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# Towards a Circular Economy

## Transdisciplinary Approach for Business

Springer

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Editors

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# Preface

The world's resources are not infinite and, in many instances, are becoming increasingly scarce. Linear production processes have historically been proposed to take raw material and use it without considering efficient manufacturing processes. Thus, activities like reducing waste of waste to generate new products, reusing specific wastes, and repairing products to avoid waste were not the usual behavior of people and companies.

When in 2015 the European Community proposed the first circular economy action plan, it marked a milestone in the global management of human activities. Under this approach, it has been possible to recognize globally the emphasis on generating ecodesign directives that guide companies in their manufacturing processes and waste management. These ecodesign guidelines have built-in requirements for durability, repairability, and recyclability of products.

However, implementing the circular economy in a region or a country requires customization, that is, to know in detail and reflect how national and local production processes are carried out. With explicit knowledge of the processes, initial regulations can be generated to promote the implementation of the circular economy. But we also need to know the limitations that companies have for such change. Another important aspect is the impact on the consumer of having products based on the circular economy. Will consumers be willing to pay a higher price for a circularity seal? Would they pay more if they knew that the product they buy is made for reuse, repair, or recycling?

In times of the COVID-19 pandemic, international businesses have been experiencing greater demands for changes in production processes to achieve eco-efficient use of natural resources. Thus, we are facing new certifications that focus on evaluating how circular companies can be. Another important element involved in international business is the supply chain, a process that has suffered significantly recently and that has led to the reformulation of times, materials, and product delivery goals. The experiences of various ports that have become sustainable is an interesting case, which can serve as a reference for other systems. But that requires a comprehensive process, since regulation must be accompanied by detailed knowledge of a country's social and business dynamics. In other words, it is not sufficient that a port becomes circular but rather it is necessary that the means of transport of the companies, their warehouses, distribution systems, and production plants are also circular. Additionally, providers must be approved as employing a circular approach. Finally, companies and governments must inform consumers of the notable benefits of products and services developed in compliance with circular economy standards to help these companies become preferred.

For this reason, this book aims to provide the theoretical and practical support needed to implement a circular economy, in a comprehensive manner. The book seeks to understand and explain the circular economy, and its concepts, applications, research and teaching needs, and successful experiences. These can guide other institutions and policy makers in establishing regulations as well as implementation and monitoring processes.

In Part I of the book, material is provided on circular economy in general. In Chap. 1, the book's vision is described, as are knowledge gaps and the urgency of developing research at a global level to meet the needs and expectations of the actors in society. Chapter 2 focuses on describing how the most accepted concepts of the circular economy can be operationalized. Also described are intangible activities, which can be measured with specific indicators, facilitating the measurement of their beneficial effects, such as the economic impact on markets and industrial production processes. Chapter 3 describes the evolution of the circular economy, describing the concept of circular economy 3.0, and describing 10R and the entire conceptual and practical foundation of this approach. Chapter 4 explains the modern conceptualization of the circular economy. In some chapters, videos are linked that describe concrete experiences on the actual implementation of the circular economy. Finally, Chap. 5 provides a somewhat contrary approach, showing how the concepts of circular economy and its implementation still have issues that must be resolved and clarified for circularity to make significant inroads. This chapter permits reflection and deep analysis that can ultimately help optimize and embrace processes of the circular economy.

Part II is centered on the applications of the circular economy in business. Chapter 6 details the activities involved in waste management, with a focus on illustrating food waste management and how it can be improved. The contribution of various types of food to the carbon footprint is detailed. There is also coverage of the waste of water, a crucial resource for humans and industrial activity. Various initiatives are shown that can contribute to circular water management. Organic waste is also considered, and a description is provided of companies already involved in offering disposal of organic waste, conversion of organic waste to fuel, and other services to other organizations. Chapter 7 explains the contributions that can be made to the circular economy through energy management, describing the use and conversion of energy. Furthermore, the industrial redesign of processes is examined to ensure energy use is efficient, and the use of exergy methods and other tools to improve and optimize industrial processes towards a circular economy is presented. Chapter 8 summarizes factors related to the supply chain, pointing out companies that establish global standards for such activities. These cases demonstrate the need to standardize the processes, in order to allow efficient monitoring and determination of the steps in the process that require optimization in ecological terms. The role of the Internet of Things in the circular supply chain is also examined. Finally, barriers to the implementation of the circular economy are described. Chapter 9 analyses the impact of the Colombian national strategy on the circular economy, which articulates the stakeholders in that country and the responsibilities of each actor, as well as the goals to be achieved. Also described are processes that can guide other regions of the world towards circularity. Chapter 10 addresses the notion that circularity can act as a resilience mechanism against COVID-19, showing the increasing and decreasing of tropospheric $NO_2$ concentrations before and after social isolation. The European proposal called European Green Deal is described, which is being embraced by some countries as a means to address the limitations on some resources due to the COVID-19 pandemic. Some practical experiences are presented of cities that focus on recycling plastic, by cleaning the water of medicines. Also, recent experiences related to circularity as a strategy against COVID-19 are listed.

Part III of the book is centered on teaching and research related to the circular economy. Chapter 11 details, through case studies, how unsustainable production is carried out, highlighting processes and tasks that can be converted through the application of the circular economy. A particularly noteworthy aspect of this chapter is how it provides a thorough analysis of current, similar industrial practices in different parts of the world. In order to appreciate the roles of universities in professional training towards circularity, Chap. 12 describes the responsibilities that study centers have in developing management competencies in future decision makers of a country, including those who will occupy business and public management positions. Understanding circularity through professional training can allow real engagement, and the necessary curricular changes can be expected in coming years.

Part IV is centered on national and international experiences and approaches. Chapter 13 details the circular water practices carried out in Colombia, including the changes made to consolidate this practice considering specific indicators and changes in the necessary processes. This experience can be of great value to other regions, when applied with the appropriate local adaptations. Chapter 14 describes the British experience in implementing the circular economy through The Clean Growth Strategy. The key policies and proposals used in the transformation process towards circularity are described. Their main components are detailed, including accelerating clean growth, enhancing industries and achieving efficient trade, improving the energy efficiency of buildings and homes, accelerating the shift to low-carbon transport, and ensuring clean energy supply. Chapter 15 illustrates a practical circularity experience in the leather tanning industry. This chapter shows that the sectors linked to export products can, and perhaps should, become circular. They are now beginning to demand, as a requirement for acceptance, that raw materials come from circular production. The experience of recycling as a component of the circular economy is described in Chap. 16, where various strategies and efforts such as clubs of recyclers and programs promoted by municipalities, firms, and universities with colored cans are presented. Additional efforts include eliminating or avoiding waste generation, keeping products and materials in use, and formalizing recyclers, environmental education, and awareness. Chapter 17 describes six X economies, namely circular, blue, collaborative, digital, feminist, and social economy. The choice of these X economies is to cover the 17 Sustainable Development Goals of the United Nations, where the social economy is the economic vision that enables the most significant number of Sustainable Development Goals to be addressed: no poverty, zero hunger, good health and well-being, quality education, gender equality, affordable and clean energy, decent work and economic growth, and, finally, reduced inequalities. International business has undergone an unprecedented change in the times of the COVID-19 pandemic and has generated various changes in people and companies. The deglobalization process has been observed as a response to mobility restrictions. However, globalization is likely to continue as a current phenomenon in the world, and will help guide the world's business plans. For this reason, reflections are raised in Chap. 18 on the need to conduct international business based on the circular economy, from teaching at universities to plans in professional and academic societies, contents of trade agreements, and local and regional regulations, so that we achieve in the not so distant future international business circularity.

Finally, Chap. 19 provides closing remarks and proposes research necessary for the circular economy, including improving the knowledge base for businesses, universities, and the general population.

All chapters were reviewed. Often authors assisted in reviewing chapters written by others.

This book shows the experience of authors and editors in a highly relevant and timely global change movement: the circular economy. Highlighted in the book are select literature and professional knowledge. We expect that this book will form a guide for governments, universities, schools, multinational and local companies, and citizens. Also, we anticipate that this work will support the transformation of firms to be more competitive based on circularity. Finally, it is shown how the circular economy is a concrete way to contribute to the UN Sustainable Development Goals, which allow circular international business and sustainable cities to develop together.

Lima, Peru — Aldo Alvarez-Risco
Oshawa, ON, Canada — Marc A. Rosen
Callao, Peru — Shyla Del-Aguila-Arcentales

# Contents

# Editors and Contributors

## About the Editors

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**Marc A. Rosen** is a professor at the University of Ontario Institute of Technology in Oshawa, Canada, where he served as founding dean of the Faculty of Engineering and Applied Science. Dr. Rosen has served as president of the Engineering Institute of Canada and the Canadian Society for Mechanical Engineering. He has held many professional roles, including editor-in-chief of various journals and director of Oshawa Power and Utilities Corporation. With over 70 research grants and contracts and 900 technical publications, Dr. Rosen is an active teacher and researcher in energy technology, sustainable energy, and energy systems' environmental impact. Much of his research has been carried out for industry. Dr. Rosen has worked for Imatra Power Company in Finland, Argonne National Laboratory near Chicago, the Institute for Hydrogen Systems near Toronto, and Ryerson University in Toronto. He has received numerous awards and honors.

