JELS Journal of Economics, Law & Society

ESREIN Economic and Social Research Institute

Harmonizing Economic Growth with Environmental Justice: Circular Manufacturing Pathway

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Abstract

The global challenge of harmonizing economic growth with environmental sustainability has become a critical issue, particularly within the manufacturing sector. This paper explores the potential of circular economy principles as a pathway to achieving a sustainable manufacturing transition that not only promotes economic development but also ensures environmental justice. By analyzing the synergies and tensions between economic growth, environmental sustainability, and social equity, the paper highlights the role of circular manufacturing in creating resource-efficient, low-waste systems. Key findings show that while circular manufacturing holds substantial potential for enhancing economic growth, job creation, and industrial competitiveness, significant barriers remain, including economic costs, technological gaps, and political and social resistance. Moreover, achieving environmental justice in this transition is essential to ensure that marginalized communities are not disproportionately affected by pollution and waste. The paper emphasizes the need for innovative policies, collaborative governance, and inclusive strategies to overcome these challenges and design equitable supply chains and manufacturing systems. Future research should focus on scaling circular practices across industries, addressing regional disparities, and developing technologies that further reduce the environmental footprint of manufacturing.

Article History

Received: November 20, 2024
Accepted: December 5, 2024
Published: December 31, 2024

Keywords

circular economy, sustainable manufacturing, resource efficiency, policy frameworks, social equity, industrial competitiveness

JEL Codes

G38; O14; O33;

How to Cite

Mohamed, H. (2024). Harmonizing Economic Growth with Environmental Justice: Circular Manufacturing Pathway. *Journal of Economics, Law and Society, 1(2),* 77-93. https://doi.org/10.70009/jels.2024.1.2.5

1. Introduction

Digitalization in manufacturing will be fueled by disruptive technologies as part of a broader ecosystem shift. Businesses worldwide are undergoing digital transformation, which is transforming manufacturing for the future. Digital designs, fabrication, use, operation, and after-sales servitization are driving this change in manufacturing, which also includes the management of manufacturing supply chains and the transformation of factory operations and processes. Organizations can accomplish what was previously only a dream by combining advanced modeling and simulation, data collection, analysis, and reporting, as well as advancements in manufacturing and imaging. The Internet of Things (IoT) was made possible by the combination of sensors and software that enables devices to communicate with one another.

One of the biggest worldwide issues of our day is balancing environmental sustainability with economic growth. Economic systems still primarily rely on resource-intensive, linear production models that worsen environmental degradation, despite the fact that many countries have made commitments to switch to renewable energy and lower their carbon footprints. The Grantham Research Institute asserts that switching to low-carbon energy sources and circular economy principles is necessary to decouple economic growth from greenhouse gas emissions in order to achieve

sustainable growth (GRICCE, 2024). This strategy synchronizes economic activity with the worldwide objectives of preserving natural resources and reducing climate change.

A key driver of economic expansion, the manufacturing sector also contributes significantly to waste, pollution, and greenhouse gas emissions. Many of these effects are frequently felt by marginalized communities, who face financial hardships and health hazards. By guaranteeing an equitable distribution of environmental benefits and burdens, incorporating environmental justice into manufacturing practices helps to address these disparities. To protect vulnerable communities and workers, for instance, programs like the European Union's Just Transition Mechanism offer financial and technical assistance to areas most impacted by industrial shifts (EC, 2024).

The Circular Economy provide revolutionary ways to address the twin objectives of environmental justice and economic growth. These concepts decrease waste and prolong the life of materials by rethinking systems to give priority to resource efficiency, reuse, and recycling. Key practices such as industrial symbiosis—where waste from one process becomes a resource for another—demonstrate the potential of circular models to align economic productivity with sustainability objectives. The United Nations Industrial Development Organization (UNIDO) emphasizes that implementing these strategies can enhance global competitiveness while meeting environmental goals (UNIDO, 2024).

This paper aims to explore the intersection of economic growth, environmental justice, and circular manufacturing. It addresses the following key questions:

1. How can circular economy strategies mitigate environmental inequities in manufacturing regions?
2. What are the economic and environmental benefits of adopting circular models?
3. What collaborative approaches among policymakers, industries, and communities can accelerate this transition?

By examining selected case studies, analysing policy frameworks, and presenting innovative practices, this research aims to provide actionable insights for fostering equitable and sustainable industrial growth.

2. Literature Review

Manufacturing offers opportunities that add value to the nation and benefit society more broadly, rather than just producing goods or production. It frequently entails a great deal of innovation (increasing research and development, productivity), and it also produces highly skilled, high-paying jobs. Manufacturing, "with its strong role on exports and import substitutions," can help rebalance the economy, according to economic theory (Mohamed, 2021). The same data can be utilized internally within the manufacturer's organization to optimize processes related to products and services. While the behavioural insights team can find additional user-related prospects, the product design team may benefit from the usage patterns and analytics of the product to further optimize features and design. Above all, the digitization of physical goods can create a way to interact and provide feedback after the initial product or service is sold. This strengthens the bond between the two parties and increases client loyalty and trust.

Lastly, remotely-connected products enable easier tracking throughout the lifetime of the product, its resale activities and project its eventual retirement, possibly to be exchanged for an upgraded model. The closure of production to 'end-of-life' cycle is especially important as we deal with high digital waste and the advent of the Circular Economy.

