research topics such as environmental economics, supply chain, economic and social effects, industrial economics, policy, strategic approach, business models, product design, industrial ecology, innovation, indicators, and resource efficiency, among others.

Cluster 2 (green): Environment, energy, and pollution, which incorporates research topics such as life cycle assessment, environmental impact, environmental sustainability, renewable energy, biofuels, recovery, carbon, climate change, greenhouse gas emissions, biomass, anaerobic digestion, valorisation, energy efficiency, environment impact analysis etc.

Cluster 3 (blue): Waste management and recovery, covers the research topics such as recycling, economy aspects, sustainable development goals, waste disposal, municipal waste, landfill, plastics, material flow analysis, cities, construction industries, demolition, elastomers, metal recovery, zero waste etc.

The cluster analysis of the co-occurrence network of terms occurring in article abstracts with the key phrases Sustainable Development and circular economy was performed. The diameter of the bubbles shown in the network visualization diagram in Figure (7) is proportional to the number of publications that include the associated phrase. This review identifies these clusters to be the thematic hotspot for research on Sustainable development related topics and Circular Economy related topics. Moreover, from keyword analysis, the following themes appear:

Themes 1:Sustainability	**2: Waste**	**3: Industry**	**4: Environment**	**5: Energy**	**6: Innovation**	**7: Economics**
sustainability	valorisation	industrial ecology	environment	alternative energy	eco-innovation	bioeconomy
sustainability assessment	waste	industrial economics	environmental assessment	energy	innovation	circular economy
sustainability performance	waste disposal	industrial research	environmental benefits	energy consumption	technological innovation	economic analysis
sustainability transition	waste incineration	industrial symbiosis	environmental challenges	energy efficiency	cleaner production	economic and social effects
sustainable business	waste management	industrial waste	environmental economics	energy policy	product design	economic aspect
sustainable consumption	wastewater	industry	environmental factor	energy recovery	production and consumption	economic conditions
sustainable development	waste-to-energy	industry 4.0	environmental impact	energy utilization		economic development
sustainable development goals	wastewater treatment		environmental impact assessment	renewable energy		economic growth
sustainable management	water conservation		environmental management	waste-to-energy		economic system
sustainable production	water pollution		environmental performance			economics
sustainable supply chains	water resources		environmental policy			economy
	zero waste		environmental protection			environmental economics
			environmental regulations			green economy
			environmental sustainability			industrial economics

Themes 1:Sustainability	2: Waste	3: Industry	4: Environment	5: Energy	6: Innovation	7: Economics
			environmental technology			socioeconomics

Table 2: Distinct Themes identified from Keyword and content analysis.

The 25 most recurring keywords are presented in Table (2) along with their links and link strength.

Keywords	Weight (Links)	Weight (Total link strength)	Weight (Occurrences)
sustainable development	366	13700	1469
circular economy	366	11770	1322
sustainability	365	6004	601
waste management	351	4565	360
life cycle	346	3929	316
recycling	353	4161	313
environmental impact	346	3142	245
supply chain	304	2308	245
life cycle assessment	328	3240	231
economics	329	2531	212
decision making	322	2094	193
environmental economics	325	2356	174
economic and social effects	306	1909	159
economic aspect	324	2440	152
environmental sustainability	323	1997	146
sustainable development goals	292	1467	142
industrial economics	280	1368	130
climate change	302	1545	122
environmental management	295	1578	121
policy	271	1327	120
business model	211	982	115
waste disposal	275	1640	103
solid waste	277	1549	97
greenhouse gases	270	1350	96
environmental protection	278	1246	95

Table 3:Top 25 Keywords with Highest Occurrence and Link Strength.

From the keyword and abstract analysis, this review present three clusters of research focused on Sustainable Development and Circular Economy, seven thematic areas of research and twenty-five most used keywords in the literatures reviewed.

5.2. GDP and Circular Economy

The use of GDP as a measure of economic performance has been often criticised as having been misused. The useful measures of advancement and well-being should be a measure of the extent to which society's goals such as sustainably, meeting basic human needs for food, shelter, and freedom, etc. are met (Costanza et al., 2009). Fioramonti et al. (2019) argues that the obsolete system of measuring economic performance by Gross Domestic Product is in itself an impediment to the materialization of economic transformation in progress.

The European Commission's "Beyond GDP" undertaking calls for developing indicators that allows for including of environmental and social aspects of progress, along with indicators for natural resources, pollution, waste, social indicators such as life expectancy, poverty, education, well-being indicators such as quality of life, satisfaction level with life, and enlarged GDP indicators adjusting shortcomings to provide a more comprehensive measure of country's wellbeing (European Commission, 2023). Lin (2020) proposes a circular GDP by summation of GDP with circular output (SD) as:

$Y = C + I + G + NX + SD$, where Y denotes domestic output, C denotes consumption spending, I is investment spending, G is government spending, NX is net exports, and SD denotes domestic demand for sustainable development or the circular output.

However, there are arrays of literature that examine the relation of CE, SD and economic performance using GDP, and indicators such as resource productivity, and purchasing power standards derived from GDP. (Marino & Pariso, 2020) asserts that achievement of national transition objectives depends on wealth production capacity, correlation of the wealth to purchasing trends and proportion of GDP invested in CE. K. Dos Santos & Jacobi (2022) highlights the legislation differences in territories with different social and economic attributes as GDP, GDP per capita, and e-waste generation using example of UK, Brazil, and Ghana. Balancing the critique and usefulness of GDP as a measure, this paper reviews the relationship between CE, SD, and GDP.

The trend of contribution to GDP from circular economy sectors as shown in Figure (8) highlights that the circular economy sector is increasing but at a slower pace and the total contribution remains low below 2.2% of total GDP.

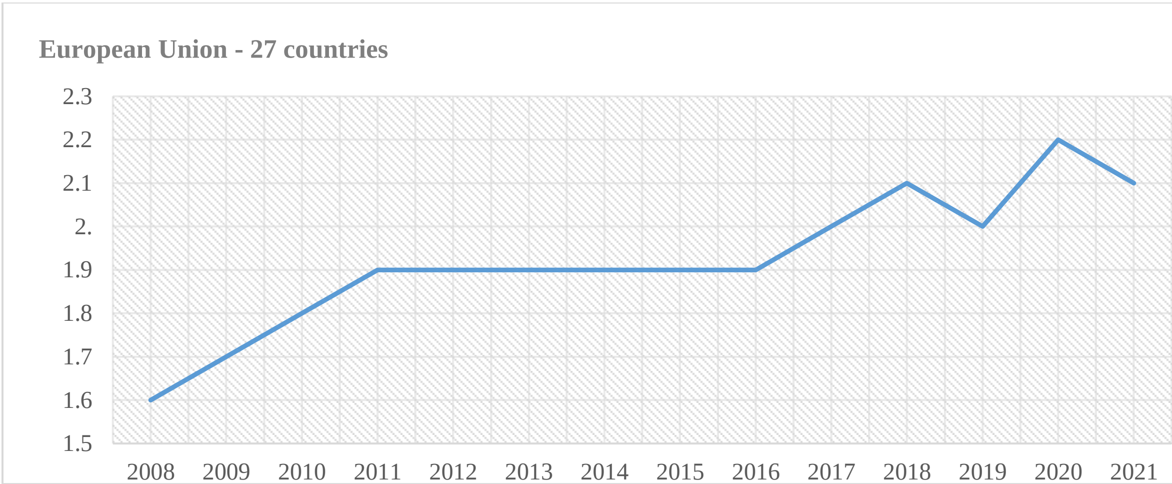

Figure 8: Gross added value related to circular economy sectors as % of GDP (Eurostat, 2023a)