**Shyla Del-Aguila-Arcentales** is a researcher in the sustainability area. She completed a doctoral program and holds a Master of Pharmaceutical Sciences degree from the Universidad Nacional Mayor de San Marcos, and she is a pharmacist at Universidad Nacional de la Amazonia Peruana. She has ancestral knowledge about medicinal plants in the jungle regarding traditional uses and for industrial process. Also, she has experience in bio-business, audit, environmental management, and import-export management.

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This book would not have been possible without the incredible and dedicated efforts and contributions of its many authors, who wrote chapters and often assisted in reviewing the chapters of others.

**Aldo Alvarez-Risco** is coauthor of Chaps. 1, 4, 5, 7, 9, 11, 12, 13, 15, 16, 17, 18, 19, 20, and 21. Also, he is one of the editors and reviewers of the book.
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**Sjors Witjes** is the author of Chaps. 3 and 4.

# Part I
# Circular Economy: Theory and Practice

# Chapter 1
# Introduction to the Circular Economy

**Aldo Alvarez-Risco, Shyla Del-Aguila-Arcentales, and Marc A. Rosen**

## 1.1 Toward a Circular World

The circular economy is based on waste management and the generation of new inputs that are alternatives to the current materials in use. For the current status of the world, greenhouse gases are emitted that are a main cause of climate change and that are caused by the increasingly widespread extractive economy based on the concept of "extract-produce-throw." The concept of circularity is increasingly discussed among companies, governments, and citizens, in the context of how to develop their activities in an environmentally benign and ecoefficient way. This involves reducing or avoiding waste as much as possible, substituting materials that are used today for more advantageous ones, and utilizing new technology for the processing of waste. Wastes come in many forms, e.g., plastic, food, and manufacturing residuals.

As reported by Alvarez-Risco et al. (2018), the extraction and processing of natural resources in some cases increases the risk of depredation of certain species, potentially with profound and irreparable damage to the ecosystem. Another way of understanding the circular economy is to avoid unnecessary consumption, waste, and the use of fossil fuels by reusing, repairing, and recycling existing materials and

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products throughout the value chain: extraction and use of resources, as well as production, distribution, use, and waste disposal.

A growth in efforts has been observed through the different Rs that have been recognized as ways of contributing to circularity. As described in Chap. 4, the 10Rs that are analyzed are as follows: refuse, reduce, resell/re-use, repair, refurbish, remanufacture, repurpose, recycle, recover energy, and re-mine.

The development of a circular economy requires multisector coordination in order to be successful. Initially, this means the design of better products, in terms of using less fuel, subject to biodegradation, optimization of lifecycles of products, promotion of re-use, improved waste collection, encouraging recycling, investment in relevant infrastructure, and provision of new and ecological materials for manufacturing (Fig. 1.1).

However, it is possible that the citizens do not know what exactly is the circular economy. For instance, it was reported in the Netherlands by Duurzaam Ondernemen (2019) that 75% of the respondents to a survey had never heard about the circular economy. More information is needed by more people in order for them to be involved in and supportive of a circular economy.

Another important requirement for a circular economy is the creation and use of indicators by organizations. Kravchenko et al. (2019) developed some indicators that can be used. These indicators include reinvent the paradigm, rethink and reconfigure business, and reduce, restore, and repair and maintenance.

Additional important data is provided in the report Future of Supply of Chain 2019, which detailed the circular economy investment motives and decisions worldwide (Statista, 2021). It is reported in that report that the reasons for investing in the circular economy vary between regions. In Asia and Australia, only 30% of people think that investment in a circular economy generates financial returns. Similar

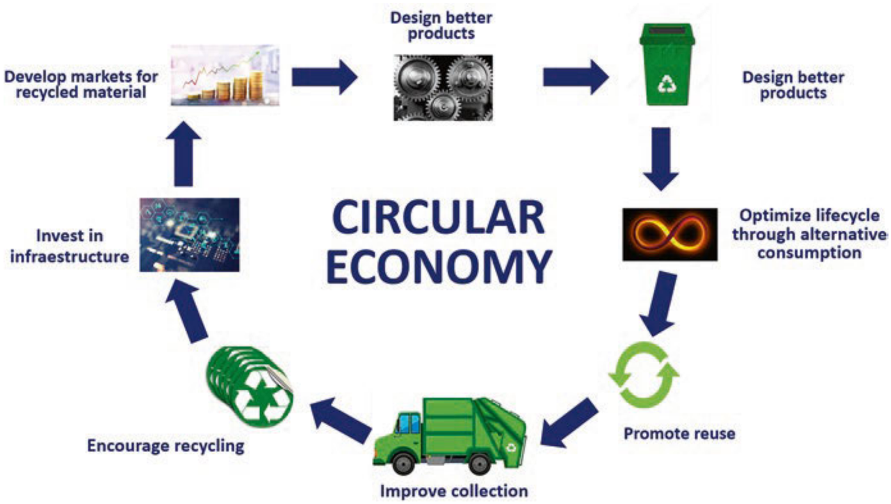


**Fig. 1.1** Basic approach for a circular economy

results were reported for Europe, Middle East, and Africa (29%) and North and South America (28%). In the same report, numerous technologies that are currently being used to facilitate the circular economy were identified: advanced analytics, 3D printing, IoT, and machine learning. Among leaders in the area of corporate social responsibility in the USA, barriers to a circular economy were reported as insufficient cases of previous successes (by 38% of respondents), logistics costs (36%), lack of executive leadership (36%), lack of understanding on the part of the consumer (36%), and prioritization of other businesses (30%) (GreenBiz, 2016).

E-waste has been reported as a source of various kinds of negative impacts, especially informal recycling, which uses open burning of e-waste and which generates various pollutants such as charcoal, oil, and smoke. The plastics that form part of e-waste have polymers that retard in case of fire, leading to the generation of dangerous chemical compounds such as polychlorinated dibenzofurans (Fig. 1.2), polybrominated dibenzofurans (Fig. 1.3), polychlorinated dibenzo-p-dioxins (Fig. 1.4), and polybrominated dibenzo-p-dioxins (Fig. 1.5). All of these are serious pollutants (Chakraborty et al., 2018).

The incineration of e-waste converts polybrominated diphenyl ethers to polybrominated dibenzofurans and polybrominated dibenzo-p-dioxins (Fu et al., 2016), which are toxic substances (Darnerud et al., 2001). Promotion of formal e-waste management is needed in order to avoid risks for the population at large.

The global e-waste monitor 2020 (United Nations University, 2020) indicates that 53.6 Mt. per year of e-waste is generated globally, which means that 7.3 kg per capita per year of e-waste is generated. In this manner, a raw material value of $10 billion USD is recovered annually in an environmental sound way from e-waste globally. Across the world, Asia generates the most e-waste annually (24.9 Mt). However, Europe reports e-waste collection and recycling rates of 42.5%, followed by Asia at 11.7% and America at 9.4%. It is also reported that there is significant growth in e-waste collection and recycling in countries that have legislation aimed at waste management. The number of such countries has risen from 61 in 2014 to 78 in 2019.

Based in crowdsourcing strategies, it is instructive to review the various actions that have been previously developed to guide future implementation of the circular economy. Global institutions have in some cases attained some goals and it is important to consider reproducing successes and best practices in other regions. This is done in the next section.

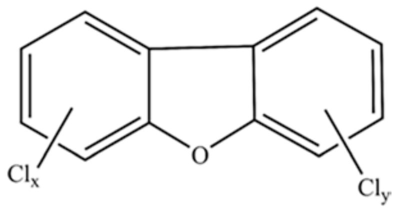


**Fig. 1.2** Polychlorinated dibenzofurans

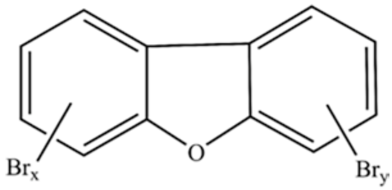


**Fig. 1.3** Polybrominated dibenzofurans

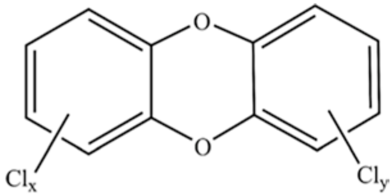


**Fig. 1.4** Polychlorinated dibenzo-p-dioxins

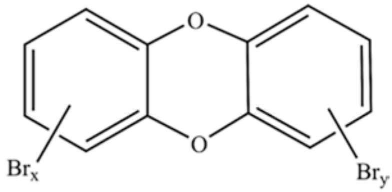


**Fig. 1.5** Polybrominated dibenzo-p-dioxins

## 1.2 Ecological Global Initiatives

The world's resources are limited (Tu et al., 2019), and their use leads to various environmental impacts. These concerns and others have fostered numerous initiatives to achieve sustainable resource use, as described by Alvarez-Risco et al. (2020).

### *1.2.1 Absorb, Anticipate, Reshape*

UN Climate Resilience Initiative A2R
Anticipate, Absorb, Reshape

Absorb, Anticipate, Reshape (A2R) is a worldwide initiative looking at developing climate resilience globally. Key elements of A2R include: Anticipate, Absorb, and Reshape. The most relevant efforts include the collaboration between the Food and Agriculture Organization (FAO) and A2R to lead UNFCCC Marrakech Partnership for Global Climate Action-MPGCA climate resilience pathway. Complete information on A2R can be found at http://www.a2rinitiative.org.