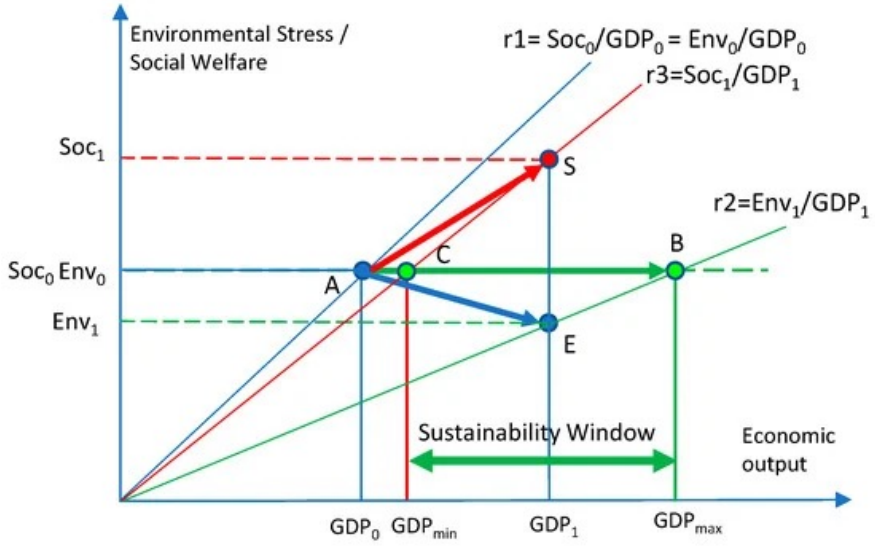
2.1. Economic Growth and Environmental Sustainability

Economic growth, which is frequently gauged by indicators like GDP, industrial output, and job creation, has long been regarded as a country's top priority. This expansion has historically been linked to patterns of resource extraction, production, and consumption that usually ignore social inequalities and environmental constraints. The advantages of economic expansion were not always shared equally, and marginalized groups—particularly those in low-income areas or among indigenous populations—were disproportionately affected by environmental deterioration. These communities have been disproportionately affected by industrial operations like mining, manufacturing, and waste disposal, which has resulted in what is now known as environmental injustice (Maru, 2023). Because polluting industries are frequently found in areas with less political clout or financial means to oppose them, there is a greater risk of air and water pollution, exposure to toxic waste, and other environmental hazards.

Proponents of environmental justice call for a paradigm change that does not put economic expansion ahead of the environment or marginalized communities (Global Witness, 2022). In order to guarantee that no community experiences disproportionate environmental harm as a result of economic activity, the idea of environmental justice places a strong emphasis on the equitable distribution of environmental benefits and burdens. This viewpoint contradicts conventional economic growth models, which have frequently disregarded the costs of advancement to society and the environment.

The "Sustainability Window" approach (Figure 1), which establishes the acceptable limits of economic growth required to preserve environmental stability while attaining social equity, is one of several theoretical frameworks that have been used to study the relationship between economic growth and environmental sustainability. This model, which is based on the theory of sustainable development (Purvis et al, 2019), combines economic, social, and environmental indicators to examine possible trade-offs and synergies and provide policymakers with useful information (Luukkanen et al, 2024). Because of resource-intensive production techniques, economic development and environmental objectives have frequently clashed in the past.

Figure 1: Determining the Sustainability Window in a case where the actual GDP output is within the Sustainability Window (GDPmin < GDP1 < GDPmax).



Source: Luukkanen et al, (2024).

Nonetheless, synergies are becoming more and more apparent, especially in industries implementing cutting-edge green technologies. Data from the World Economic Forum, for example, shows

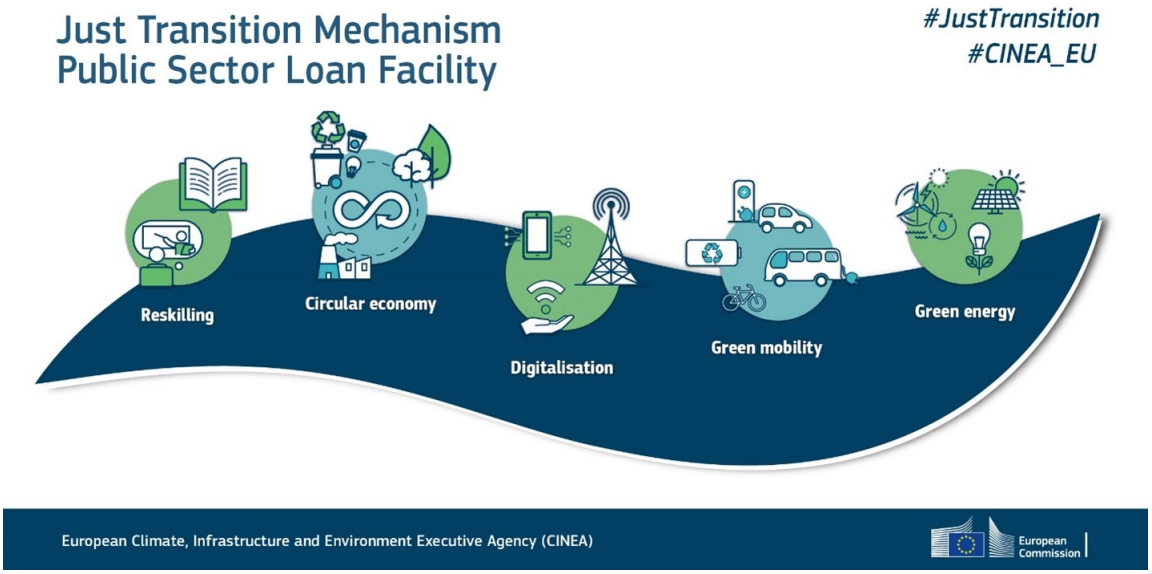
how developments in carbon capture, sustainable energy storage, and circular economy techniques are changing the growth paradigm by lowering environmental impacts and promoting economic innovation (WEF, 2024).

2.2. Environmental Justice in Manufacturing

Regardless of race, socioeconomic status, or geographic location, environmental justice guarantees equitable treatment and meaningful participation of all individuals in environmental decision-making. It includes addressing worker safety, community health effects, and pollution disparities in the manufacturing context. Protecting underprivileged populations that are disproportionately harmed by industrial operations is part of this (Fabozzi et al, 2022).