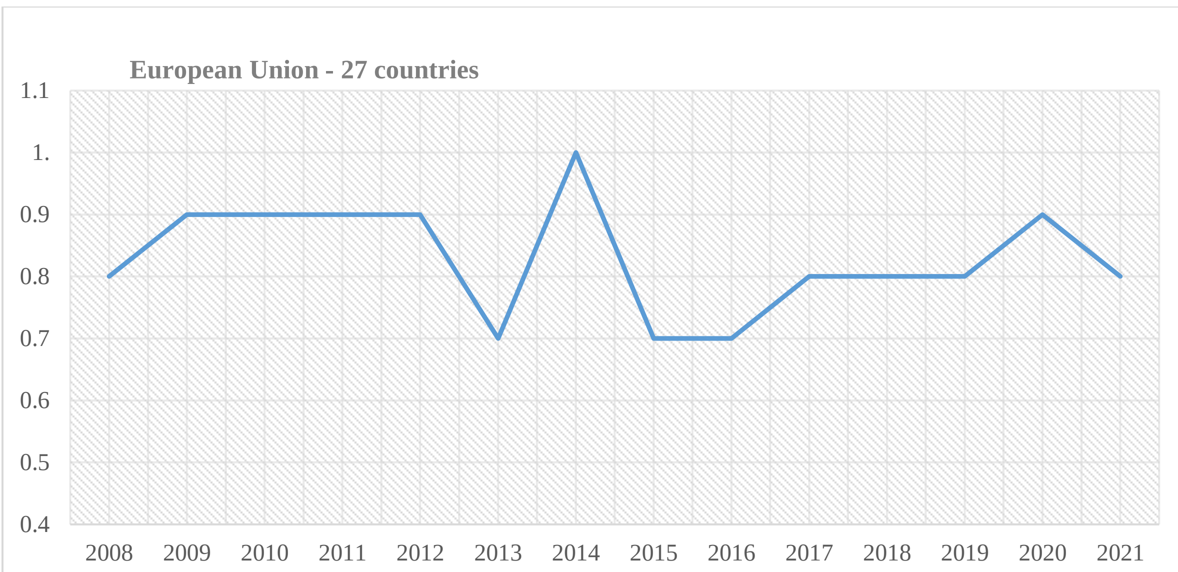

Figure 9: Private Investment in EU related to Circular Economy sector as % of GDP (Eurostat, 2023a)

The trend of private investment in EU related to circular economy as presented in Figure (9) does not show a promising future for circular economy in the sense that the investment has remained low and does not show significant increase over time.

A summary of literatures that examine the relationship between GDP and CE has been presented in Table (4).

Study Information		Country/ Region	Methodology	Variables		Relationship	Findings
Citation	Description			Dependent	Independent		
(Chen & Pao, 2022)	Causal relationship between CE indicators (Municipal Waste Recycling Rate, CE related Investment, Municipal Waste generation per Capita, Circularity Rate, and Trade in recyclable raw materials) and economic growth (GDP)	European Union	Panel Vector error correction model	GDP	RMW, TRM, CE_INV, GMWp	$LGDPit = \omega0 + \omega1RMWit + \omega2LTRMit + \omega3LINVit + \omega4LGMWpit + \omega5CURit + \varepsilon it$	1. waste generation decreased with an increase in material recycling, an increase in waste generation led to an increase in CE-related investment, and economic growth led to circular economy growth, in short run causality but not vice versa. 2. long-term equilibrium relationship between CE indicators and GDP 3. encouraging 20 CE-related innovation investments and promoting material recycling to stimulate the secondary raw material market can help achieve zero waste goals 4. GDP and CE indicators constituted a causal loop in the long run, which implies that there is co-evolution between GDP and CE.
(Arru et al., 2022)	estimates the level of circularity in 27 European countries and the role of agriculture and agri-food in determining circularity.	27 European countries	Regression	CI	GDP, AEV	CIi = α + ß1 GDPi and CIi = α + ß1 AEVi	1. Circularity Index is positively and significantly related to GDP, but correlation is not high ($R2$ = 0.641) 2. the elasticity of CI with respect to the only agricultural sector income is remarkably higher than the entire domestic income of each country with magnitude of the coefficient is about five times higher than that estimated for the GDP, and the standard coefficient of determination is high 3. the level of circularity related to the entire EU system is found to be low 4. The amount of waste not used in a circular way by the 5 worst countries (Poland, Germany, Italy, France, Spain) is more than twice that of the other 22 countries. 6. Agriculture contributes, on average, to determine 80.5% of the total circularity in the European countries. This percentage varies from 57.4% of Finland to 97.7% of Malta.

Study Information		**Country/ Region**	**Methodology**	**Variables**		**Relationship**	**Findings**
Citation	Description			Dependent	Independent		
(Skvarciany et al., 2021)	Evaluate the relationship between economic performance and Sustainable Development Goals Indicators	32 OECD Countries	Fixed effect regression	SDGI	Unemp, GDP, Disposible income,	$\ln SDGI = \beta 0 + \beta 1t \ln Unempit + \beta 2 \ln GDPit + \beta 3 \ln Povit + \beta 4 \ln DispIncit + \beta 5 \ln RDit + \beta 6 \ln Patit + \beta 7 \ln REit + \beta 8 \ln AQit + \beta 9 \ln CO2it + \beta 10 \ln NoCarit + \beta 11 \ln Intit + \beta 12 \ln Wasteit + \beta 13 \ln ECit + ui$	1. GDP, disposable income, patents, municipal waste generated, and electricity consumption had statistical insignificance (p-value > 0.05).
(Marino & Pariso, 2020)	Evaluate the correlation between the GDP and the strategic elements (Circularity Indicators) identified by EU	28EU Member States	Corelation analysis	GDP per capita expressed in Purchasing Power Standards (PPS)	PMW, PFW, MWRr, DMC, PMRr, MrRRM	Corelation between GDP in PPS and PMW, PFW, MWRr, DMC, PMRr, MrRRM	1. direct correlation between PMW and GDP per capita, indicating that waste management systems in nations are strongly tied to waste output. 2. direct correlation of MWRr with GDP per capita of the countries. the upper-middle- and high-income countries collect and recycle more waste 3. PFW has direct correlation with GDP, high-income countries generate less food waste (32% of total waste) and more easy to recycle dry waste whereas middle - and low-income countries generate more food waste (53% of total waste). 4. DMC has negative correlation with GDP, explained by efficient production process in high income countries. 5. Positive correlation of PrCE with GDP/CEI 6. positive correlation of PMRr and MrRRM with GDP per capita,

Study Information		Country/ Region	Methodology	Variables		Relationship	Findings
Citation	Description			Dependent	Independent		
(Skrinjaric, 2020)	Evaluation of GDP, GINI with GRD calculated from selected CEI	Selected European Countries	Grey Relational Analysis (GRD)	GDPpc,ER p.c. .,REC p.c,GI % .,Emp %,CMR, Pat) used to calculate GRD	GINI Coefficient, GDP per capita	GRDit = α i + β1GINIit + β2GDPpcit + εitt	1. greater effects on GRDs are found for the GINI variable compared to the GDP per capita. 2. The best performing countries have greater GDPpc. With better infrastructure, education and R&D.
(Fioramonti et al., 2019)	Evaluation of GDP as a non-fit to measure wellbeing and suggestion of Sustainable Wellbeing Indicator	NA	NA	NA	NA	NA	1. Moving beyond GDP-based framework of measurement in favour of wellbeing indicators allows for a better connection with recent evolutions in global governance and shifts in the economy. 2. GDP is not fit for measuring the economic contributions of activities that are redefining the roles of producers and consumers. 2. The CE, sharing etc. economic activities have the potential to provide simultaneous environmental, social, and economic benefits, which are systematically mismeasured or neglected in the GDP framework
(Vuta et al., 2018)	analyses the impact that circular economy indicators, such as the MWRr, packaging waste and bio-waste, the expenditure on R&D to extend the life cycle of materials and reusing waste	28 EU States	data panel model for estimating the impact CE has on the resource productivity and economic growth.	Resource Productivity as the ratio of GDP to DMC	Recycling of Municipal Waste, R&D Investment, and patent	$yit = \alpha + Xit$ βit + μit + ϑit (i=1, ... ,N; t = 1,...,T) where: I = cross-section dimension (transversal section); t = time; α, β =coefficients; X'it observation of the explaining variables, uit = individual effect; ϑit = residual.	1. Resource Productivity as the ratio of GDP to DMC increases by 0.01307; 0.159988; and 0.068711 with 1 % increase in recyling rate of municipal waste, 1% increase in R&D investment as % of GDP, and patent per 1 million inhabitant increases by 1 unit. 2. GDP has positive correlation with CEI 3. Environmental taxes have negative impact on real GDP growth rate. 4. negative relationship between the real GDP growth rate and the number of patents related to recycling and secondary raw materials.