### *1.2.2 Adaptation Fund*

The Adaptation Fund was created in relation to the Kyoto Protocol of the UN Framework Convention on Climate Change. Its efforts have reached US$ 720 million for investment in programs for climate adaptation and resilience, with more than 100 projects. This initiative seeks to finance programs to support vulnerable people, so as to tackle climate change. Initiatives are based on national needs. The projects include circular economy contents, as in the Safekeeping-Surviving-Sustaining Towards Resilience project.

The most relevant efforts include Resilient Fishing (Pesca Resiliente in Spanish) and the accreditation by the Adaptation Fund of the Pacific Community to Accelerate Climate Action in Pacific Region. Complete information on the Adaptation Fund can be found at https://www.adaptation-fund.org.

### *1.2.3 Africa Renewable Energy Initiative*

The Africa Renewable Energy Initiative (AREI) is an Africa-owned and Africa-led inclusive effort to achieve greater and better use of the potential of renewable energy to generate more productive activities, accounting the renewable energy that can be generated. Endorsed by Committee of African Heads of State and Government on Climate Change (CAHOSCC), the Initiative has the important mission of being able to generate at least 300 GW of electricity by 2030, which implies that it could be possible to accelerate the industrialization process in Africa, with the consequent economic and social benefits for the countries involved and positive environmental effects through the use of renewable energies.

The most relevant efforts include a joint statement on advancing of the Africa Renewable Energy Initiative and the report of the Africa Renewable Energy Initiative detailing the mapping of renewable energy initiatives, education material, and an action plan. Complete information on AREI can be found at http://www.arei.org.

### 1.2.4 Climate and Clean Air Coalition

This initiative is to treat short-lived climate pollutants. It was formed to generate and carry out action plans for various lines for activities. The main topics include epidemiology, energy management, climate change, and food availability. To date, the Coalition has developed many projects. The circular economy is promoted by this initiative (Climate & Clear, Air Coalition, 2021).

The most relevant efforts include the International Methane Emissions Observatory and the WHO releasing of new Air Quality Guidelines. Complete information on the Climate and Clean Air Coalition can be found at http:// www.ccacoalition.org.

### 1.2.5 Global Environment Facility

Created to tackle the most relevant ecological problems, .

the Global Environment Facility (GEF) has supplied approximately $20 billion in grants and $107 billion in co-financing for more than 4700 projects in 170 countries. Some initiatives regarding the circular economy are being developed by the GEF (2020).

The most Relevant Efforts Include the Following Projects: GEF-8 Replenishment and GEF-7 Corporate Scorecard. Complete Information on the GEF Can Be Found at Http:// www.ccacoalition.org

### 1.2.6 GRID-Arendal

GRID-Arendal is a center established to support ecological sustainable development together with the United Nations Environment Programme (UNEP). GRID-Arendal is working to transform raw data and information on environmental issues in order to create new programs. This initiative is also developing projects and efforts focused on the circular economy.

The most Relevant Efforts Include Development of the Little Book of Green Nudges Webinar Series and Ecological Tipping Cascades in the Arctic Seas (ECOTIP). Complete Information on GRID-Arendal Can Be Found at https://www.grida.no.

### *1.2.7 International Carbon Action Partnership*

This initiative is focused on sharing best practices in emissions trading system (ETS) design elements. The objectives of the International Carbon Action Partnership (ICAP) are as follows:

- Sharing best practices and teaching-learning about ETSs.
- Helping governments and firms recognize and attain ETS design compatibility.
- Facilitating next relation of trading plans and initiatives.
- Establishing alliances among nations.

Some initiatives on the circular economy are being developed by ICAP (2020). The most relevant efforts focus on emissions trading and carbon leakage and deep decarbonization. Complete information on ICAP can be found at https://icapcarbonaction.com/en.

### *1.2.8 International Environmental Technology Centre*

The International Environmental Technology Centre (IETC) is focused on developing countries in order to support the implementation of solutions based on sustainability for ecological challenges and on holistic waste management. Key directions of the initiatives are as follows:

(a) Developing knowledge products using ecological process and practices.
(b) Providing support for technical and utilization processes involved in implementing green technologies.
(c) Encouraging ecological waste management.

Some initiatives on the circular economy have been developed by UNEP (2020). The most relevant efforts include the future of electric vehicles and material resources and waste management during the COVID-19 pandemic. Complete information on IETC can be found at https://www.unep.org/ietc.

### *1.2.9 Portfolio Decarbonization Coalition*

As an initiative that seeks a reduction of GHG emissions, the Portfolio Decarbonization Coalition (PDC) is a group of organizations and citizens that aim to create programs for a gradual decarbonizing process.

The most Relevant Efforts Include Having the New York State Pension Fund Join the Portfolio Decarbonization Coalition, and the Portfolio Decarbonization Coalition, Sovereign Wealth Fund Research Initiative, and Trucost Announcing a Research Prize Winner. Complete Information on PDC Can Be Found at https://www.unepfi.org/pdc

### *1.2.10 Partnership for Action on Green Economy*

Since 2013, this initiative has sought to follow the statements developed in the 2012 United Nations Conference on Sustainable Development in Rio (called Rio + 20) to support nations to implement more green activities in their production processes. The aim of PAGE is to shift the focus of policies and practices toward the UN Sustainable Development Goals and to guide countries in transforming their activities with a goal to promote more jobs, reduce poverty, care for the environment, and encourage citizens to have ecological behavior.

Some Initiatives on the Circular Economy Have Been Developed by PAGE. The most Relevant Efforts Include Argentina Creating a New Diploma on Green Jobs and a Just Transition, and “driving force for change” Calls on Youth Entrepreneurs for 2021 Awards. Complete Information on PAGE Can Be Found at https://www.un-page.org

### *1.2.11 UNEP DTU (2019)*

UNEP DTU PARTNERSHIP

This is a partnership between the Danish Ministry of Foreign Affairs, UN Environment, and the Technical University of Denmark to promote climate change plans based on research goals and developing actions in 26 countries. Some initiatives regarding the circular economy have been developed by UNEP DTU (2019).

The most Relevant Efforts Include the Launch of a New Street Lighting Energy Efficiency Calculator and a New Guide: Climate Tech in an Urban Context. Complete Information on UNEP DTU Can Be Found at https://unepdtu.org

## 1.3 Initiatives on the Circular Economy

There are various types of organizations that are working to achieve the implementation of the circular economy. The Ellen MacArthur Foundation is one of the most active institutions, with an abundance of publications with general guidelines for implementing the circular economy.

In terms of nations, official declarations have been made by many countries toward a circular economy, such as the Plastics Innovation Fund in New Zealand (2021), the sustainable manufacturing and environmental pollution program by The United Nations Conference on Trade and Development (UNCTAD) (2021), guidelines on the shared environmental information system reporting mechanism by The United Nations Economic Commission for Europe (UNECE) (2021), funding opportunities for individuals or businesses in Canada (2021), business models in the circular economy The Organisation for Economic Co-operation and Development (OECD) (2019), and circular economy, economic diversification, and aid for trade by the World Trade Organization (WTO) (2021).

In addition, the following programs are of note: innovation and circular economy in the Mountain Forest Supply Chain by the FAO (2017), Circular Economy in Industrial Parks: Technologies for Competitiveness by the World Bank (2021), the Circular Economy Package policy statement in the UK (2021), the whole of government circular economy strategy 2021–2022 in Ireland (2020), Shifting Victoria to a Circular Economy in Australia (2021), Norway's strategy for developing a green, circular economy (2021), Uruguay Circular 2021 as a support for the circular economy and the competitiveness of companies in Uruguay (2021), the technical roundtable on a circular economy in Argentina (2019), the green table in Peru (2021), the circular economy policy in the UAE (2021), and the National Zero Waste Council Circular Economy Business Toolkit in Pakistan (2021).

Further national initiatives are as follows: the circular economy as a key component of South Africa's post-COVID-19 recovery (2021), the circular economy working group in Nigeria (2021), the circular Taiwan network (2021), the circular economy roadmap of France (2021), the circular economy platform in Hungary (2021), transitioning to a circular economy in Sweden (2020), ecodesign for circular production in Switzerland (2021), the Circular Economy Spanish Strategy in Spain (2021), the national strategy for a circular economy in Denmark (2021), the circular economy roadmap for Germany (2021), the circular economy promotion in China (2021), proposals for legislation in Scotland (2019), the recycler program as a circular economy strategy in Wales (2021), the roadmap to a circular economy 2016–2025 in Finland (2021), and the transition from Linear to Circular Economy in India (2021).

Numerous academic institutions have created specific departments for advancing the circular economy. These include Circular Economy Research Center in École des Ponts Business School (2021), the course on the circular economy in the University of Amsterdam (2021), the Master in Circular Economy in Cranfield University (2021), the Centre for Circular Economy in the University of Exeter (2021), the online course on the circular economy in Delft University of Technology (2021), the circular economy lab in University College London (2021), the MOOC on a circular economy in Wageningen University & Research (2021), the circular economy MBA in the University of Bradford (2021), and the circular economy center at the University of Cambridge (2021).