The varying effects of manufacturing on communities are demonstrated by case studies from industrial areas. For instance, by offering targeted financial and structural support, programs such as the European Union's Just Transition Mechanism (Figure 2) demonstrate the potential to mitigate negative effects on vulnerable populations (Desai, 1994). Similar initiatives are being carried out all over the world, with manufacturing hubs prioritizing cleaner production methods and greener technologies.

Figure 2: European Union's Just Transition Mechanism



Source: European Commission (2024).

2.3. Circular Economy Framework

The Circular Economy is a revolutionary approach to economic growth that emphasizes sustainability and resource efficiency. Its foundation is based on three fundamental ideas: minimizing waste and pollution, preserving materials and products, and restoring natural systems. This model promotes regenerative systems that put sustainability and longevity first, challenging the conventional linear economy. Manufacturing waste outputs are being greatly reduced by increasingly popular practices like closed-loop recycling and industrial symbiosis (Hoffrén, 2001; Fabozzi et al, 2022).

Through programs like modular design, which makes products easy to repair and recycle, the manufacturing industry has successfully adopted circular principles. For instance, the implementation of industrial symbiosis in Scandinavian nations shows how waste from one industry can be used as a resource for another, maximizing resource utilization and minimizing environmental effects (Desai, 1994; Hoffrén, 2001).

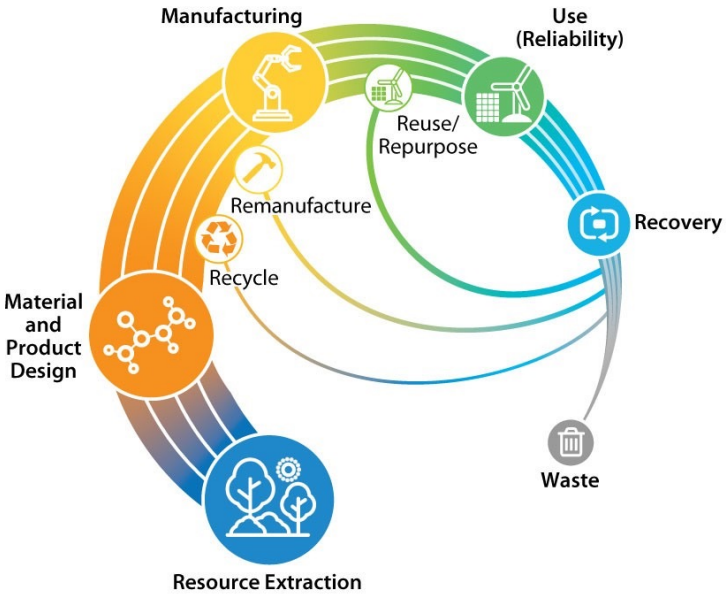
By combining these ideas, it creates a fundamental comprehension of the interrelated opportunities and problems at the nexus of circular manufacturing, environmental justice, and economic growth.

2.4. Circular Manufacturing

A strong substitute for conventional linear production systems is provided by circular manufacturing, which is a component of the larger circular economy model. Resources are taken, used, and then thrown away as waste in a linear economy, frequently with little regard for the effects on the environment and society. Instead of throwing away materials and products, circular manufacturing aims to close the loop of product life cycles by reusing, recycling, and refurbishing them. In order to better align with the concepts of environmental justice, this model seeks to minimize waste, reduce resource consumption, and lessen environmental impacts (see Figure 3).

By encouraging sustainable business practices that generate long-term value rather than immediate profits, circular manufacturing contributes to economic growth. For instance, manufacturers can develop closed-loop systems that lessen dependency on virgin materials by designing products that are easily disassembled for recycling or reused. In the long run, this lowers expenses because companies save money on waste disposal and the purchase of raw materials, in addition to conserving natural resources. Additionally, circular practices can open up new markets and encourage innovation, which will result in the creation of jobs in industries like waste management, recycling, and remanufacturing. Therefore, incorporating circular principles into manufacturing processes can promote sustainable economic growth while minimizing environmental impact and ensuring more equitable distribution of economic benefits.

Figure 3: Circular manufacturing where materials are reused, repurposed, and recycled.



Source: https://ctitool.com/circular-economy-materials/

Through increasing resource efficiency and encouraging innovation, circular manufacturing makes a substantial contribution to economic growth. It could produce a significant amount of economic value (Siderius & Zink, 2022). For example, adopting circular practices in industries like cement and steel could cut the world's material demand by as much as 20% by 2050, which would save money in the long run and ease environmental strains (IEA, 2020). Furthermore, it is projected that circular initiatives will generate millions of jobs worldwide, with 4.8 million new jobs in Latin

America and the Caribbean by 2030, primarily in the reuse, repair, and recycling sectors (Calisto Friant et al, 2023). By implementing circular economy roadmaps, cities like London and Amsterdam anticipate thousands of new jobs and significant economic benefits, proving the scalability and profitability of this approach (GRICCE, 2024).

3. Methodology

This study uses a qualitative methodology to investigate how circular economy tactics can balance environmental justice and economic growth in manufacturing sectors. Environmental economics (Fabozzi et al, 2022), socio-ecological systems theory (Siderius & Zink, 2022), and circular economy models (Think2030, 2024) are all incorporated into the analytical framework.

The method was chosen to address the multifaceted nature of the research questions, and the chosen case studies and policy analyses offer contextual knowledge that captures the intricacies of putting circular strategies into practice and their effects on society. This strategy is in line with sustainability research best practices, which place an emphasis on integrating various viewpoints and data sources to produce useful results.