Study Information		Country/ Region	Methodology	Variables		Relationship	Findings
Citation	Description			Dependent	Independent		
(Dinda, 2020)	investigates CE approach for SD in the framework of endogenous economic growth model	22 EU States	OLS Regression	GDP per capita	recycle rate per capita	economic growth rate as a function of marginal productivity of recyclable waste	1. economic growth depends on marginal productivity of waste recycle and increased life cycle
(M. Wang et al., 2020)	investigates the causal relationship between carbon dioxide (CO_2) emissions and economic factors in Chinese provinces. comparative analysis of the eastern, central, and western provinces	China	Regression Analysis using a vector autoregressive model and panel data	CO_2,FDI, GDP per capita , EX and IM	CO_2,FDI, GDP per capita , EX and IM	Estimation of variables	1. unidirectional causality from per capita gross domestic product (GDP) to CO_2 emissions in eastern and central provinces 2. unidirectional causality from CO_2 emissions to GDP per capita in western provinces 3. unidirectional causality betweenCO_2 emissions to foreign direct investment in central and western provinces but no impact in eastern provinces. 4. unidirectional causality between CO_2 emissions to export volume only in eastern provinces
(Dasanayaka et al., 2022)	Evaluation of Renewable Energy Consumption on GDP	Sri Lanka	structural equation modelling	GDP	EI, HC, TB, CF, RE	Estimation of variables and multivariate relationships	1. no strong direct correlation between the Renewable Energy consumption and the GDP of Sri Lanka. 2. strong positive correlation between renewables and Capital Formation; and between Capital Formation and GDP
(Petković et al., 2022)	Analysis of effect of energy and nonenergy material productivity on the gross domestic product (GDP)	OECD members countries	adaptive neuro fuzzy inference system (ANFIS)	GDP	Energy, RE, biomass, metal MWG, non-metallic minerals	ANFIS prediction of GDP index based on two energy productivity, and energy intensity	1. consumption of metals as a percentage of DMC is most influential on GDP 2. non-energy material productivity and municipal waste generated provides optimal combination for the GDP prediction.

Table 4: A Summary Table of Examples of Literature Showing the Relationship between GDP and CE

Chen & Pao (2022) show that waste recycling and CE-related investment had significant positive relation with GDP. However, the materials recycling had a negative impact on GDP, which could be explained by higher cost and inefficiency in material recycling. The use and trading of products manufactured with second generation raw materials are higher in countries with higher GDP per capita (Marino & Pariso, 2020), which implies that GDP per capita is directly correlated with reuse of secondary raw materials. The greater effects of GINI on CEI could mean that variables pertaining to inequalities could have more dampening effects on CE achievements and SD goals than compared to economic growth measured by GDP (Skrinjaric, 2020). This review finds that the relationship between GDP and CE indicators vary, and lacks uniformity in the results, for example, the findings of (Dasanayaka et al., 2022) state that increment in renewable energy consumption does not have significant impact on GDP growth, which stands in a contradiction with the findings of (Doytch & Narayan, 2021) that renewable energy consumption matters for economic growth (manufacturing and service growth) in low and middle income countries.

From review of literature regarding the relationship between GDP and CE, it can be inferred that CE implementation is in its early stages. However, CE and GDP is found to be co-evolutionary which can foster sustainable development that can provide welfare to generations to come (Chen & Pao, 2022).

5.3. Sustainable Development and Circular Economy

The circular economy viewed as a potential remedy for issues such the rising global demand for resources, the instability of raw material prices, and the expanding population and consumption globally (Rodriguez-Anton et al., 2019), can be considered a promising route to achieving Sustainable Development Goals (Stillitano et al., 2022). The circular economy has been seen as critical strategy for fostering sustainability in the twenty-first century by policymakers, academic researchers, and consulting practitioners (Lin, 2020).

With the ratification of three ambitious agreements: the Sharm el-Sheikh Implementation Plan for a new global climate accord, the Kunming-Montreal Global Biodiversity Framework, and UN Environment Assembly Resolution 5/14 on reducing plastic pollution in 2022, the need and urgency in adapting consumption and production practices which are sustainable and circular (United Nations, 2023c). Countries, for example Germany, has incorporated CE as a guiding transformative area in its sustainable development strategy (*German Sustainable Development Strategy*, 2021; United Nations, 2022b, 2023a) . Some examples of Circular economy measures and tools those can serve to achieve sustainable development are innovation to increase resource efficiency, business models to reduce waste including food, solid and plastic waste, innovation to address sustainability challenges in transportation, consumption patterns, nutrition, and water, ecosystem restoration using nature-based solutions.(Ghisellini et al., 2016; Moallemi et al., 2022; Pereira et al., 2021; United Nations, 2023c).

United Nations (2019) identifies six entry points for necessary transformations in the underlying system to expedite achievement of sustainable development, viz: (i) Human well-being and capabilities, (ii) Sustainable and just economies, (iii) Food systems and nutrition patterns, (iv) Energy decarbonization with universal access, (v) Urban and peri-urban development, and Global environmental commons. These entry points include Circular Economy measures such as reducing inputs of fertilizers, reducing post-harvest losses, reducing food waste by 50%, encouraging sustainable lifestyle and behaviour change, reducing carbon emissions, raising the usage of renewable energy and doubling the percentage of municipal waste recycled and composted (United Nations, 2019, 2022b, 2023b). European Commission (2015) reckons that a transition to more circular economy by minimising waste generation while keeping value of products, materials and resources to the longest extent in the economy is paramount to EU's efforts in creating a competitive economy that is sustainable, decarbonized, and resource efficient. Elevated circularity in economy and behaviour change (Gil et al., 2019) along with adoption of improved technologies can act as catalyst to obtain shifts towards sustainable development (Pastor et al., 2019).

Agricultural practices of today cetera paribus, can sustain only 3.4 billion people if the four planetary boundaries viz: (i) climate change, (ii) loss of biosphere integrity, (iii) land-system change, and (iv) altered biogeochemical cycles- phosphorus and nitrogen (Stockholm Resilience Centre, 2015) are respected, but by adopting more sustainable food production, consumption practices and CE action plans to close the loop, such as halving of per capita food waste and reduce food loss along supply chain (European Commission, 2015), the average dietary energy requirement food supply could be increased to feed 10.2 billion people (Gerten et al., 2020).

Moreover, investment in innovation that are green, and economy models that are circular and sharing (Soergel et al., 2021) could create 100 million jobs by 2030 and the revenue could support a virtuous cycle towards as sustainable and just economy that is resilient, inclusive and equitable (United Nations, 2019, 2023a).

In order to measure and evaluate meaningful relationship among SD and CE, it is equally important to have proper indicators in place. There are 17 SDGs and 169 targets and indicators across them. De Pascale et al. (2021) through a systematic review presents a survey of 61 CE indicators groping them into spatial dimensions of sustainability as micro, meso and macro, and on basis of 3R CE principle. Moreover, the challenges to evaluating sustainable development measures such as demand-side sufficiency, material efficiency, energy efficiency etc. arises from shortcomings of material cycles, end-use services, and energy use indicators to assert the impact of material cycles, the life-cycle , or changes in technology, even though many significant empirically derived relationships between these indicators are relevant to global scenario modelling efforts. Fishman et al. (2021). Though there are several metrics to measure different dimensions of economic circularity, the indicators become rare when trying to analyse the interrelationships among CE and SD (Martinho, 2021). Skvarciany et al. (2021) classifies and compiles CEI based on CE loops. Table (5) presents CEI based on with (Skvarciany et al., 2021) compilation with author’s elaboration.

Loop of CE	CE specific area	Indicators	Examples
	Spatially effective economy	Forest cover indicator, urbanization rate.	Forest area annual net change in %, Above ground biomass stock in forest measured in tonnes/hectare
	Bioeconomy	Biofuels, biomass, bio-based products.	Net productivity per hectare, avoided CO_2 emissions
Raw materials extractions	Energy-efficient and renewable energy-based economy	Share of renewable energy sources in total production of electricity, electricity consumption, final energy intensity of GDP, resource intensity of GDP, domestic material consumption, circularity rate,	Air pollution exposure (Exposure to PM2.5 (µg/m³)) Electricity total production (MWh/1000 capita) Renewable energy (% of primary energy supply)

	Resource and material-efficient economy	Productivity of resource, domestic material consumption, production material reuse rate, Trade in Recyclable raw materials, circular material use rate	Production material reuse rate (% of natural resource extraction in tonnes)
Product design	Innovative economy	Eco-innovations, recycling sectors patents research and development expenditure in relation to GDP, patents of recycling of secondary materials, expenditures on research and development (R&D) expenditure in biotechnology etc, CE related investment,	Patents in environment-related technologies (Number) Gross domestic expenditure on R&D (% of GDP)
Production and remanufacturing	Low carbon economy	Emission of particulates, CO2 emission intensity, pollution treatment, Production material reuse rate,	CO2 emission intensity (Tonnes/capita umber of passenger cars in use (Cars/1000 population)
Consumption	Economic prosperity	GDP, increase in household income, poverty risk indicator, number of persons employed, economic growth, Domestic Material Consumption,	Gross Domestic Product (USD/capita) GDP Unemployment rate (Total, % of labour force) Unemp Poverty rate (%) Household disposable income Gross adjusted (USD/capita)
	Socially oriented economy	Innovative social enterprises.	
	Smart economy	Households with Internet access.	Households with Internet access (%)
Waste management	Zero-waste economy	Municipal waste, food waste, municipal waste recycling rate, market rate of recyclable raw materials, zero waste index, sustainable circular index, municipal waste generation rate,	Municipal waste generated (Tonnes/1000 capita)

Table 5:Distribution of CE specific areas and indicators by CE loops used for SDGI Calculation adopted from (Ellen MacArthur Foundation, 2015; Marino & Pariso, 2020; Saidani et al., 2019; Skvarciany et al., 2021) with author's elaboration.