Additional academic initiatives on the circular economy are as follows: the circular economy course on managing materials sustainably at Lund University (2021), research on the circular economy at Aston University (2021), the circular economy initiative at Deakin University (2021), the Centre for Water, Environment, Sustainability & Public Health at the University of Strathclyde (2021), the international master's program on a circular economy at Universität Graz (2021), the regenerative and circular economy lab at the University of Oxford (2021), studies on social responsibility and sustainability at the University of Edinburgh (2021), the sustainable consumption institute at the University of Manchester (2021), a course on an introduction to the circular economy at the University of Harvard (2021), case studies at the Massachusetts Institute of Technology (2021), circular economy promotion activities at Universidad EAFIT (2021), the diploma in innovation for a circular economy at Universidad Austral (2021), the master in circular economy at Universidad Publica de Navarra (2021), the diploma on a circular economy at Universidad de Chile (2021), the recycling and circular economy group at the

University of Birmingham (2021), research of the circular economy at the University of Sydney (2021), and the center of sustainability at Universidad de Lima (2021).

There are several companies that have also launched circularity implementation efforts and that announce the commitments on their web pages. The following companies that are part of the Fortune 500 or the Forbes Global 2000 have circularity implementation activities:

1. Industrial and Commercial Bank of China (ICBC), with efforts to become a green financial institution (ICDC, 2021).
2. Walmart, with a zero waste goal (Walmart, 2021).
3. JPMorgan, with plastic management initiatives (JPMorgan, 2021).
4. Amazon, with efforts for increasing recycling (Amazon, 2021).
5. Aramco, with initiatives for management of the footprint (Aramco, 2021).
6. Apple, with a carbon-neutral goal (Apple, 2021).
7. Samsung, with activities on circular economy principles (Samsung, 2021).
8. 8 Toyota, with the objectives of maximizing recyclability (Toyota, 2021)
9. ExxonMobil, with efforts for plastic waste management (ExxonMobil, 2021).
10. Verizon, with its moving forward sustainably plans (Verizon, 2021).
11. Unilever, with an artificial intelligence recycling system (Unilever, 2021).
12. Microsoft, with zero waste goals by 2030 (Microsoft, 2021).
13. General Motors, with its waste minimization actions (General Motors, 2021).
14. Johnson & Johnson, with progress toward its 2025 targets for tackling plastics pollution (SCJohnson, 2020).
15. Intel, with its zero waste initiatives (Intel, 2021).
16. Sony, with its contribution plans for the Sustainable Development Goals (SDGs) (Sony, 2021).
17. Nestlé, with a new plastic economy (Nestlé, 2019).
18. Procter & Gamble, with its net zero ambitions by 2040 (P&G, 2021).
19. Cisco, with its driving circularity actions (Cisco, 2021).
20. Google, with various environment projects (Google, 2018).

## 1.4 Research Advances on the Circular Economy Based on the Web of Science

A search was carried out on the Web of Science to identify the countries that have published the most on the circular economy, the journals that have published the most on the circular economy, the top publishers of articles about circular economy, and the top funding agencies for the circular economy research. The search is based on listings in the Web of Science between 2012 and September 2021. The terms used were "circular economy" and "circularity."

The countries that have published the most on the circular economy are as follows: Spain (1580), Italy (1427), China (1249), England (1091), USA (839), Germany (790), Netherlands (628), Poland (538), Portugal (486), Sweden (481), France (479), Brazil (417), Australia (384), and Finland (377).

The following institutions have published the most about the circular economy:

1. Consejo Superior de Investigaciones Cientificas (CSIC): 274.
2. Delft University of Technology: 184.
3. Centre National de la Recherche Scientifique (CNRS): 173.
4. Consiglio Nazionale Delle Ricerche (CNR): 165.
5. Chinese Academy of Sciences: 138.
6. Helmholtz Association: 121.
7. Aalto University: 108.
8. Polytechnic University of Catalonia: 106.
9. Universidade de Lisboa: 105.
10. Universidad Politécnica de Madrid: 103.
11. Polytechnic University of Milan: 102.
12. Autonomous University of Barcelona: 100.
13. Lund University: 100.
14. Technical University of Denmark: 99.
15. Ghent University: 98.

The journals that have published the most on the circular economy are as follows:

1. Journal of Cleaner Production: 1064.
2. Sustainability: 926.
3. Resources, Conservation and Recycling: 445.
4. Waste Management: 223.
5. Science of the Total Environment: 207.
6. Energies: 155.
7. Energy Reports: 152.
8. Journal of Environmental Management: 136.
9. Journal of Industrial Ecology: 129.
10. Applied Sciences-Basel: 125.
11. Materials: 107.
12. Waste Management and Research: 98.
13. ACS Sustainable Chemistry and Engineering: 94.
14. Sustainable Production and Consumption: 94.
15. Environmental Science and Pollution Research: 92.

The top publishers of articles about the circular economy are as follows:

1. Elsevier: 4077.
2. MDPI: 2041.
3. Springer Nature: 827.
4. Wiley: 618.
5. Taylor & Francis: 416.
6. Amer. Chemical Soc.: 256.
7. Emerald Group Publishing: 239.

8. Sage: 188.
9. Frontiers Media SA: 121.
10. Royal Soc. of Chemistry: 111.
11. IEEE: 59.
12. IOP Publishing Ltd.: 59.
13. Gh Asachi Technical Univ. of Iasi: 49.
14. EDP Sciences SA: 48.
15. CISA Publisher: 45.

Finally, the top funding agencies for the circular economy are as follows:

1. European Commission: 1031.
2. National Natural Science Foundation of China (NSFC): 568.
3. UK Research and Innovation (UKRI): 309.
4. Spanish Ministry of Economy and Competitiveness: 236.
5. Portuguese Foundation for Science and Technology: 209.
6. Engineering and Physical Sciences Research Council (EPSRC): 203.
7. Conselho Nacional De Desenvolvimento Cientifico E Tecnologico (CNPq): 166.
8. Coordenacao De Aperfeicoamento De Pessoal De Nivel Superior (CAPES): 143.
9. National Science Foundation (NSF): 130.
10. Spanish Government: 107.
11. Federal Ministry of Education and Research (BMBF): 103.
12. European Commission Joint Research Centre: 84.
13. Fundamental Research Funds for the Central Universities: 83.
14. Ministry of Knowledge Economy Republic of Korea: 80.
15. Ministry of Education, University and Research (MIUR): 73.

The authors of hot papers about the circular economy, as recognized in the Web of Science, are as follows: Ghobakhloo (2020), Rosa et al. (2020), Ibn-Mohammed et al. (2021), Jabbour et al. (2019), Bag et al. (2021), Chen et al. (2021), Vanapalli et al. (2021), Qureshi et al. (2020), Bishop et al. (2021), Vollmer et al. (2020), Rissman et al. (2020), and Tournier et al. (2020). These papers provide particularly interesting reading.

## 1.5 Innovations Related to Circular Economy

Many advances and innovations related to the circular economy have been reported recently. Some notable and recognized innovations based on circularity are as follows:

1. Compostable and Biodegradable Sanitary Napkins

They are produced with natural resources. They can be recycled through the composting process when they are disposed. More information can be found at https://www.aakarinnovations.com/anandi.

2. Re-Using Locally Excavated Earth to Make Eco-Friendly Building Materials

Building constructions create 40% of $CO_2$ emissions globally (Web of Forum, 2021). BC Materials recovers surplus earth-mass from construction sites and transforms it into construction raw material. More information can be found at https://www.bcmaterials.org.

3. First Food-as-a-Service Platform for Sustainable Nutrition Globally

Blendhub's food powder solution extends the life of food items and facilitates industrial production and transportation of food. More information can be found at https://www.blendhub.com.

4. Home Appliances-as-a-Service to Extended Lifecycles

Many home appliances are used daily and, due to the continuous use, can become broken. Options are needed to avoid having to discard broken home appliances as waste. In line with this need, for example, BlueMovement has introduced an alternative business model where the consumers gain more money when more appliances are repaired. More information can be found at https://www.bluemovement.nl.

5. Circular Fashion Industry

The fashion industry in general involves unsustainable consumption. The initiative called BRING by the company JEPLAN enables textile recycling in order to promote in customers more ecological behavior. More information can be found at https://www.jeplan.co.jp/en/service/bring.

More examples include Algramo, which offers a platform technology that enables to sell consumer products at the most affordable prices (Algramo, 2021), and BanQu, which follows raw materials and finished goods from source, ensuring supply chain traceability (BanQu, 2021). Other examples are as follows: BIOHM, which created building materials and manufacturing methods from sustainable materials (BIOHM, 2021), and Circularise, which developed a blockchain technology for traceability of supply chains (Circularise, 2021). Some final examples are as follows: Hello Tractor, which operates a tractor contracting platform in emerging markets by connecting farmers to fleet owners through IoT-enabled software (HelloTractor, 2021); Natural Fiber Welding (NFW), which shapes and molds plant materials and is used across different industries (NaturalFiberWelding, 2021); and Recykal, which facilitates transactions for stakeholders in India for waste management (Recykal, 2021).