Although qualitative research employing policy and case study analysis is a potent methodology, there are a number of possible drawbacks. Case study results are frequently context-specific and might be difficult to extrapolate to different contexts. This is because every case is different and depends on its circumstances. Different political, social, and economic contexts impact policy decisions, making it difficult to extrapolate findings to other jurisdictions or periods of time. Evaluation and criticism of policies can be subjective, particularly if the interpretation of the objectives or results of the policy is influenced by ideological or value-based preferences. It can be challenging to separate the direct effects of policies from other influencing factors because they frequently interact with external variables. Both methods involve synthesizing complex information, which can lead to oversimplification or omission of critical variables, especially when involving space or time constraints.

4. The Intersection of Economic Growth, Environmental Justice, and Circular Manufacturing

It is necessary to support programs that link local innovation projects under public initiatives with the technical expertise of industries and research at universities. Although manufacturing generates value from raw materials, material innovation still plays a major role in manufacturing technology, science, and economic policy because it supplies the "work" for manufacturing. The most inventive areas in the manufacturing sector are successful because of both factors. Certain industries have demonstrated exceptional potential to be positioned as leaders of cyber-physical systems (CPS) initiatives, particularly the automotive and smart city sectors. It is becoming increasingly clear that the new data-enhanced manufacturing requires a skilled workforce as the production floor transitions to CPS and a more integrated IoT environment. The next-generation intelligent manufacturing model could be halted by the lack of qualified personnel.

Governments must constantly retrain workers and continuously entice young, adaptable individuals to pursue STEM (science, technology, engineering, math) and data science courses in order to meet the demand for a highly skilled and talented workforce. Authorities can concentrate on luring and utilizing mobile talent through special international work visas in areas where there is an urgent, severe labour shortage in new manufacturing environments. Technology transfer is another policy that may be taken into consideration, particularly when it comes to training current employees to analyse Big Manufacturing Data. It is possible to implement supplemental programs like apprenticeships, ongoing vocational education, and worker cross-training.

Table 1: Selected Case Studies on Economic Impact from Circular Manufacturing

1. Cost Reduction through Resource Efficiency
Case Study: Signify (formerly Philips Lighting) – Circular Light-as-a-Service Model. https://www.signify.com/
Philips offers "light-as-a-service," where customers lease lighting systems instead of purchasing them outright.
Process: Philips retains ownership of the equipment, ensures its maintenance, and takes responsibility for refurbishing and recycling components at the end of their lifecycle.
Economic Impact: Customers reduce upfront capital expenditures.
2. New Revenue Streams
Case Study: Renault's Circular Economy Business Units
https://www.renaultgroup.com/en/our-commitments/environment-circular-economy/
Renault's circular manufacturing initiatives at the Choisy-le-Roi plant generate revenue through the remanufacturing and resale of automotive parts.
Process: Components like engines and gearboxes are collected, reconditioned, and resold at lower prices compared to new parts.
Economic Impact: (i) Significant savings in production costs (up to 40% less compared to manufacturing new parts). (ii) Revenues generated from secondary markets for refurbished parts. (iii) Reduced material costs by reintroducing recycled content into the supply chain.
3. Job Creation
Case Study: Patagonia's Worn Wear Initiative. https://wornwear.patagonia.com/
Customers can trade in old gear, which is then repaired and resold or recycled into new products.
Process: Skilled technicians repair damaged clothing, while design teams innovate to increase product durability.
Economic Impact: (i) Jobs created in repair centres and retail outlets. (ii) Expanded customer base attracted by sustainable and affordable refurbished products. (iii) Revenue diversification by monetizing previously unsellable items.
4. Enhanced Competitiveness and Brand Value
Case Study: Unilever's Sustainable Packaging Initiatives. https://www.unilever.com/sustainability/plastics/
Unilever uses recycled and recyclable materials in its packaging to align with circular economy principles.
Process: Investment in recycling infrastructure and partnerships to source post-consumer plastics.
Economic Impact: (i) Reduced material costs from using recycled plastics. (ii) Increased brand loyalty and market share among environmentally aware consumers. (iii) Regulatory compliance leading to cost savings by avoiding fines and penalties.
5. Risk Mitigation and Supply Chain Resilience
Case Study: Apple – Daisy Recycling Robots
https://www.apple.com/sg/newsroom/2022/04/apple-expands-the-use-of-recycled-materials-across-its-products/
Techniques include combining multiple wet-cycle processes, using ozone gas, and recycling water.
Process: Valuable materials like cobalt and aluminum are extracted and reused in manufacturing new devices.
Economic Impact: (i) Lower raw material costs due to reduced reliance on virgin materials. (ii) Stabilized supply chains by reducing vulnerability to geopolitical risks associated with mining. (iii) Significant cost savings in waste management and material sourcing.
6. Increased Innovation
Case Study: Interface – Modular Carpet Design. https://shop.interface.com/SEA/en-SG/carpet-tile/
The company works with the Forest Stewardship Council (FSC) to ensure sustainable forestry and uses wood waste in furniture production.
Process: Carpets are designed to be easily recyclable, and customers return used tiles for refurbishment or recycling.
Economic Impact: (i) Reduced costs for customers by extending the usable life of installations. (ii) Continuous innovation in materials and processes enhances Interface's market leadership. (iii) Expanded market share due to the environmentally friendly business model.

Source: Author's own.

The interaction of circular manufacturing, environmental justice, and economic growth offers both possibilities and difficulties for developing just and sustainable systems. Industrialization and resource extraction have historically been associated with economic growth, frequently at the expense of social justice and environmental health. But in recent years, there has been a movement

toward more sustainable methods, like circular manufacturing, which could bring environmental justice and economic growth together. Circular manufacturing provides a way to rethink the design, production, and consumption processes in order to foster equitable and inclusive outcomes for communities and the environment in addition to accelerating economic development.

4.1. Economic Impacts of Circular Manufacturing

Circular manufacturing not only contributes to environmental sustainability but also creates significant economic benefits by reducing costs, driving innovation, and opening new revenue streams. ***Table 1*** above presents key economic impacts supported by real-world case studies.