This paper further summarizes the findings of literature under review to investigate the relationship between Sustainable Development and Circular Economy, presented in Table (6).

Study Information		Country/ Region	Methodology	Variables/ Indicators		Relationship	Findings
Citation	Description			Dependent	Independent		
(L. C. T. Dos Santos et al., 2022)	evaluate the relationship between circularity and sustainability in ASEAN, Mercosur, and the EU regions	ASEAN, MERCOSUR, EU	5SEnSU Model that combines environmental, economic, and social aspects into a single index, and the use of goal programming to calculate the Synthetic Indicator of Systems Sustainability	SDG goals (1, 3, 4, 7, 8, 9,10,11, 12,13, 15 ,16)	CEI (Emergy per capita, Renewable Energy Consumption, CO2, Electronic Waste, GDP, GINI, EOI, Emp, HDI, GHI)	Relationship between environment, economic and social aspect of sustainability with CEI	1. CE contributes significantly to sustainable development but the primary and secondary data analysis were not conclusive that circularity guarantees sustainability. 2. EU has superior SD performance compared to ASEAN and Mercosur 3. The impacts generated in the economic system had positive impact on social sectors but negative impact on environment.
(Wardeh & Marques, 2023)	examines the water and sanitation procedures refugee camps	Jordan, Lebanon, Iraq	Qualitative and Quantitative Data analysis collected through questionnaire	SGD 6		Water and Sanitation Use	1. Waste water treatment and reuse technologies in refugee camp in Jordan is a significant shift from unsustainable to sustainable CE practice, that can help to achieve SDGs 6, 3, 4, and 5, with impact on SDG 7, 8, 9, 10, 15, and 17 as it saves time of women and children, decrease water-related illness, minimize water waste, and generates employment.

Study Information		Country/ Region	Methodology	Variables/ Indicators		Relationship	Findings
Citation	Description			Dependent	Independent		
(Rossi et al., 2020)	develop set of indicators linking CE principles, CBM, and the pillars of Sustainability.	Brasil	expert consulting, user's feedback, and case studies	Indicators: system thinking, innovation, stewardship, collaboration, value optimization, transparency, product as a service, sharing economy, product life cycle extension, on demand, recovery by product, dematerialization, Control Variables: financial results, taxation, circular investment, reduction of raw materials used, Renewability, Recyclability, Reduction of toxic substances, reuse, refurbishment, remanufacturing, product longevity, stakeholder structure and diversity, job creation, income generation, employee participation in CBM, Market characterization, involvement of stakeholders in decision making, mindset, cultural change		Relationship between CE principles, CE indicators, CBM and three pillars of Sustainability	1. construction of a set of indicators focusing on the three pillars of sustainability (environmental from a material standpoint, economic, and social), to be utilized in Circular Business Models to capture the innovations brought about by the Circular Economy 2. The proposed indicators are intrinsically related to Clean water and sanitation (SDG 6), Affordable and clean energy (SDG 7), Decent work and economic growth (SDG 8), Industry, innovation, and infrastructure (SDG 9), Responsible consumption and production (SDG 12) and Climate action (SDG 13).

Study Information		Country/ Region	Methodology	Variables/ Indicators		Relationship	Findings
Citation	Description			Dependent	Independent		
(Geissdoerfer et al., 2018)	examination of sustainability performance of the CBM and circular supply chains (CSC), and integration for SD	NA	literature analysis and case studies			Relationship between circular business model and sustainable business model through intensifying resource loops, dematerializing resource loops, closing resource loops, slowing resource loops, narrowing resource loops	1. circular business and circular supply chain help in attaining sustainable development 2. Elements of business model (value proposition, creation and delivery, and capture) need to be circular for sustainable performance 3. CBM and CSC can contribute to SD by promoting economic, environmental, and social goals
(Y. Liu et al., 2021)	empirical investigation of implementation barriers to sustainable food consumption and production	China	Fuzzy DEMATEL) technique	(B1)Weak legal enforcement, (B2)Inadequate infrastructure, (B3)Behavioural barrier, (B4)Lack of investment in advanced equipment/ technologies, (B5)Lack of expertise,(B6) Lack of cross-sector collaboration, (B7)Cost barrier, (B8)Lack of economies of scale, (B9)Lack of environmental education and accountability, (B10) Lack of benchmarking and standards,		interrelationships of the barriers	1. (B1), (B4), (B5), (B8) and (B9) are the cause barriers from food processors' perspective. 2. (B1), (B4), (B6), (B7), (B9) and (B10) are the cause barriers from distribution channels' perspective. 3. (B1), (B4), (B7) and (B9) are the most significant cause barriers from consumers' perspective

Study Information		Country/ Region	Methodology	Variables/ Indicators		Relationship	Findings
Citation	Description			Dependent	Independent		
(Centobelli et al., 2021)	investigate the connections between societal pressure, environmental commitment, green economic incentives, supply chain relationship management, sustainable supply chain design, and circular economy.	NA	Survey through questionnaire, Confirmatory factor analysis (CFA) and structural equation modelling (SEM)	social pressure, environmental commitment, green economic incentives, supply chain relationship management (SCRM), sustainable supply chain design (SSCD), and CE capability		relationship of Supply Chain with CE, and social pressure, environment commitment and green economic incentives	1. Environmental commitment and green economic incentives have a significant positive impact on supply chain relationship management and sustainable supply chain design. 2. supply chain relationship management and sustainable supply chain design to improve the circular economy capabilities of SMEs 3. show a positive effect of social pressure on environmental commitment and green economic incentives
(Ngan et al., 2019)	quantify the priority weights of the SD indicators to provide guidelines to transition toward the circular economy	Malaysia	Fuzzy Analytics Network Process (FANP)	Sustainability Indicators (Economic: Cost, Profit; Social: Health and safety, Education and Training, Public Acceptance; Environment: Carbon Footprint, Water Footprint, Ecology) with industry life cycle (Pioneering/emerging, Rapid Growth, Maturity and Stable Growth, and Deceleration of Growth		Prioritization of Sustainability indicators at different stages of industry life cycle	1. sustainability indicators in encouraging the transition toward CE throughout the whole industry life cycle, Cost is the top factor, followed by Profit, and Public acceptance 2. economic gain is still the key driver for the stakeholders in the palm oil industry to adopt and integrate sustainability components

Study Information		Country/ Region	Methodology	Variables/ Indicators		Relationship	Findings
Citation	Description			Dependent	Independent		
(Pla-Julián & Guevara, 2019)	analysis of the findings of a CE exploratory study for socio-economic and environmental benefits as well as technological, organizational, financial, institutional and social challenges, care ethics and gender	Spain	In depth interviews and group discussion, Circular Economy Assessment Toolkit		Design, manufacturing and distribution, Use, Repairing, Reuse and redistribution, Remanufacturing, Recycling, Turning products into services	qualitative point of view	1. is to say, although the assessment of enterprises focuses on the micro level there are crucial interconnections with the macro level. Shortcomings on the prevailing working conditions, labour practices, gender gaps to unleash capacities and gendered organizations might prevent CE to avail opportunities to generate shared value 2. Increasing women participation, promoting gender equality, generating gendered innovation, and exploring new market niches represent not just new business opportunities but an advancement towards SDGs, forging inclusive and egalitarian futures.
(Martinho, 2021)	exploration of circular economy indicators to measure interlinkages with numerous facades of sustainability		systematic literature based on meta-data and bibliometric analysis				1. confirms the relevance of the sustainability indicators in order to assess and monitor the relationships between circular practices and sustainable development 2. conflicting metrics and the lack of uniformization

Study Information		Country/ Region	Methodology	Variables/ Indicators		Relationship	Findings
Citation	Description			Dependent	Independent		
(Lahane & Kant, 2022)	significant CE practices and SDGs that can be derived from its adoption from emerging nations' perspectives		literature review, experts inputs, multi-criteria-decision-making (MCDM) techniques	SDG goals and CE practices		Ranking of the SDGs in: restorative/regenerative aspects of circularity, material, and resource effectiveness, economic efficiency, and operational performance, and sustainable production and consumption.	1.'government', management', and 'economy' initiatives has 50 % influence on CSC, 2.SDG 12 is most critical for CE adoption 3. SDG12 has highest assessment score among all SDGs and SDG 2 the lowest. 4. management initiative practices is most crucial CE practice for SDG

Table 6: Summary Table of review of relationship between Sustainable Development and Circular Economy

The summary table reveals that Circular Economy, Circular Economy Indicators, CE Principles, and CE practices are related to Sustainable Development but the degree of significance of such relation is elusive to quantify with mix results. The triple bottom line approach based one the three pillars of sustainability, economic, environmental and social are relevant but not sufficient (Geissdoerfer et al., 2018), and demands for a proactive shareholder management and long term perspective. Geissdoerfer et al. (2018) further argues that in order to achieve sustainability, it is necessary for all the elements of business model, viz: value proposition, value creation and delivery, and value capture to be circular. Figure (10) below shows the intersection of sustainable development and circular economy.