## 1.6 About the Book

The many advances from institutions, universities, and companies, as evidenced in numerous scientific and other reports, show that the circular economy continues to be on the rise. This can be observed in planning by governments, teaching, and research in the area at universities and an increasing group of startup companies that present local and global markets with various innovations aligned with the circular economy. For better context and understanding, these efforts need to be evaluated in a broad way to provide a "big picture," so that the origins, growth, and development of the circular economy and initiatives around it can be understood.

With this book, the authors describe many global advances in the circular economy. The authors believe that doing so can serve to generate new scholarly and applied research on the circular economy, as well as innovative standards that promote the circular economy and the creation of new ventures that can have a sustainable impact. These advances can assist in the fulfillment of the Sustainable Development Goals (SDGs), which were developed by the United Nations together with 193 countries to promote prosperity while protecting the planet, and various environmental commitments such as the Paris Agreement which is the first-ever universal, legally binding global climate change agreement, adopted at the Paris climate conference (COP21) in December 2015 and focused on avoiding dangerous climate change by limiting global warming to well below 2 °C and pursuing efforts to limit it to 1.5 °C. We expect that the information presented throughout the chapters will serve to generate new knowledge and experiences around the world.

The editors welcome communications from readers of the book in order to share more information, generate new research and publications, and continue to disseminate the next circular economy developments and innovations.

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# Chapter 2
# Circular Economy Research: From Theory to Practice

**Erinn G. Ryen, Callie W. Babbitt, and Komal Kooduvalli**

## 2.1 Circular Economy Foundational Theories

### *2.1.1 Historical Roots*

The circular economic (CE) model has strong connections to management, economics, ecology, and design; also, the CE concept grew from a long history of research across several fields. CE blossomed into popular mainstream ideals with the Ellen MacArthur Foundation (EMF) formation in 2010 (2013). According to the EMF, "The circular economy refers to an industrial economy that is restorative by intention; aims to rely on renewable energy; minimizes, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design" (EMF, 2013, p. 23). This vision takes inspiration from our natural systems' restorative and regenerative flows to create a framework for slowing and closing resource loops in biological and technical cycles. The EMF approach focuses on three strategic ideals: designing out pollution and waste, retaining products and resources, and regenerating natural systems (EMF, 2020). The biological cycle focuses on *regenerative* flows, such as restoring nutrients, carbon, and energy in wasted food into agricultural and ecological systems (Morseletto, 2020). The technical side centers on *restorative* flows, with repair, reuse, and remanufacturing strategies that extend the product life cycle and recycling strategies that recover and maintain materials in the system (EMF, 2020). Approaches spanning each academic domain that have led to today's understanding of the CE concept are shown in Fig. 2.1.

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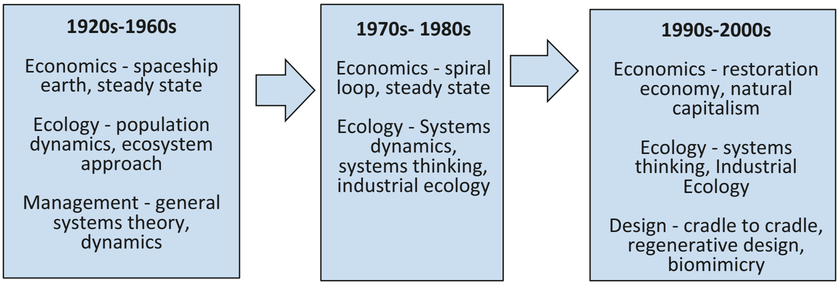


**Fig. 2.1** Evolution of circular economy domains

### *2.1.2 Management*

Early connections to the circular economy are found in concepts of feedback within cycles popularized by systems dynamics (originally called industrial dynamics), systems thinking, and general systems theory in the management science literature and operations research after World War II (EMF, 2020; Forrester, 1958, 1961; Forrester, 2007; Von Bertalanffy, 1950). Human social systems, like those of other organisms, have complex networks of feedback processes, both self-reinforcing (positive) and self-correcting (negative) (Sterman, 2006). Feedback loops, a component of systems dynamics, were developed by Forrester and Brown while researching military applications (Forrester, 1968, 2007). Forrester (1958) recognized that "industrial company success depends on the interaction between the flows of information, materials, money, manpower, and capital equipment" (p.37). General systems theory also recognized complexity in natural systems, a significant change in scientific thinking, from a previous focus on simple analytical and reductionist thinking modes (Mang & Reed, 2012). This field sought to integrate mathematical thinking and the scientific method to address societal issues, starting with a focus on steady-state conditions in the late 1950s and growing to apply systems concepts to the social sciences and nonlinear problems in the 1960s (Forrester, 1968).

Systems dynamics connects engineering principles of feedback with "the circular causal complexity that strategic thinkers encounter" (Richardson, 1999, 40) and emphasizes the importance of understanding how "the many circular, interlocking, sometimes time-delayed relationships" among components in a system behave over time (Meadows et al., 1972, p.31). Systems dynamics were furthered by "The Club of Rome" in 1968 during an informal meeting of 30 individuals from 10 countries representing academics, policy, and business (Meadows et al., 1972). This association sought a new understanding of the diverse and interconnected economic, political, natural, and social components in the global environment so policymakers could develop new initiatives to address complex issues like resource depletion, economic inequity, economic disruptions, lack of faith in institutions, rejection of traditional values, overpopulation, and transition society to a stable state (Meadows et al., 1972).

In 1970, Forrester applied systems dynamics to analyze these relationships and show how technological advancements and policy changes could disrupt existing feedback loops and enable a state of global dynamic equilibrium (Meadows et al., 1972). Systems dynamics and industrial dynamics led to the concept of systems thinking (Forrester, 2007), which was furthered by Meadows et al. (1972). Meadows defines a system as "a set of things—people, cells, molecules, or whatever—interconnected in such a way that they produce their pattern of behavior over time" (Meadows, 2008, p.2). Systems thinking is a tool to help manage complex environmental, social, political, and economic issues by analyzing how the system's structure (e.g., stock, flows, and feedback) behaves over time and is impacted by events (Meadows, 2008).

### *2.1.3 Economics*

Many scholars consider Boulding (1964, 1966) a key pioneer of the circular economy concept (Ghisellini et al., 2016; Zink & Geyer, 2017). However, in the mid-nineteenth century, economist and philosopher John Stuart Mill proposed the goal of a steady-state economy as one with stable population rates that can maintain a consistent stock of capital (stopping growth) and the extraction of natural capital at rates consistent with nature's ability to renew resources (Chang, 2010; Kibert et al., 2012).

Boulding also argued for a closed, stable system with high levels of technology (Boulding, 1964, 1966). His perspective stems from humanity's transition from agricultural to industrial economies, fraught with threats like nuclear war, population explosion, and misuse of natural resources (Rome, 2015). Boulding envisions a shift from an open or "cowboy economy" that entails reckless, exploitative, romantic, and violent behavior to a closed environment that is more like a "spaceship economy" where "man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy" (Boulding, 1966, p. 58). This transformation would require a change in our consumption behaviors, a concept believed to be disregarded by existing economic principles (Boulding, 1966). The closed systems must minimize the throughput of materials and energy and maintain stock, reducing the need for increased extraction, consumption, and production of virgin materials (Boulding, 1966).

Another foundational concept from economics is Daly's call for our economic system to transition away from a growth economy to a steady-state economy by implementing economic policy tools such as resource depletion quotas because they are price parameters that can be applied gradually and continuously and will not disrupt the efficiency of the market (Daly, 1974, 2008). Using food as a metaphor for resources and the economy as a digestive system, Daly (2008) argues for eating better, quality "food" and "digesting" more efficiently and thoroughly, rather than pushing more food through a more extensive digestive system (growing the economy). A CE principle is raised in Daly's recommendations to produce more durable and longer-lasting goods and refocus our perspectives on maintenance costs as an economic benefit rather than production. He tries in the policy tool of taxes to promote minimizing cost and using leasing models for equipment, so the "lessor/owner maintains, reclaims and recycles at the end of its useful life" (Daly, 2008, p. 6). Rethinking our views on growth has been a challenge as growth serves as the "basis of national power and prestige...with the sacrifice by none" (Daly, 1974, p. 19).

Stahel (1982) further develops the CE concept by describing an economic model consisting of a "spiral loop" that would minimize the flow of matter and energy to minimize environmental degradation without hindering growth. According to several scholars (Andersen, 2007; Ghisellini et al., 2016 and Morseletto, 2020), economists Pearce and Turner (1990) are considered originators of circular economy concepts focusing on the principle of *regeneration* (Rizos et al., 2017*)*. Pearce and Turner (1990) proposed a paradigmatic transition from a linear usage of the resource, product development, and resultant pollution generation to a system that replaces pollution with regenerated resources (noted in Morseletto (2020)). The authors highlight interconnections between the economic functions of the environment, recognizing that nature provides value for human amenities and serves as a resource base and sink for economic activities and life support system services (Andersen, 2007).