4.2. Social Impacts: Ensuring Environmental Justice

Circular manufacturing must consider the social aspects of production, though, if it is to be genuinely in line with environmental justice. This involves making certain that all communities, especially those that have historically been marginalized, can benefit from the circular economy. Creating economic opportunities and jobs in communities that have been impacted by environmental degradation is a crucial part of this. In underprivileged areas, for instance, the development of green manufacturing technologies or the expansion of recycling facilities can stimulate economic growth and local job opportunities (see ***Table 2***).

Additionally, circular manufacturing provides a means of involving communities in decision-making procedures, guaranteeing that their opinions are heard in the development and application of sustainable practices. Upcycling projects and local recycling programs are examples of community-based initiatives that can enable locals to actively participate in waste reduction and environmental improvement. These programs support the local economy and advance environmental justice, fostering a cycle of sustainability, economic opportunity, and empowerment.

4.3. Environmental Outcomes

Circular manufacturing reduces environmental impact by conserving resources, lowering greenhouse gas (GHG) emissions, reducing pollution and conserving resources. It requires collaboration between stakeholders, including governments, businesses, and consumers, to ensure effective implementation. Below are some key environmental outcomes from circular manufacturing, supported by case studies, as described in ***Table 3***.

As demonstrated by these case studies, companies integrating circular practices experience environmental, economic, and reputational benefits. In the long term, scaling circular manufacturing could transform industries and significantly reduce the environmental pressures of traditional linear manufacturing systems. Practices such as recycling construction materials and reusing wastewater in industrial processes contribute to lower emissions and improved resource efficiency (Siderius & Zink, 2022; Tukker et al, 2023).

5. Policy Frameworks and Governance Mechanisms

Global economic dynamics have an impact on the evolution of manufacturing, which is fuelled by sophisticated machinery and intricate procedures. These days, to create “smart” and advanced products, they use interoperable digital technologies like artificial intelligence, the Internet of Things, and robotics. As a result, these jobs now demand higher skill levels, which will pay more but lead to new fields. By comprehending these changes in manufacturing, nations can develop their own capacity for innovation and sector specializations for new development opportunities. They will gain from economic expansion and high worker wages if they do this.

Table 2: Selected Case Studies on Social Impact from Circular Manufacturing

1. Job Creation and Workforce Development
Case Study: Renault's Refactory in Flins, France. https://www.renaultgroup.com/en/our-company/locations/refactory-flins-2/
Renault established the Refactory to integrate circular economy practices, including remanufacturing car parts, recycling materials, and repurposing electric vehicle batteries.
Impact: Generates employment in repair, recycling, and remanufacturing industries. It also provides opportunities for skill enhancement in sustainable practices.
Social Outcomes: (i) Created new jobs in specialized fields, with a projection of employing 3,000 workers by 2030. (ii) Training programs enhance workers' expertise in advanced technologies like battery refurbishment and sustainable mobility solutions. (iii) Partnerships with local educational institutions support workforce development.
2. Community Empowerment
Case Study: Interface's Net-Works Program https://eom.org/oxford-case-studies/interface-inc/
Interface collaborates with coastal communities to collect discarded fishing nets, recycling them into carpet tiles.
Impact: Engage local communities in sustainable practices, improving economic stability and collective environmental stewardship.
Social Outcomes: (i) Provided supplemental income to over 2,200 households. (ii) Empowered communities to clean up coastal areas, enhancing health and tourism. (iii) Encouraged the adoption of sustainable business models within the community.
3. Equitable Access to Resources
Case Study: Fairphone – Ethical Electronics https://www.fairphone.com/en/impact/fair-materials/
Fairphone designs modular smartphones for easy repair and longer lifespans.
Impact: Makes refurbished and recycled products more affordable, promoting equity in resource access.
Social Outcomes: (i) Increased affordability of sustainable technology, promoting accessibility. (ii) Supported ethical supply chains by sourcing conflict-free materials and fair labor practices. (iii) Raised consumer awareness of the social and environmental costs of electronics production.
4. Health Improvements
Case Study: Apple's Daisy Robot for E-Waste Recycling https://www.apple.com/sg/newsroom/2019/04/apple-expands-global-recycling-programs/
Apple uses robots to disassemble devices and recover valuable materials, minimizing e-waste.
Impact: Proper waste management through circular practices reduces exposure to harmful substances in vulnerable communities.
Social Outcomes: (i) Reduced health risks associated with informal recycling methods involving toxic exposure. (ii) Improved urban living conditions, especially in regions disproportionately affected by e-waste. (iii) Set higher safety standards for global recycling practices.
5. Fostering Sustainability Awareness
Case Study: Patagonia's Worn Wear Program. https://wornwear.patagonia.com/
Techniques include combining multiple wet-cycle processes, using ozone gas, and recycling water.
Impact: Influences consumer and societal behaviour toward sustainable lifestyles.
Economic Impact: (i) Promoted a culture of reuse and repair, challenging fast-fashion norms. (ii) Engaged communities through workshops and events on sustainable consumption. (iii) Created networks of environmentally conscious consumers and advocates.
6. Reduction in Social Inequalities
Case Study: Waste-to-Wealth Initiative in Accra, Ghana https://thevaultzafrica.com/investment-world/waste-to-wealth-exploring-opportunities-in-ghanas-recycling-industry/
An UN-backed project trains informal waste collectors to process plastic waste into marketable materials.
Impact: Circular initiatives often involve partnerships with underserved communities, creating economic opportunities and reducing disparities.
Social Outcomes: (i) Improved livelihoods for waste pickers through stable incomes. (ii) Reduced waste in urban areas, leading to healthier living conditions. (iii) Fostered collaboration between local governments, businesses, and communities.

Source: Author's own.