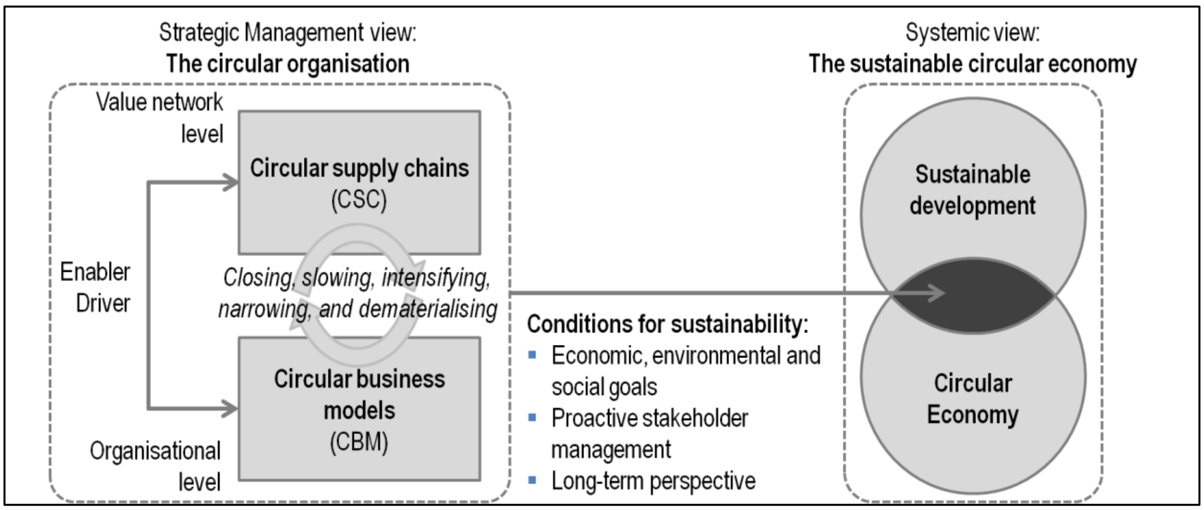

Figure 10: Interlinkages of Circular Economy and Sustainable Development in the Sustainable Circular Business Model, adopted from (Geissdoerfer et al., 2018).

5.4. Waste Management and Valorisation of Waste

Circular Economy is creating new business opportunities by redefining framework conditions for waste management (Teigiserova et al., 2020). This review finds that valorisation of all kinds of waste adds economic, environmental, and social benefits leading to sustainability in comparison to conventional waste treatment and disposal. By treating waste as a secondary resource, high value-added products can be created and thus valorisation of waste adds economic incentives to circular economy practices. Valorisation can also serve as a policy instrument, as for instance, the EU’s commitment to achieving the Sustainable Development Goal (SDG) 12.3 to halve per capita food waste at retail and consumer level, and reduce food losses along production and supply chain by 2030 in its Circular Economy Action Plan (European Union, 2020) can rely on the reuse, recovery and remanufacturing of value added products from food waste. Table (6) show contribution of waste treatment and energy supply activities to different macro-economic indicators in France adopted from (Rodrigues et al., 2021) which indicates that valorisation can be viable and contribute to the economy.

	COICOP code		TOTAL	44	444	45
Family Budget Survey (€ per household per (INSEE,2020b)	Average (HE_AV)	€	27,408	834	578	1,353
		%	100%	3.04%	2.11%	4.94
	Decile 1 (HE_D1)	€	16,123	728	537	967
		%	100%	4.52%	3.33%	6.00
Supply and Use Table (billion € per year) (INSEE 2018)	NACE Code		TOTAL	E	E**	D
	Gross value added (GVA_D)	B€	2,043,99	15,053	10,433	33,75
		%	100%	0.74%	0.51%	1.65
	Output by industry* (GVA_T)	B€	4,039,95	37,370	25,899	107,1
		%	197.65%	1.83%	1.27%	5.24
	Compensation of (COE)	B€	1,198,01	7,592	5,600	12,41
		%	100%	0.63%	0.47%	1.04
	Final consumption (FCE)	B€	1,783,09	14,130	9,793	40,77
		%	100%	0.79%	0.55%	2.29

HE_AV : Contribution to annual expenditures of Average Household; **HE_D1:** Contribution to the annual expenditures of the 10% of the households with the lowest income (decile 1), **GVA_D:** Direct contribution to total national Gross Value Added (GVA), i.e. the main component of Gross Domestic Product (GDP) before adding taxes and subtracting subsidies on products (like VAT, etc.). **GVA_T:** Cumulative direct and indirect contribution to total national GVA, **COE:** Direct contribution to total Compensation of employees, i.e. the sum of all wages and salaries. **FCE:** Contribution to Final Consumption Expenditures, **COICOP codes: 44** - Water supply and miscellaneous services relating to the dwelling; **444** - Miscellaneous services relating to the dwelling; **45** - Electricity, gas and other fuels.

NACE codes: **E** – Water supply, sewerage, waste management and remediation activities; **D** – Electricity, gas, steam and air conditioning supply

Table 7: Contribution of waste treatment and energy supply activities to several macroeconomic (INSEE, 2018; INSEE, 020b) Adapted from (Rodrigues et al., 2021)

5.4.1. Solid Waste

The production of solid trash has significantly increased with rapid urbanization and industrialization. Urban growth must now overcome a significant challenge of effectively managing solid waste. Due to (a) permanent loss of materials and energy, (b) increasing demand for new landfilling sites resulting in loss for housing and agricultural land, and (c) increasing air, water and land pollution from landfilling sites, countries such as The Netherlands, Germany and Sweden developed national policies to address their growing waste problems (King et al., 2006). The European Union extended the policy measures to all member countries through a landfill directive and legislation on Extended Producer Responsibility (ERP).

Despite the fact that some municipalities have adopted the model of zero waste, circular economy and sustainable materials management as sustainable practices, it is still difficult to incorporate these ideas into solid waste policy and planning (Anshassi et al., 2019). United Nations (2023c) forecasts that annual generation of solid waste reaches 3.4 billion tonnes by 2050.

Stahel (1999) argues that the best loop is the smallest loop, and King et al. (2006) concurs by suggesting that remanufacturing can benefit the society and environment the most among repairing, reconditioning, remanufacturing and recycling.

5.4.2. Metal Recycling

It has proven feasible to achieve high recycling rates for metals like copper, iron, nickel, and aluminium when simple, bulk commodities are involved or when the raw material is fairly simple to extract from industrial uses. Lithium, cobalt, and REEs are other energy transition minerals for which it is impossible to draw the same conclusion. High levels of recycling with a focus on the metals needed for sustainable energy technologies rely on further investment and R&D, as well as on international collaboration and cooperation between diverse suppliers (IEA, 2022b).

5.4.3. Construction

The circular economy is a necessary condition for the construction industry to actively play a strategic role in reduction of GHG emissions (Orsini & Marrone, 2019). However, construction material manufacturing is more in line with traditional production patterns characterized by high energy consumption and high GHG emissions. The transformation to a low-carbon, circular, and green economy should be the main emphasis of these models.

A summary of different practices and potential avenues of valorisation is presented in Table (7).