Another precursor to the CE concept is the idea of restoration found in Hawken's *Ecology of Commerce* (Hawken, 1993). Restoration is about acknowledging the loss or removal of a resource but renewing, regenerating, or returning the resource to its original state (Hawken, 1993). Restoration activities include repairing, rebuilding, and even correcting past mistakes (like returning land to indigenous populations) so we can move towards a state of "health and equilibrium" (Hawken, 1993, p.58). Hawken also points to the circular economy by noting the natural cycles by which waste from one organism becomes the food for another, providing a model for societal waste to be valued via reclamation, reuse, or recycling (Hawken, 1993). Hawken also recognizes nature as a closed system, the need for running on solar energy, and that health systems are diverse and not mass-produced (Hawken, 1993).

In the same vein, Hawken et al. (1999) developed the *natural capitalism* approach to protect the biosphere while improving business competitiveness and profit. *Natural capitalism* requires valuing our ecosystem services properly by shifting business practices to (1) reducing wasted resources in production, (2) using "biologically inspired" closed-loop production models where outputs can either be safely returned to nature or used as inputs to other production systems, (3) transitioning from the sale of goods to models that promote "flow of services," and (4) reinvesting in and restoring natural resources (1999, p. 147). This concept connects to CE through the idea that natural capital needs to be restored and rebuilt (regenerated) (Morseletto, 2020) while preserving value by circulating products, materials, and waste in a system.

### 2.1.4 Ecology

In the natural sciences, early roots of CE are traced to Lotka (1925), who developed population dynamics theory, a mathematical representation of the predator-prey relationship (Ghisellini et al., 2016; Kibert et al., 2012). Lotka (1925) believed that an ecosystem's living and nonliving components interact and cannot be understood individually without understanding the system as a whole (Kibert et al., 2012). His work inspired ecologists such as Howard and Eugene Odum, who pioneered ecosystem ecology (Kibert et al., 2012). As noted in Ghisellini et al. (2016), Odum and Odum (2006) believed that a pulsing system, based on Lotka's (1925) predator-prey model, Hollings' resilience and adaptive capacity models (Holling, 1986, 2001), and general systems theory via Von Bertalanffy (1950) would perform better and be more productive than a steady-state model. Even with a decline in economic growth and resources, human society can be happy and prosperous, living on less and restoring renewable resources and natural capital (Odum & Odum, 2006).

Another motivation for the circular economy concept is suggested to come from Rachel Carson's *Silent Spring* (Carson, 1962) (Winans et al., 2017). *Silent Spring* was a call for a new paradigm in how humanity views the world, as Carson challenged the chemical sector and government about the prolonged use, misuse, and impacts of pesticides on people and the environment (Carson, 1962). Carson notes that humans have focused on simplifying the diverse landscape, which "undoes the built-in checks and balances by which nature holds the species within bounds "(1962, p.75). Nature is a complex balance system, precision, and interrelationships constantly evolving and changing, one we can no longer ignore or try to defy (1962).

Ecological foundations of the circular economy also dovetailed with the concept of systems thinking. Charles Krone developed a living systems thinking approach in the 1960s and 1970s based on general systems theory. He applied this approach to natural and human systems (Mang & Reed, 2012), ultimately influencing fields of ecology (Odum's ecosystem modeling) and design (Lyle's regenerative design) (Mang & Reed, 2012). Systems thinking focuses on the whole system, interrelationships of components within the system, and patterns of changes (Mang & Reed, 2012). Systems thinking was also influenced by Lotka's ecological and economic systems integration in mathematical, quantitative terms (Kibert et al., 2012). Characteristics of systems thinking that influence CE include recognizing systems as dynamic and complex and understanding that "we are all part of the system in which we function" (Anderson & Johnson, 1997, p. 20).

Nature's inspiration for the circular economy is firmly grounded in the field of industrial ecology through, for example, early work by Frosch and Gallapolous (1989) and Frosch (1992). They theorized that industrial ecosystems could be created to mimic their biological analogs, whereby waste from one process becomes the "food" for another. Industrial ecology draws analogies between the structure of a natural system and the structure of economic and industrial systems (Frosch, 1992). Industrial ecology is seen as another paradigmatic shift in thinking about human activities, place, and our interconnections with the natural world; we are part of the global system and "no longer standing outside of nature" (Ehrenfeld, 1997, p. 90). The first textbook on industrial ecology (Graedel & Allenby, 1995) suggested that humanity can maintain carrying capacity if we consider our industrial systems as connected to their surroundings (rather than isolated) and use ecological inspirations to optimize resource energy capital.

As a core tenet within industrial ecology, the concept of "industrial metabolism" (Ayres, 1989; Ayres & Kneese, 1969) proposes that consumption and transformation of raw materials and energy can be mapped across the interacting physical processes that ultimately generate both economic outputs and wastes, mimicking the way that a biologist might analyze those biochemical processes that convert nutrients to energy and biomass in organisms. Ayres (1994) also notes that industrial systems metabolize technical "nutrients" in an open system compared to the mostly closed systems found in nature. Natural material cycles (e.g., water, carbon, oxygen) consist of *stocks* of one or more nutrients, linked by *flows* in a closed system operating in a material balance and steady state, while industrial systems extract and process high-quality materials from nature and that is returned in a degraded form (Ayres, 1994). In stable ecosystems, scavengers play an essential role in ensuring closed-loop, efficient material flows by converting waste into food (Ghisellini et al., 2016), and industrial analogs are needed to close the loop in technical material flows. While Ayres (1989) recognizes that technological innovations to reduce waste are limited due to market failures and resistance to giving up fossil fuels, he proposes that they may emerge and diffuse as waste becomes expensive for firms to manage and fossil fuel prices increase.

Many see industrial ecology as a metaphor offering a new paradigm and a foundation for the science that could transform our industrial systems (Ehrenfeld, 2000). Ehrenfeld connects the field of industrial ecology to design, as it is a roadmap to develop more sustainable products, services, and systems (Ehrenfeld, 1997). Ehrenfeld recognizes the need for design guidelines to develop "different, not just better, designs for the future," focusing on closed material loops, efficient use of energy and implementation of energy cascades, eliminating wastes or materials that interfere with the metabolism of the system, and to materials or function using fewer materials (Ehrenfeld, 1997, 2000, p. 243). CE models still grapple with substantial justice, equity, and resource usage issues, as they are not yet entirely solvable by technology (Ehrenfeld, 2000).

Industrial ecology also contributes to CE by offering a framework to design products and policies that emphasize the metabolic flow of material and energy, create loop-closing systems (for waste and energy), dematerialize with services rather than product ownership, and use energy efficiently (Ehrenfeld, 1997). Policies would also shift away from pollution control and end-of-pipe solutions, while designers must move beyond satisfying consumer needs and consider the complete product life cycle (Ehrenfeld, 1997). Industrial ecology also contributed several modeling methods and tools now used in CE studies. The methods and tools include material flow analysis used to evaluate the flow of energy and materials, industrial symbiosis used to design eco-industrial parks that mimic the "waste equals food" model of natural systems, and life cycle assessment used to analyze the holistic environmental impact for a product or system (Ehrenfeld, 1997). More recent models have expanded the ecological metaphor by, for example, modeling environmental outcomes for entire communities or ecosystems of materials (Moore et al., 2018) or products (Ryen et al., 2014, 2015) or equating recyclers in a circular economy with animals foraging in nature (Ryen et al., 2018).

### 2.1.5 Design

The connection between circular economy and the field of design reaches back to the late nineteenth century. Designing systems planning is a vital mechanism to operationalize CE principles and appears to be inspired by the concept of "regenerative design" by John Tillman Lyle. In his book *Garden Cities of To-Morrow*, planner Ebenezer Howard notes early roots to regenerative design in the 1880s, which started the garden city movement in Great Britain (Mang & Reed, 2012). Regenerative design strategies are based on Krone's framework of four levels of work that living systems at any scale need to accomplish over time, starting from basic operations to regenerative work (Mang & Reed, 2012).

Lyle's definition of regenerative systems connects to CE by replacing linear systems with one having "continuous replacement, through its functional processes, energy and materials used in its operations" (Lyle, 1994, p.10; Mang & Reed, 2012). In 1984, Lyle demonstrated the importance of creating "durable, responsible, beneficial designs" by understanding ecology at all scales and connecting values to ecology (Mang & Reed, 2012; Lyle, 1999, p. v.). Lyle contrasts nature's evolution of "infinite diversity" with the way design has evolved for "manageable uniformity" (Lyle, 1994). We as a species have substituted ecological cycling and recycling of materials and processes with "a system of one-way flows, moving the materials that support life in vast quantities from source through consumption to sink" (Lyle, 1994, p.4). Lyle believed that one-way flows in linear systems are not sustainable, so we need to design systems where energy and materials self-renew and regenerate (1994).

The design concepts of "cradle to cradle" and "biomimicry" also inspire a circular economy by drawing inspiration from natural innovations (Mang & Reed, 2012). Cradle to cradle focuses on "rematerialization of safe, productive materials in systems powered by the sun" and enables materials to flow safely via technical or biological metabolisms (McDonough & Braungart, 2003, p.14). McDonough and Braungart, key thought leaders behind this design concept, describe the example of how a cherry tree in nature operates "according to cycles of nutrients and metabolism… powered by the sun and constantly adapts to local circumstances" (1998, p.87). McDonough and Braungart's "cradle to cradle" design concept is based on closed-loop cycles of nutrients flowing in ecological systems where there is no waste (McDonough & Braungart, 1998). This approach seeks to translate design strategies from eco-efficiency to eco-effectiveness (Braungart et al., 2007) by designing materials that are safe to return to the organic cycle (e.g., biodegradable packaging) and technical nutrients to return to the technical cycle (recycling and downcycling materials into new products) (McDonough & Braungart, 1998). A related principle, biomimicry, was popularized by Janine Benyus (1997) and has served as a platform to design sustainable products, building, processes, and systems to function congruently with ecological processes (Mang & Reed, 2012).