Table 3: Selected Case Studies on Environmental Outcomes from Circular Manufacturing

1. Reduction in Resource Extraction
Case Study: Renault's Closed-Loop Automotive Manufacturing. https://www.renaultgroup.com/en/news-on-air/news/circular-economy-what-if-cars-were-to-become-our-main-resource/
Process: Renault's Choisy-le-Roi plant specializes in remanufacturing engines, gearboxes, and injection pumps using reclaimed materials.
Impact: The facility recycles 43% of vehicle parts by weight and uses 80% less energy and 88% less water compared to manufacturing new parts.
Environmental Benefits: Reduced raw material extraction and significantly lower carbon emissions.
2. Decreased Waste Generation
Case Study: Interface's Carpet Recycling Program. https://www.interface.com/US/en-US/sustainability/recycling.html
Process: The company uses old carpets to produce new ones through its ReEntry recycling program. Nylon fibres are extracted, and the backing material is processed for reuse.
Impact: Since the program began, Interface has diverted over 350 million pounds of carpet from landfills.
Environmental Benefits: Reduction in landfill waste, conservation of natural resources, and decreased lifecycle emissions.
3. Lowered Greenhouse Gas Emissions
Case Study: Patagonia's Worn Wear Initiative. https://wornwear.patagonia.com/
Process: Customers can trade in old gear, which is then repaired and resold or recycled into new products.
Impact: Over 100,000 garments have been repaired, significantly lowering demand for new raw materials and production energy.
Environmental Benefits: Reduced carbon footprint due to lower production energy requirements and extended product lifecycle.
4. Prevention of Toxic Emissions and Pollution
Case Study: Apple's Recycling Robots – Daisy and Liam. https://www.apple.com/sg/newsroom/2018/04/apple-adds-earth-day-donations-to-trade-in-and-recycling-program/
Process: These robots can disassemble 200 iPhones per hour, recovering materials like gold, silver, aluminium, and cobalt without releasing toxins into the environment.
Impact: Apple reduced mining activities for rare earth metals, which are often associated with toxic emissions and environmental degradation.
Environmental Benefits: Prevented environmental pollution from improper e-waste disposal and reduced mining-related emissions.
5. Conservation of Water and Energy Resources
Case Study: Levi Strauss's Water<Less® Program https://www.levistrauss.com/2019/03/25/world-water-day-2019-saving-h2o/
Process: Techniques include combining multiple wet-cycle processes, using ozone gas, and recycling water.
Impact: Since 2011, Levi's has saved over 4.2 billion litres of water and reused 9.6 billion litres in its manufacturing.
Environmental Benefits: Conservation of freshwater resources and reduced water pollution from dyeing processes.
6. Biodiversity Preservation
Case Study: IKEA's Sustainable Forestry Practices https://www.ikea.com/global/en/our-business/sustainability/ikea-forest-positive-agenda/
Process: The company works with the Forest Stewardship Council (FSC) to ensure sustainable forestry and uses wood waste in furniture production.
Impact: In 2020, IKEA achieved 98% sustainability in its wood supply chain, including recycled content.
Environmental Benefits: Reduced deforestation, preservation of habitats, and enhanced carbon sequestration.
7. Reduction of End-of-Life Environmental Impact
Case Study: The Ellen MacArthur Foundation's Circular Economy Pilot Projects. https://circulareconomy.europa.eu/platform/sites/default/files/knowledge_-_circular_business-models-for_the_environment.pdf
Process: A pilot project in Amsterdam reused construction and demolition waste for building new structures.
Impact: Reduced landfill waste and conserved raw materials.
Environmental Benefits: Lower lifecycle emissions and minimized environmental disruption from construction waste.

Source: Author's own.

In addition, comprehensive legislative and regulatory frameworks are required in order to successfully combine environmental justice, economic growth, and circular manufacturing. By establishing unambiguous sustainability standards and offering incentives to companies that implement circular practices, governments can play a crucial role. Companies may be encouraged to design products with reuse and recyclability in mind by policies like extended producer responsibility (EPR) laws, which mandate that manufacturers assume responsibility for the full lifecycle of their products, including post-consumer waste (UNIDO, 2024).

Furthermore, the creation of green public procurement regulations can encourage businesses to embrace circular practices by increasing demand for products made sustainably. By funding the required infrastructure, such as recycling centres, repair hubs, and reverse logistics systems, governments can also help facilitate the shift to a circular economy.

Regulations must guarantee that the advantages of circular manufacturing are shared fairly in order to uphold environmental justice. This entails giving disadvantaged communities access to the economic opportunities brought about by the circular economy in addition to shielding them from the detrimental effects of industrial activity. For instance, governments can stimulate economic growth and create jobs in historically underserved communities by focusing investments on green industries in underserved areas.

5.1. International Policies Supporting Circular Manufacturing

Global climate agreements like the Paris Agreement and international frameworks like the EU Circular Economy Action Plan (CEAP) are essential for promoting circular manufacturing. As a component of the European Green Deal, the EU CEAP places a strong emphasis on resource reuse, waste reduction, and sustainable product design within the EU economy. It suggests legislative measures for sustainable product policy while focusing on high-impact industries like textiles, electronics, and plastics. In order to coordinate global efforts, this action plan also seeks to lower material consumption and advance a "Global Circular Economy Alliance."

In a similar vein, circularity in industrial practices is promoted by the UN Sustainable Development Goals (SDGs), particularly Goal 12 on responsible consumption and production. These frameworks guarantee worldwide agreement on resource efficiency by offering direction for incorporating sustainability into economic policies (EC, 2023).

5.1.1. Legal Instruments for Promoting Environmental Justice

In order to achieve environmental justice, legal mechanisms that address industrial externalities are essential. While rights-based strategies place a higher priority on fair resource distribution and shield marginalized communities from disproportionate environmental harms, regulations such as the EU's Industrial Emissions Directive place limits on pollutants from manufacturing activities. Many nations, for instance, have enacted environmental justice laws to guarantee community involvement in decision-making processes and to enforce equitable industrial facility siting (EC, 2023).