V#: Valorisation Instance, RC: Recycle, RU: Reuse, RM: Remanufacture, RY: Recovery, DS: Disposal

V#	Case Information		Country	Approach	Output	Related SDG	Sustainability				Classification	Waste Hierarchy
	Citation	Description			Primary		Env	Soc	CE	Sus	Archetype	
V1	(Suhartini et al., 2022)	oil palm empty fruit bunches (OPEFBs	Indonesia	Anaerobic Digestion	Methane as biofuel, edible mushroom, bio fertilizers	SDG 6, 7, 9, 12	H	H	H	S	Minimize landfills, conversion to energy, bio-products	RC
V2	(Laso et al., 2018)	Food Waste and Loss	Spain	Incineration	food- waste - energy-food	SDG 12.3	L	H	M	S	Minimize landfills, conversion to energy, bio-products	RC
V3	(Laso et al., 2018)	Food Waste and Loss	Spain	valorisation	food-waste-food	SDG 12.3	H	H	H	S	Minimize landfills, conversion to energy, bio-products	RC
V4	(Laso et al., 2018)	Food Waste and Loss	Spain	Landfill	food- waste - energy-food	SDG 12.3	L	L	L	W	Minimize landfills, conversion to energy, bio-products	
V5	(Khwaldia et al., 2022)	Valorisation of by products from Olive oil production		Extraction, purification, and characterization	phenolic compounds and terpenoids for food packaging, pharmaceuticals, cosmetics, Bioenergy, Biomolecules	SDG 9, 12	H	H	H	S	Reduce waste and recover	RC, RU, RY
V6	(Rodrigues et al., 2021)	Assigned Carrying Capacity consumed by Municipal Waste Management	France	Sorted waste, incineration, Landfill	Paper, glass, gravel, compost, plastic, heat, electricity, metals and bottom ash	SDG 11, 12	H	H	H	H	Reduce Unsustainability	RC, RU

V#: Valorisation Instance, RC: Recycle, RU: Reuse, RM: Remanufacture, RY: Recovery, DS: Disposal

V#	Case Information		Country	Approach	Output	Related SDG	Sustainability				Classification	Waste Hierarchy
	Citation	Description			Primary		Env	Soc	CE	Sus	Archetype	
V7	(Mazzei & Specchia, 2023)	Different Technologies of Solid Medical Waste Management		Incineration	Significant reduction of volume (90%) and weight; Heat recovery potential , hazardous solid output, harmful corrosive gases	SDG 7, 11, 12	M	M	M	M	Conversion to energy and bioproducts	RY
V8	(Mazzei & Specchia, 2023)	Different Technologies of Solid Medical Waste Management		Pyrolysis	gas and liquid with the highest energy value, around 40 MJ/Kg	SDG 7, 12	M	M	M	M		
V9	(Mazzei & Specchia, 2023)	Different Technologies of Solid Medical Waste Management		Gasification	heat, gaseous and residual amounts of sub-products like ash and impurities including dust, alkali compounds, nitrogen, sulphur, chlorine, fluorine, and tar, Plasma gasification has higher WtE recovery efficiency	SDG 3, 6, 7, 11, 12	M	M	M	M		
V10	(Mazzei & Specchia, 2023)	Different Technologies of Solid Medical Waste Management		Bio converter	water is removed for sewage disposal and the solid waste is sent to the sanitary landfill	SDG 3, 6, 7, 11, 12	M	M	M	M	Reduce Environmental Impact	DS
V11	(Mazzei & Specchia, 2023)	Different Technologies of Solid Medical Waste Management		Syngas	substitutes for natural gas, fertilizers, transportation fuels, and hydrogen, and liquid fuels	SDG 6, 7, 12	M	M	M	M		

V#: Valorisation Instance, RC: Recycle, RU: Reuse, RM: Remanufacture, RY: Recovery, DS: Disposal

V#	Case Information		Country	Approach	Output	Related SDG	Sustainability				Classification	Waste Hierarchy
	Citation	Description			Primary		Env	Soc	CE	Sus	Archetype	
V12	(Elegbede et al., 2021)	Valorization of corncob as Agri waste		Microbial Treatment	bio energy, enzyme production, biochemicals, biofield, dye degradation, wastewater treatment, heavy metal removal, cultivation of mushroom, nano-tech application	(SDG 3), (SDG 6), (SDG 7), (SDG 9), (SDG 13)	H	H	H	H	Conversion to energy and bioproducts	RY
V13	(Morero et al., 2023)	treatment solutions for municipal and industrial wastes	Argentina	Anaerobic Digestion	biogas	SDG 7, 11, 12	H	H	H	H	Conversion to energy and bioproducts	RY
V14	(Morero et al., 2023)	treatment solutions for municipal and industrial wastes.		composting	fertilizers, agents for bioremediation, Negative Impact on OFo, FE, TE, HT, LU, MRS (mineral resource scarcity) and WC.	SDG 12, 15	M	M	M	M	Conversion to energy and bioproducts	RY
V15	(Morero et al., 2023)	treatment solutions for municipal and industrial wastes.		bioremediation	removal of highly contaminated hydrocarbon from oil-based drillings	SDG 6, 12, 14	M	M	L	M	Impact Reduction on Environment	DS
V16	(Morero et al., 2023)	selection and treatment solutions for municipal and industrial wastes		compost amendment	biosolids mature compost applied to Water based drill cutting in oil and gas industry in a 50% volume ratio , can create a soilless-plant growing media for halo-tolerant rustic plant species used in land restoration.	SDG 2, 12, 15	M	M	M	M	Impact Reduction on Environment, bioproduct	RY, DS

V#: Valorisation Instance, RC: Recycle, RU: Reuse, RM: Remanufacture, RY: Recovery, DS: Disposal

V#	Case Information		Country	Approach	Output	Related SDG	Sustainability				Classification	Waste Hierarchy
	Citation	Description			Primary		Env	Soc	CE	Sus	Archetype	
V17	(Morero et al., 2023)	treatment solutions for municipal and industrial wastes		Thermal Desorption	IR (ionizing radiation), OFo (ozone formation), TE (terrestrial ecotoxicity), FRS (fossil resource scarcity) and WC (water consumption) categories.	SDG 12, 13	M	M	M	M	Impact reduction on Environment	DS
V18	(Morero et al., 2023)	treatment solutions for municipal and industrial wastes		Disposal in Landfill	The impacts associated with the landfill mainly contribute to the GWP (global warming), FE (freshwater eutrophication), FET (freshwater ecotoxicity), HT (human toxicity) and LU (land use) categories.	SDG 12,11, 15,	L	L	L	L	Impact reduction on Environment	DS
V19	(Awasthi et al., 2022)	bioenergy generation and resource recovery with techno-economic assessment (TEA) and life cycle assessment (LCA) of live stock manure management		Anaerobic digestion/co-digestion	bioenergy, hydrothermal carbonization, hydrochar	SDG 7, 12	M	L	L	L	Conversion to energy and bioproducts	RY
V20	(Awasthi et al., 2022)	resource recovery of live stock manure		Composting/co-composting	reduce NH3, CH4, NOx, N2O and VOCs emission, reduce phototoxicity, soil fertilizer	SDG 12, 13	M	M	M	M	Impact reduction and bioproducts	RY
V21	(Awasthi et al., 2022)	resource recovery of live stock manure		Nutrient recovery from manure	Phosphorus and Nitrogen, reduce use of non-renewable phosphate rock	SGD 7, 9, 12, 13, 15	M	M	M	M	Impact reduction and bioproducts	RY

V#: Valorisation Instance, RC: Recycle, RU: Reuse, RM: Remanufacture, RY: Recovery, DS: Disposal

V#	Case Information		Country	Approach	Output	Related SDG	Sustainability				Classification	Waste Hierarchy
	Citation	Description			Primary		Env	Soc	CE	Sus	Archetype	
V22	(Xiong et al., 2021)	Valorisation of starch rich rice waste humins as a raw material for fabricating biochar-supported Lewis acid catalysts.		microwave heating in aqueous medium	hydroxymethylfurfural and sugar, potentially competitive, low-cost precursor of carbon supports for catalysis used in isomerization	SGD 7, 9, 12, 13, 15	M	M	M	M	substitute bioproducts for carbon-based chemicals in isomerization	RC
V23	(X. Wang et al., 2022)	valorisation technologies in food, agricultural, textile, plastics, and electronics waste		Fermentation, enzymatic hydrolysis, extraction, anaerobic digestion, carbonisation, gasification, pyrolysis	Energy recovery, Wax, Bioethanol and xylooligosaccharides, Pectin, Succinic acid	SGD 7, 9, 12, 13, 14, 15	M	M	M	M	Reduced Environment Impact, Energy efficient processes	RC, RY
V24	(X. Wang et al., 2022)	valorisation technologies in food, agricultural, textile, plastics, and electronics waste		Mono-extraction, thermochemical, biochemical, enzymatic conversion, fermentation of spent coffee ground	Compost; biodiesel	SGD 7, 9, 12, 13, 14, 15	M	M	M	M	Reduce emission	RC, Ry
V25	(X. Wang et al., 2022)	valorisation technologies in food, agricultural, textile, plastics, and electronics waste		Pyrolysis, hydro processing, fluid catalytic cracking of plastic waste	Recycled materials, energy, and fuels (hydrocarbons), Monomers, wax,	SGD 7, 9, 12	M	M	M	M	positive environmental impacts on products containing additives (e.g., WEEE plastics, Chemical upcycling of PET	RC, RY