## 2.2 Translating Theory to Practice

These theoretical underpinnings of the circular economy concept have evolved separately and together to bring about a widely varied understanding of CE and its approach to its implementation. CE adoption has succeeded in Asia and Europe, where policies support or mandate its application (Rothenberg et al., 2019). Many examples of CE in China started in the 1990s with the eco-industrial park model, which was furthered by top-down policy aiming to address environmental and human health problems (Ghisellini et al., 2016; Winans et al., 2017). "The Circular Economy Promotion Law of the People's Republic of China" formalized the commitment to CE with a strategy in 2002 and law in 2009 (Lieder & Rashid, 2016; Yuan et al., 2006). In 2002, European Union (EU) circular economy laws started with a top-down approach with the Waste Electrical and Electronic Equipment (WEEE) Directive (Directive 2002/96/EC), requiring producers to pay for a collection system for consumers to return their WEEE to be recycled (EC, 2021). The EU adopted the Circular Economy Action Plan in 2015 to provide a systematic approach to improving circularity across the value chains, such as setting ambitious recycling targets, closing the loop on recovered materials, and integrating circular principles into plastic production and consumption, water management, and food systems (EC, 2019).

In the USA, there is no unifying CE policy as found in the EU or China. However, policies have evolved from no environmental regulations, restrictive, reactive "command and control" regulations during the 1970s to proactive, voluntary, and market-based approaches focusing on pollution prevention, life cycle design, waste management frameworks, and ecolabels. The conventional eco-design assumes the product's fate is the waste pathway (van den Bergh, 2020). To enhance circular business models, tax, depreciation, procurement, and liability policies need to be realigned for an economy that extends the performance of goods and services (Stahel, 2010). CE models should also focus on slowing (e.g., reuse, repair) rather than only closing the loop (e.g., recycling) with suggested rules of thumb: "Do not repair what is not broken, do not remanufacture something that can be repaired, do not recycle a product that can be remanufactured" (Stahel, 2010, p. 195).

One challenge in the field is that there are many ways to operationalize circular economy models (Kalmykova et al., 2018; Kirchherr et al., 2017). Models range from the traditional "3R" (reduce, reuse, and recycle) to an enhanced "9R" framework that also includes repairing, refurbishing, remanufacturing, repurposing, rethinking (sharing), and refusing (making a device obsolete by replacing product function with device convergence) (Kalmykova et al., 2018; Kirchherr et al., 2017). These "R" frameworks are based on a waste management hierarchy that prioritizes reduction over other strategies (Bocken et al., 2017; Kirchherr et al., 2017). Even with this prioritization, some strategies may compete with one another; for example, a company focused on recycling may be less inclined to reduce resources or reuse products (Ghisellini et al., 2016). While many view the biosphere as an ideal system for cycling materials, recycling benefits diminish over time in an industrial system as material recovery cannot realistically occur indefinitely (Andersen, 2007; Ghisellini et al., 2016).

Many CE business models aim to reduce reliance on resource extraction but face limits to which recycling, refurbishing, or reuse can achieve these goals. Historically, incremental efficiency improvements without external pressures from policy or prices rarely reduce consumption (Dahmus, 2014). A rebound in production could occur unless a secondary material or good completely substitutes for a primary one, which is hard to predict due to the circular economy's complexity of systems and markets. Realistically, substitution depends on the buyer's willingness to replace primary materials with recycled alternatives and the ways that buyers and sellers react to the price of both kinds of materials (Zink & Geyer, 2017). Companies need to market secondary goods, explain the benefits, and educate target customers about the value proposition of durable, longer-lasting goods over lower quality, disposable ones (Rizos et al., 2017; Zink & Geyer, 2017). Consumer behavior and conformity also play essential roles in the uptake of CE. Beyond utility, consumers are influenced by illogical attraction towards aesthetically pleasing motifs, the influence of social structure, prestige, and enjoyment (Planing, 2015). CE business models will also continue to be challenged by meeting mass-market pricing to actively compete with incumbent technologies and products (Deubzer et al., 2015).

These challenges are echoed in recent research demonstrating that circular economy strategies depend on consumer behavior (Kasulaitis et al., 2020) and stakeholder decision-making (Singh et al., 2021). Additional opportunities exist in exploring stakeholder management theory (Kahupi et al., 2021) to understand perceived barriers and identify factors to enable the success of new models. The managerial focus should maximize the displacement of primary production through increased quality, price competitiveness, and alignment with target markets, rather than just closing material and product loops. One example of a collaboration that has attempted to align target markets and development of new products to close material loops is H&M's relationship with Danone AQUA, the Indonesian packaged drink business; plastic bottles found on Indonesian beaches are collected and processed into an input for garment manufacturing (Lahti et al., 2018). However, marketing is critical to ensuring reused, refurbished, or remanufactured products are communicated appropriately to consumers, developed to meet consumer needs, and answer any questions or perceptions about quality. Unfortunately, CE management research has focused on corporate social responsibility and very little on marketing or management information systems (Rothenberg et al., 2019). Moreover, the net benefits of widely marketed CE approaches have not yet been validated and grapple with issues like responsible sourcing, ethical labor practices, and shortened lifespans (e.g., fast fashion and electronics) (Kossoff, 2020).

Recent research has also highlighted the challenge in assessing CE implementation strategies to understand if they deliver the environmental benefits for which they were intended. Little agreement exists on measuring the circular economy (Kirchherr et al., 2017; van den Bergh, 2020). There is also a lack of standardization in available assessment techniques (Singh et al., 2021) and government standards (Tecchio et al., 2017). EMF has introduced its measurement tool, Circulytics®, which aims to assist organizations in measuring their performance and transitioning their supply chains to be circular (EMF, 2021). Scores like "C-metric" or "circularity index" focus on the degree to which materials and value are recirculated within the economy and typically – but not always – correlate with reduced environmental impact (Linder et al., 2020). Some methods, such as "Material Circularity Indicator" and "Material Reutilization Score," can lead to conflicting environmental outcomes, although these can be resolved mainly by further integrating multi-criteria decision analysis (Niero & Kalbar, 2019). Systems-based methods, such as material flow analysis and life cycle assessment, are widely used in CE research and are particularly useful for ranking CE strategies rather than relying on predefined hierarchies (Richa et al., 2017). However, such methods are not always well-suited to capturing marginal change or nonlinear responses that may occur in CE transitions (Singh et al., 2021), underscoring the need for methodological advancements (EMF, 2020).

## 2.3 Case Studies

The varied approach to applying circular economy in practice can also be seen through the tested and applied business models across different sectors. For-profit companies use business models to create value by identifying a solution to a problem and then capturing that value by charging the customer for providing them with the solution (Linder & Williander, 2017). CE models (illustrated here with an example of a washing machine) are viewed as *ownership-based* (purchasing the appliance), *access or usage-based* (leasing the appliance), *performance-based* (leasing the washing machine for 1000 washes), and *result-based* (pickup/delivery, subscription, or payment for laundry service) (Kim et al., 2007). Circular business models in this section are categorized into five main approaches: (1) circular supply model (substituting traditional virgin inputs with renewable, bio-based, or recovered materials), (2) resource recovery (recycling and diverting waste into secondary raw material, (3) product life extension, (4) sharing models, and (5) product-service systems (PSS) (OECD, 2018). Here, we examine two sectors with high environmental impacts, complex and costly waste streams, and low degrees of material and value recovery and retention in the current linear economy. However, each demonstrates unique challenges and opportunities for translating CE from theory to practice.

### *2.3.1 Food and Food Waste*

Food production is both resource-intense and wasteful. In the USA, over 100 million tons of "wasted food" is generated each year from agriculture, processing, distribution, retailers, institutions, and households (U.S. EPA, 2018). This waste stream represents the loss of water, fertilizer, and land resources (Kummu et al., 2012), embodied energy (Cuéllar & Webber, 2010), economic value (Buzby & Hyman, 2012), and nutritional content (Spiker et al., 2017) of food that is never consumed. Further, wasted food is typically landfilled in the USA, leading to climate impacts due to carbon dioxide and methane release. However, these impacts can be minimized by two circular economy business models: *sharing and redistribution* of high-quality food surplus that is rescued before it becomes waste (Reynolds et al., 2015) and *resource recovery* through processes including composting and anaerobic digestion of food waste to recover the energy and nutrients it contains (Ebner et al., 2018).