A number of important laws and directives have been established by the European Union (EU) with the goal of advancing justice and environmental protection. These laws set the stage for policies that strike a balance between social justice and environmental concerns, preventing vulnerable communities from suffering disproportionately from environmental harm. Some of the core legal instruments include:

I. The European Convention on Human Rights (ECHR) and Environmental Rights

An important legal framework that promotes environmental justice is the European Convention on Human Rights (ECHR), which was ratified by the Council of Europe. Although environmental concerns are not specifically addressed by the convention, the ECHR has interpreted it as falling under the purview of human rights. Notably, the right to a healthy environment has been construed as part of Article 8 of the ECHR, which protects the right to respect for private and family life. This has resulted in historic decisions in support of citizens who contend that environmental degradation jeopardizes their livelihoods or health.

II. The Aarhus Convention

One of the most important international agreements on environmental justice in Europe is the Aarhus Convention,[1] which is officially known as the "Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters." The convention, which was adopted in Aarhus, Denmark, in 1998, aims to empower citizens by giving them the right to access environmental information, take part in environmental decision-making, and seek justice when their rights are infringed.

Because it promotes accountability, transparency, and participation in environmental governance, the Aarhus Convention is essential to environmental justice. The convention states unequivocally that the rights of people to participate in public life and to pursue legal recourse are intimately related to environmental protection. Its three pillars—access to information, public participation, and access to justice—are foundational in ensuring that vulnerable groups are not excluded from decisions that directly affect their environment and health.

III. The EU's Environmental Justice Mechanism

Through its institutional framework, the EU has further developed policies to promote environmental justice. During the 2014–2020 timeframe, the EU's 7th Environmental Action Programme[2] (EAP) established a clear vision for "living well, within the limits of the planet." This initiative combined social justice and sustainability, advocating for improved safeguards for marginalized communities that are disproportionately affected by environmental damage.

The EU Green Deal,[3] another component of the EU framework, intends to change the EU economy in order to attain climate neutrality by 2050. In order to guarantee that no community is left behind during the shift to a low-carbon economy, the Green Deal places a high priority on "just transition" policies. This involves support for regions and communities that may face economic hardship as a result of shifting industries, such as those dependent on fossil fuels or traditional manufacturing.

IV. The EU's Environmental Liability Directive (ELD)

The EU adopted the Environmental Liability Directive (2004/35/EC),[4] which establishes the "polluter pays" basis for environmental liability. According to this directive, companies and other organizations that cause environmental harm must pay for its repair, especially when land, water,

1 Original document: https://unece.org/DAM/env/pp/documents/cep43e.pdf. The Aarhus Convention as a tool for enhancing the role of the public in tackling climate change https://unfccc.int/sites/default/files/aarhus_convention.pdf?download

2 7th Environment Action Programme https://www.eea.europa.eu/policy-documents/7th-environmental-action-programme

3 The European Green Deal: Striving to be the first climate-neutral continent https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

4 Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32004L0035

and biodiversity are contaminated. By giving citizens and communities the ability to sue for damages, the directive establishes an accountability framework that helps shield vulnerable populations from bearing an unfair share of the costs associated with industrial activity's environmental effects.

In addition to offering a way for impacted people or communities to request compensation for damages, the directive seeks to serve as an effective deterrent against environmental harm. It has the potential to be a powerful tool for achieving environmental justice in cases where disadvantaged communities are exposed to environmental risks due to industrial operations or government negligence.

5.2. National and Local Governance Strategies

Governments, both national and local, are crucial in encouraging circular practices. Policies include tax breaks for recycling programs, subsidies for companies implementing circular business models, and public procurement guidelines that give preference to sustainable goods. These initiatives are strengthened when the public and private sectors work together. For example, the EU promotes innovation by supporting projects that aim to achieve circularity through funding mechanisms such as the LIFE Programme and the European Regional Development Fund (EC, 2023; EEA, 2024).

Many European nations have created their own national laws and regulations to advance the objectives of environmental justice, even though the EU offers broad frameworks for environmental protection and justice. These laws are frequently more focused on particular issues impacting local communities and serve as a supplement to EU directives.

I. Environmental Justice in the UK: The Environmental Protection Act

Environmental justice has long been acknowledged in the UK, especially with the passage of the Environmental Protection Act of 1990. This Act established policies to control waste, prevent pollution, and guarantee that industrial operations follow environmental safety regulations. The Act has been especially helpful in tackling problems that disproportionately impact impoverished communities, like contamination, waste management, and air pollution.

Furthermore, the necessity of taking environmental justice into account in the framework of social equity has been emphasized by the UK's Equality Act (2010).[5] The Act encourages equity and inclusivity in environmental decision-making processes by requiring public bodies to consider how environmental policies may affect vulnerable and marginalized groups.

II. Environmental Justice in Germany: The German Federal Environmental Agency

The work of Germany's Federal Environmental Agency (UBA),[6] which is essential to making sure the nation's environmental policies support social justice and sustainability, serves as the foundation for the country's approach to environmental justice. Equal access to environmental benefits and safeguarding underprivileged communities from environmental harm are two aspects of the UBA's environmental justice focus. The nation's Energy Transition (Energiewende),[7] which aims to lessen dependency on fossil fuels while making sure that the switch to renewable energy doesn't negatively affect vulnerable communities, is one noteworthy example. Furthermore, Germany's focus on community-based environmental monitoring, citizen participation, and guaranteeing fair access to clean air, water, and green energy has strengthened the country's incorporation of environmental

5 UK's Equality Act 2010 https://www.legislation.gov.uk/ukpga/2010/15/contents
6 German Environment Agency (UBA) https://www.bmuv.de/en/ministry/tasks-and-structure/federal-and-laender-authorities/german-environment-agency-uba
7 Germany's Energiewende – The Easy Guide https://www.cleanenergywire.org/easyguide

justice principles into its policies.