V#: Valorisation Instance, RC: Recycle, RU: Reuse, RM: Remanufacture, RY: Recovery, DS: Disposal

V#	Case Information		Country	Approach	Output	Related SDG	Sustainability				Classification	Waste Hierarchy
	Citation	Description			Primary		Env	Soc	CE	Sus	Archetype	
											to cyclohexane di-methanol)	
V26	(X. Wang et al., 2022)	valorisation technologies in food, agricultural, textile, plastics, and electronics waste		melt spinning, and enzymatic hydrolysis of textiles	PET fibre and glucose syrup, Sound-absorbing nonwoven materials, Sweater and lanolin	SGD 9, 12,	H	H	H	H	Reducing the reliance on fossil fuels, climate change mitigation, energy-efficient processes, sustainable production of chemicals (e.g., urea, ammonia) and enzymes (cellulase and beta-glucosidase), lower global warming potential than stone wool, reduce emissions of transport in the supply chain.	RC, RY
V27	(X. Wang et al., 2022)	valorisation technologies in food, agricultural, textile, plastics, and electronics waste		Pyrometallurgical, bio-hydrometallurgical, hydrometallurgic	Recycled materials (metals, resin, glass fibre), Energy recovery,	SGD 9, 12,15	H	M	H	H	Reduce environmental impact, reduce freshwater ecotoxicity	RC, RY

V#: Valorisation Instance, RC: Recycle, RU: Reuse, RM: Remanufacture, RY: Recovery, DS: Disposal

V#	Case Information		Country	Approach	Output	Related SDG	Sustainability				Classification	Waste Hierarchy
	Citation	Description			Primary		Env	Soc	CE	Sus	Archetype	
				al processes of electronic waste								
V28	(Cavicchi & Vagnoni, 2022)	CE collaborations for sustainability of a wine value chain based on agro-waste valorisation.			Alcohol, musk, red colour, bioethanol, biomethane, tartaric acid, energy, natural fertilizers	SGD 9, 12, 13, 15	H	H	H	H	Prevent release of CO2, Reduce Environmental Impact, Recovery	RC, RY
V29	(Bonato et al., 2022)	waste management and biomass valorisation realization in small breweries value chains	Brazil, Germany	Not Specified	Human Food, Fertilizer, Biogas, Substrate for mushrooms production, Substrate for enzymes production, Absorbents, Concrete and ceramic materials, Paper Bricks, Bioethanol, Beer yeast capsules, Xylitol, Replacement of Wood Antioxidant	SGD 9, 12,15	H	H	H	H	Biomass Valorisation for increased sustainability in value chain	RE, RM, RC
V30	(Tawfik et al., 2022)	evaluation of biomethane production from microalgal biomass		anaerobic co-digestion with co-substrate	Higher biogas productivity, minerals and nutrients for agriculture, soil conditioner,	SGD 12	H	H	H	H	Cost reduction and increased yield in biogas generation	RU, RC, RY
V31	(Parlato et al., 2022)	Valorisation of sheep wool waste by using as building material	Italy		insulation material based on wool waste, soft mats (100% wool) and semi-rigid panels (80% wool and 20% polyester),	SGD 9, 12,15	H	H	H	H	Reduce impact on water and energy consumption, reduce greenhouse gas emissions (GHG), and reduce pollution caused due to the chemical additive	RU, RY

V#: Valorisation Instance, RC: Recycle, RU: Reuse, RM: Remanufacture, RY: Recovery, DS: Disposal

V#	Case Information		Country	Approach	Output	Related SDG	Sustainability				Classification	Waste Hierarchy
	Citation	Description			Primary		Env	Soc	CE	Sus	Archetype	
V32	(González-González et al., 2022)	valorisation of lignin from rice straw and industrial potential of lignin-derived products		Not Specified	biofuels, biopolymers, biopesticides, and fertilizers.	SGD 9, 12,15	M	M	M	M	Shift to higher value bio-products	RU, RY
V33	(Conidi et al., 2022)	chestnut shells valorisation to recover valuable compounds and reduce risk in disposal		ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO)	gluten-free products for celiac patients, cosmeceutical, nutraceutical and pharmaceutical products	SGD 9, 12,13	H	M	H	H	Shift to higher value bio-products, reduction of environmental risk in disposal	RU, RY
V34	(Leite et al., 2022)	Valorisation of Bauxite residue (BR) by creating a soil conditioner composed of BR and palm oil residual biomass	Brazil	Composting	batch soil conditioner	SDG 11, 12	H	H	M	M	promote the sustainability of the aluminium production chain.	RU, RY

Table 8: Summary of Valorisation Practices and Avenues

There are myriads of opportunities for decreasing the waste disposal problems and achieving rational resource recycling through the recovery of valuable compounds from industrial by-products (Conidi et al., 2022). However, there exist challenges to valorisation of wastes. The research for valorisation is found to be concentrated on specific circumstances and lacking comprehensive approach to recycling, reuse, and remanufacturing solutions giving special emphasis only to particular contexts such as biorefineries and energy production, specific processes such as heat production (Bonato et al., 2022). More research on technologies and methods to analysis and formulation of high added-value solutions to valorisation is required for economic sustainability of the circular economy practices in waste management and valorisation, as landfills seems to be less costly economically but has higher adverse environmental, and social impact. It is also found that lack of resources, know-how, funds, and capacity, sustainable waste management and biomass valorisation solutions are challenging for small manufacturers and in the value chain involving small manufacturers. For instance, (Bonato et al., 2022) reported that although industry experts and specialized literatures mentioned 21 reuse and recycling alternatives, the small breweries mostly disposed the brewer’s spent grains for animal feeding.

Though the opportunities are enormous, the Sankey Material Flow Diagram Figure (12) representing the material flow in EU nations show that circularity is still in infancy.

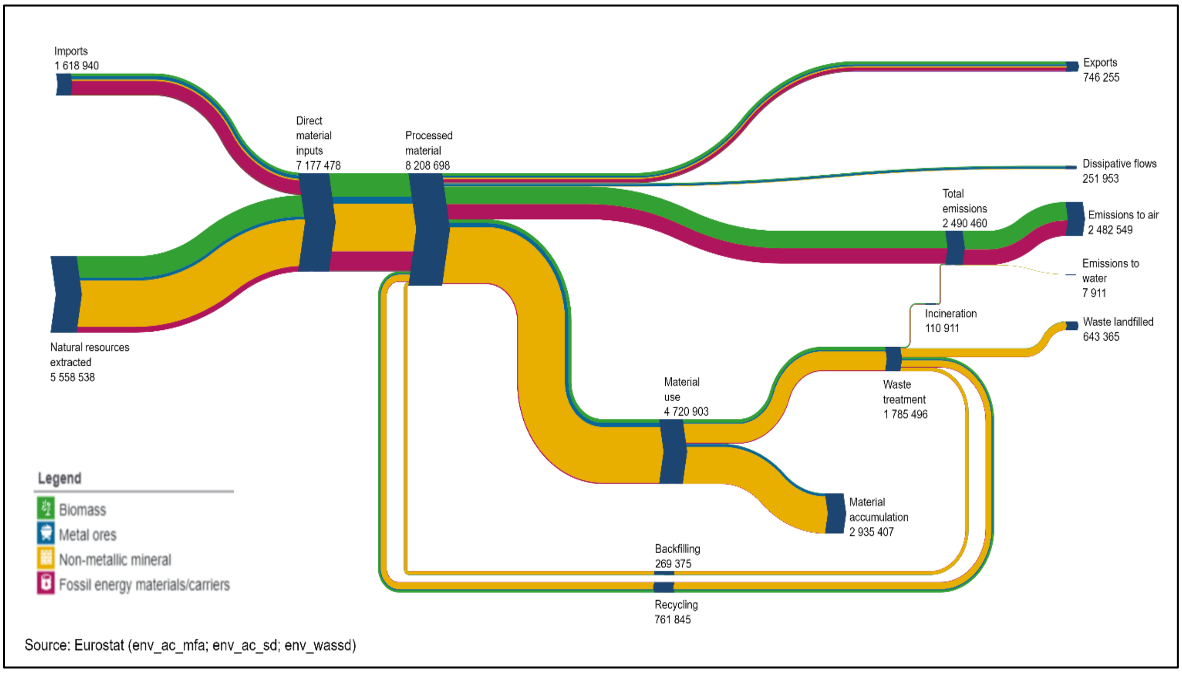

Figure 11: Sankey Material Flow Diagram of EU nations 2023, in thousand tonnes (Eurostat, 2023a)

The material flow diagram in Figure (10) shows insignificant number of materials put back into the loop compared to the new natural resources extracted within the EU countries. Only 14.36% of the natural resources materials extracted and imported get back to the circular loop through recycling and backfilling, whereas 34% is emitted to air, and 43.6% is dumped to air, water and land to be never recovered, which shows a bleak picture of circularity and therefore calls for a greater intervention in closing the loop.