Environmental justice is also being incorporated more and more into corporate law as part of the larger European legal system, where companies are expected to disclose their environmental effects and accept accountability for how their operations affect marginalized communities. This legal obligation is expanding in light of corporate social responsibility (CSR) and environmental, social, and governance (ESG) standards.

Companies are now required to disclose their environmental and social impacts, especially with regard to marginalized communities, under strict EU regulations such as the Sustainable Finance Disclosure Regulation (SFDR)[8] and the Non-Financial Reporting Directive (NFRD).[9] Companies are held responsible for their part in causing or reducing environmental injustice thanks to these legal frameworks.

6. Challenges and Barriers

There are several obstacles in the way of the shift to circular manufacturing, chiefly social, political, and economic. The initial expense of switching to circular systems is a major obstacle. When implementing new technologies or rethinking their production processes, many businesses encounter financial challenges, particularly in sectors that mainly rely on conventional linear models. Long-term cost savings may be possible with circular manufacturing, but the initial outlay needed to redesign products, acquire new technologies, and establish new supply chains may be a turnoff. Significant economic barriers are created by high upfront costs for new technologies, less expensive alternatives from linear supply chains, and a lack of consumer demand for circular products. Organizational resistance to circular principles, which are frequently marginalized by conventional business models, gives rise to social challenges. Politically, inconsistent regulations and lack of global cooperation on circular strategies further hinder widespread adoption, keeping industries locked into linear systems (EEA, 2024).

Additionally, recycling and material recovery present technical difficulties. Many products contain hazardous materials that are challenging to process in a circular system, or they are made with limited capacity for recycling. Innovation in product design and investments in cutting-edge recycling infrastructure and technologies are needed to meet these challenges. Even though technology is developing, there are still big gaps in infrastructure, scalability, and circular design. Lack of recycling facilities, restricted availability of circular products, and difficulties setting up cross-border material recycling systems are some of the main obstacles. Due to these constraints, companies find it challenging to implement circular manufacturing models on a large scale (EEA, 2024).

The requirement for systemic change presents another difficulty. Communities, governments, and industries must work together to transition from a linear to a circular economy. Legislators must establish regulatory frameworks that encourage circular practices and guarantee that companies follow environmental justice standards. This entails giving tax breaks or subsidies to businesses that use circular manufacturing techniques and making sure that these methods don't unfairly disadvantage marginalized communities. Businesses' short-term financial demands frequently clash with the long-term expenditures necessary for a circular transition. Because of the perceived high risks and unpredictable returns, businesses that prioritize short-term profitability are reluctant to adopt circular strategies. The broad adoption of circular practices in most countries is hampered by this conflict between sustainability and profitability (EEA, 2024).

8 Sustainability-related disclosure in the financial services sector https://finance.ec.europa.eu/sustainable-finance/disclosures/sustainability-related-disclosure-financial-services-sector_en

9 Non-financial Reporting Directive https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/654213/EPRS_BRI(2021)654213_EN.pdf

7. Pathways to Harmonization

Prioritizing circular economy principles—which promote resource efficiency and waste reduction—is a crucial tactic in combining economic, social, and environmental objectives for a sustainable manufacturing transition.

Collaboration between stakeholders is essential to the transition's success. In order to align policies that support environmental justice and circular manufacturing, governments, corporations, and communities must have ongoing conversations. Incorporating sustainability into corporate operations can promote equitable economic growth while preventing disadvantaged populations from bearing an unfair share of the costs associated with industrial externalities. Putting money into education and innovation will help the economy shift to a circular economy by giving workers the skills they need for new green jobs (ERM, 2024). In order to balance short-term growth with long-term sustainability, stakeholders can address the challenges presented by the transition through thoughtful policy frameworks and equitable supply chain design. By fostering innovation through sustainable practices, circular manufacturing can unleash substantial growth potential. These practices not only increase competitiveness but also generate employment in a variety of industries. Businesses can support environmental and economic sustainability by emphasizing material recycling, resource reuse, and production waste reduction. Additionally, it is believed that circular economy principles are essential to achieving global climate goals and sustainable development objectives (Think2030, 2024; ERM, 2024).

8. Conclusion

Through the promotion of innovation, resource efficiency, and decreased waste generation, the circular economy provides a revolutionary means of accomplishing these goals. However, equity must be at the heart of governance structures and policy design for circular practices to be in line with environmental justice, guaranteeing that underserved communities have access to green jobs and cleaner production systems.

Coordinated international and local efforts are needed to align the circular economy with environmental justice and economic growth. To guarantee that no community is left behind during the transition, policymakers and corporations must embrace strategies that prioritize social equity in addition to economic efficiency. Designing circular manufacturing systems should be based on environmental justice, which addresses current disparities in pollution exposure, resource access, and waste burdens.

Strong policy frameworks, cutting-edge technologies, and stakeholder collaboration are necessary to achieve this balance, as the research has demonstrated, but there are also many obstacles to overcome. These include the need for systemic change in industries, technological gaps, and balancing long-term sustainability objectives with immediate economic pressures. Future studies should investigate how the concepts of the circular economy can be applied to a variety of sectors and geographical areas, especially in developing nations, and how advancements in green technologies and materials science can further lessen the negative environmental effects of manufacturing (Deutz, 2023). Future research could also concentrate on examining the social aspects of circular economies, specifically with relation to equitable distribution of the advantages of sustainability shifts.

Promoting cross-sector cooperation and making sure policies are inclusive are essential for continued policy improvement and sustainable development. These initiatives ought to be in line with international frameworks that prioritize fair, sustainable growth across sectors, like the Paris Climate Agreement and the Sustainable Development Goals (SDGs) (Schröder and Barrie, 2024).

Declarations

The authors have no relevant financial or non-financial interests to disclose.

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