Recycling (or valorising) waste is only sensible if there is a market for the related goods. The limited or saturated market for these products would require greater transportation distances to be sold, thus reduces their environmental or economic relevance, or not allow any savings at all. In many cases, customer acceptance of such products could also be the required. The advantages of secondary products exists if there is a market for them and if they enable the reduction of primary products that require pollution in their production.

5.5. Other Findings

In this section, this paper presents findings on topics related to CE and SD during the course of conducting the literature review.

5.5.1. Decoupling of Growth and Environment Impact:

Stahel (2020) argues that CE is sustainable because it decouples generation of wealth or value from resource consumption, such that the value of objects is determined by the use-value and not on newness or fashion, and that eco-design is a conscious corporate decision to minimize environment impairment. CE strategies and promotion of CE are directed towards decoupling the use of resource and pressure on environment from the economic growth (Chen & Pao, 2022; Ghisellini et al., 2016).

5.5.2. Energy Consumption

Introduced by (Kaya, 1995), "Kaya identity" is a mathematical framework to assess the major factors effecting global carbon emission, represented as [F = P * (G/P) * (E/G) * (F/E)] where, F is global CO_2 emissions; P is global population growth; G is global gross domestic product; E is global energy consumption. (G/P) is the per capita GDP, (E/G) is energy intensity, (F/E) is CO_2 intensity. Kaya identity implies that growing population and increasing GDP keep raising the total carbon emission until and unless the energy intensity or carbon intensity is reduced (Feron, 2016). (Giraud, 2016) argues, deriving from Kaya identity, that assuming Y is GDP, N is population size, and E is primary energy consumption per capita, then, Y/N = (Y/E) * (E/N), which when expressed in logarithmic growth rates implies that GDP is always equal to energy efficiency (Y/E) and energy consumption per capita (E/N), thereby placing energy at the centre of economic growth rate and thus sustainable development agenda (Giraud, 2016). However, analysing data from 2014 and 2015, IEA reported that the once predictable relationship between economic activity, growth in energy demand and energy related CO_2 has started to weaken (IEA, 2016). IEA in the Net Zero Emission scenario prediction, estimates CO_2 emissions to be reduced by 40% within 2030, methane emissions by 75% and both to zero by 2050 while the global economy size doubles and global population increases by 2 billion, in which it also accounts for the large potential of emerging and developing economies in producing renewables-based electricity and bioenergy considered as major carbon dioxide removal source (IEA, 2021), as well as reduced energy intensity and carbon intensity. Substantial policy intervention with increased R&D investment is required for the creation of a circular economy for low emissions energy generation technology (IEA, 2022a).

Moreover, implementation of the Paris Agreement is considered crucial for the accomplishment of the SDGs. The main objective of this agreement is to put efforts into limiting the increase in the average global temperature to below 1.5 degrees Celsius above pre-industrial levels. Whether this ambitious commitment can be fulfilled is for the time to unravel, however, because of differences in supply chain structure, consumption patterns, and energy demand, the burden of energy costs differs by household group whereas an extra 78 to 141 million people are anticipated to fall into extreme poverty as a result of rising living costs (Guan et al., 2023).

5.5.3. Critique of CE

CE is myopic in its environmental focus, as more emphasis is place on recycling and recovery, and rarely on pathway to zero-waste and reduced extraction of virgin resource.. In comparison to legislative instruments for modifying ingrained industrial processes, consumer patterns, justice , and prevailing linear economic system, the CE practices and principles dwell on waste management measures such as landfill avoidance and recycling which are basic targets.(Steenmans & Lesniewska, 2023). The recycling loop in CE is finite, as materials such as paper fibre, cannot be infinitely recycled, and also because financial benefits are valued less as cost of recycling increases, the incentives may be perceived to be low to follow a circular business model (Schaubroeck et al., 2021).

5.6. Avenues for Future Research

The relation between economic performance and circular economy can be better established with more research on the topic. Furthermore, the circular economy strategies that can fuel the economic growth as well as retain sustainability can be an important scientific contribution for policy level intervention as well as implementation in business firms. The transition to a low-carbon economy and the relationship between the CE model and the use of renewable energy can also be a topic of interest for future research. The analysis of CE strategy, the position of subsidies, fines, and taxes, supply chain, micro level productivity and its juxtaposition with Sustainable development can help determine areas where CE adds to sustainable development and where it fails to do so.

Evaluation of the impact of innovations and investment in innovation pertaining to eco-friendliness and circular businesses, as well as the adoption of disruptive technologies, digitalization, intelligent manufacturing, use of Internet of things (IoT), industry 4.0 integration by the firms, industries and at national and regional level can provide actionable insights for CE strategies useful to attain a sustainable development.

The scope of research into valorisation of waste can be extended to all stages of extraction, manufacturing and use across the sectors of economy to obtain circularity and zero-waste manufacturing. Increasing WtE plants efficiency can be a crucial research topic to aid in replacing fossil fuels with eco-friendly energy sources (Mazzei & Specchia, 2023).

Similarly, research into development of a systematic approach that can be adopted in designing CE laws and policies along with conceptual clarity and boundaries of CE can help achieve a sustainable future. Such approach can help determine if CE laws, policies and strategies are to be devised as standalone documents or in an integrated way, as for example, number of environmental and non-environmental rules, including the Consumer, Education, Public Health, Public Property, Maritime, Highway, Insurance, Housing and Construction, and Regional and Local Authorities rules, are amended by France's Anti-waste and Circular Economy Law 2020 (Steenmans & Lesniewska, 2023) .

6. Conclusion

This study based on systematic literature review of 1748 journal articles and use of reports, policy documents and action plans issued by the United Nations, European Union, and other agencies presents hotspot in CE and SD research, examines the relationship between GDP and CE, finds linkages between SD and CE, and reflects on use cases of valorisation of waste as a sustainable CE practice. This review provides three clusters and seven thematic areas of CE and SD research trends. Similarly, the review finds that the contribution of CE sector to GDP is nominal, and that level of circularity needs to be increased. Similarly, this review points out that the need of standardised and comprehensive measurement indicators which can capture the environmental and social aspects of development and not just economic growth. The review finds that the level of recycling, reusing and backfilling is significantly low compared to materials use and natural resource extraction.

A circular economy can only be created by bringing together the business sector, government, and civil society. More ecologically friendly industrial techniques as well as private sector innovation are required. Increasing collaboration and synergies across two or more industries can increase resource efficiency, waste management, reuse and recycling, and closing of the loop. Circular Economy technologies for remanufacturing, product lifecycle extensions, reuse, refurbishment, valorisation, waste to energy, biofuels, renewable energy, emissions reduction etc. can be the drivers to sustainable development as well as keeping the globe in the track to achieve sustainable development goals.

Similarly, while circular economy is promoted as a viable strategy for achieving sustainable development goals, the building of credible measurement metrices to evaluate the degree of circularity and sustainability performance is necessary. Policy intervention and investment in R&D to negate the hindrance on efficiency of secondary raw materials market can be an enabler for economic resilience while making the products clean, circular, and sustainable. Incentivising businesses and population the switch to circular economy and sustainability-oriented behaviours can help in resource conservation. Consumption behaviour inclined towards high efficiency through CE processes those deploy reusing of waste products as resources, decreasing energy intensity and lowered water and land use can aid in a sustainable development.

CE is not merely confined up to reducing the use of resources but rather with the development of sustainable production and supply design in which resources and materials can be utilized over and over again (Genovese et al., 2017). Therefore, the design of distinct types of circular business models involving organizations and consumers (Ertz et al.,2019) will enable firms in creating corporate value (Wirtz et al., 2016).

There is a need to redesign manufacturing processes to improve adaptation to the functioning of ecosystem by focusing on material and energy recirculation. Such redesign creates value in each cycle of returning of the materials and energy into the system in economic terms as well as in maintaining the planetary boundary and carrying capacity of the earth's ecosystems, employment generation, reduced energy consumption, reduced emissions, and reduced waste. More study on technology and methodologies for analysis and development of high added-value valorisation solutions is necessary for the economic viability of circular economy waste management and valorisation practices.

CE may not be the panacea to the sustainability problem but can play significant role in progressing the sustainability paradigm through eco-efficient practices, contribution to economic growth, reducing environmental impact and organizational and social innovations.

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Appendix 1: List of Literatures Reviewed in the Systemic Literature Review.

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