While food rescue has historically been carried out in the USA through charitable organizations, commercial enterprises are more common in other parts of the world and are now beginning to emerge in the USA (Hecht & Neff, 2019). The underlying business model for food rescue is to continue obtaining valuable from saleable food through interventions that redistribute it through alternate pathways. Examples include grocery retailers selling items nearing their expiration or food with cosmetic blemishes at a discounted price or via lower-income markets, or businesses selling boxes of "ugly" fruits and vegetables. Even in charitable donations, businesses in the USA receive tax benefits for providing quality food to those in need. Many for-profit food rescues and sharing models leverage growing web platforms and app capabilities (Michelini et al., 2018), underscoring the importance of data and information flows to enable this pathway. The ability to share decision-relevant data, such as food quality, availability, freshness, and variety (Göbel et al., 2015), is a precursor to building trust and cooperation between key partners, i.e., those that rescue and those that receive food. Another challenge facing this business model is the issue of scale. While many of the emerging examples of food rescue businesses are small entrepreneurial endeavors, upscaling can help overcome inefficient transportation and logistics issues and mismatched food supply and demand (Sedlmeier et al., 2019).

While food rescue has a more significant potential to retain the primary nutritional value of food, resource recovery through food waste recycling has been more widely studied in the literature. Most resource recovery models focus on converting wasted food into compost, bio-based energy carriers, or other bio-products and commodities. The environmental benefit is twofold: creating products that displace fossil fuel-derived chemicals or energy sources while at the same time avoiding landfilling food waste and the attendant greenhouse gas emissions (Bernstad & Jansen, 2012; Ebner et al., 2018). The business proposition for firms operating waste-to-value systems is similarly dualistic. Revenues arise from charging tipping fees to food waste generators and selling the produced electricity, natural gas, or other products back to the market (Franchetti & Dellinger, 2014; Shahid & Hittinger, 2020).

Realizing food waste resource recovery's economic and environmental potential relies on building coordination and communication among disparate stakeholders to ultimately reframe organic wastes as bio-based resources (Perey et al., 2018). Some of the critical enablers of food waste resource recovery include consistent data collection methods to quantify amounts and characteristics of wasted food (Xue et al., 2017), new incentive structures (Borrello et al., 2017), and multi-stakeholder collaboration (Halloran et al., 2014). However, physical infrastructure also plays an important role, given that there is not currently sufficient capacity to process the magnitude of food waste generated (Shahid & Hittinger, 2020). This infrastructure must be resilient to variability in wasted food characteristics (Fisgativa et al., 2016) and generation volume (Armington et al., 2018; Lebersorger & Schneider, 2014). Further, siting food waste recovery facilities will require that stakeholders optimize what are often competing objectives, including local regulation compliance, transport costs, revenue sources, public opinions, and downstream systems to treat any residual organic waste left after the primary waste-to-value process (Armington et al., 2018; Ma et al., 2005; Thompson et al., 2013).

For both circular models discussed above, effective policy is likely to be required as a critical enabler for bringing sustainable innovations into practice (Kahupi et al., 2021). Such policies may include expanded liability protection for companies who donate usable food (Evans & Nagele, 2018), expanding economic incentives for firms to produce bio-products from organic waste (De Clercq et al., 2017), or providing capital grants to lower costs of resource recovery infrastructure (Shahid & Hittinger, 2020). However, the optimal nature and scale of policy most likely to drive circular food system models are unclear. In the USA, for example, no federal food waste policy exists, and the handful of state and local laws currently enacted have wide variability, which may diminish their effectiveness. On the contrary, Leipold and Petit-Boix (2018) note that the universal approach entailed in the EU Circular Economy Action Plan may not effectively align with local variability inherent to bio-based resource recovery. As new policies and business models emerge to address the challenges of food waste, a parallel research need is systemic evaluation of their efficacy and ability to achieve sustainability goals of the circular economy.

### *2.3.2 Consumer Electronics*

While food is a basic need for human health and existence, consumer electronics enhance the functionality of modern life as critical enablers of work, education, communication, and entertainment. However, consumer electronics also have significant environmental impacts that span their life cycle, from energy- and resource-intense manufacturing processes, electricity demand during use, declining product lifespans, and poor management at the end of life. Despite the potential to reuse consumer electronics after their first life or recover the valuable materials they contain, most of these products are treated as wastes. Plastics in electronics are a particular challenge, as they have a low recycling rate, contain additives like brominated flame retardants that limit their recycling, and lack the global infrastructure to effectively enable CE practices, as many companies are focusing on models to reduce or eliminate plastics in packaging rather than products. However, emerging circular business models address these challenges, primarily through *resource recovery*, *circular supply*, *product lifespan extension*, and *product-service systems*.

The majority of circular economy efforts in the electronics sector have focused on closing rather than slowing resource loops. This emphasis is reflected in policy, such as the extended producer responsibility model underpinning the WEEE Directive in the EU and state electronic waste laws in the USA. Economic performance of resource recovery hinges on solid and stable markets for recovered materials in countries with low labor costs, which has until recently supported the recycling industry in mature economies. However, the global recycling industry was recently disrupted with the passing of China's National Sword Policy (Katz, 2019). Voluntary design standards like the Electronic Product Environmental Assessment Tool (EPEAT) enhance the circular economy with environmental and social responsibility performance standards addressing the life cycle impacts of consumer electronics. These criteria focus on reducing hazardous material content and substance management (thereby limiting impacts to the biocycle), energy conservation, recovery of materials, end-of-life management, packaging, design for end-of-life, and life cycle extension/longevity (EPEAT, 2021).

A flow of information alongside materials from each node of the system at all organizations and stakeholders is critical for *resource recovery* models. Organizations like WorldLoop assist in contracting business to business recyclers, smelters, and buyers of e-waste components (Deubzer et al., 2015). The resource recovery model relies on a solid financial case for the recovery and recycling of materials, which is not as straightforward for some plastics within electronics (e-plastics). A report published in Ethiopia (Deubzer et al., 2015) anticipates downstream market capabilities for various e-waste components by looking into buyers and sellers from the formal sector for various components, including pre- and post-processing. However, dealing with plastic components containing flame retardants has not been adequately addressed for mass-scale operations.

Sustainability commitments are considered essential to ensuring the supply chain develops and invests in new sustainable materials that can also be available and adopted by the electronics industry as a whole and not just one company (Bourne, 2020). Examples of circular supply models have been applied by companies like Google, Apple, HP, Samsung, and Dell, who are attempting to close the loop by integrating recycled materials in products and packaging or using renewable materials (Apple, 2021; Bourne, 2020; Jackowski, 2020; Moore, 2019; Raudaskoski et al., 2019). Recently Google set a goal to use recycled or renewable material in at least 50% of the plastic used in products' hardware (prioritizing recycled plastic) and zero plastics in packaging by 2025 (Bourne, 2020). Samsung aims to replace conventional plastic packaging materials with paper or recycled or bio-based plastic (Moore, 2019). HP and Dell have made progress on their goals. HP's partnership with Haiti has resulted in recycling and reusing 450 tonnes of ocean-bound plastic bottles into several products that would otherwise end up in the ocean (Jackowski, 2020), and Dell's closed-loop plastics recovery supply chain processes plastics from old computers into new parts for over 100 new Dell products (Raudaskoski et al., 2019).

For the circular economy of consumer electronics to be fully realized, reuse loops (sharing and repair loops) need to be leveraged (Singh et al., 2021). However, realizing this goal requires *product lifespan extension* models. Enhancing the longevity of products requires designs that eliminate high failure parts, strengthen emotional attachment, minimize perceived or planned "software-induced hardware obsolescence," developing repair and testing tools, integrating sensing technologies, and creating new technologies to access bill of material data (GEC, 2018, p.8, Komeijani et al., 2016; Bovea et al., 2016; Nobre & Tavares, 2017). Implementation is a challenge because devices are still constructed in ways that limit access to components or are hard to repair, with hidden screws, glued components, or embedded computer chips in atypical products like clothing or small wearables (van den Bergh, 2020). Remanufacturing to extend the life of electronics has occurred in some cases, but consumers remain skeptical about purchasing used products; purchasing decisions are often influenced by fashion, status, and technical preferences (van den Bergh, 2020). Educating consumers about refurbished or remanufactured devices is essential to the success of this strategy (van Weelden et al., 2016). Strong stakeholder collaborations are needed on the supply side to share information and understand roles and responsibilities (Ghisellini et al., 2016; Lieder & Rashid, 2016). Partnerships are also critical for implementing product longevity models. For example, in 2020, Google purchased Neverware, a company that extends the product life of old PC and Mac computers by using a Chrome operating system (Hachman, 2020).

One untapped opportunity is the emergence of the *PSS* and *sharing* models, which may reduce consumption by replacing ownership with subscription, leasing, or other service-oriented options (Singh et al., 2021). A few sharing models exist for consumer electronics, and the few that exist typically focus on business rather than retail consumers. Computers and server equipment in business settings are leased, but for some devices, the leasing model may be replaced with cloud-based devices shared by many users (e.g., Chrome's Grab and Go laptops). A recent example envisions how this concept might be applied for consumer smartphones: a modular design, with three parts – skin (casing), organs (processor), and skeleton (circuit board) – would be combined with a PSS model that enables access to leased parts that can be updated as technology advances (Bridgens et al., 2017). The success of consumer PPS models for electronics relies on understanding how consumers use and interact with devices and finding ways to help users develop emotional connections to their products (Lobos & Babbitt, 2013). The lack of sharing models is not surprising, as the Bocken et al. (2017) review of S&P 500 company press releases from 2005 to 2014 found "radical business models" like sharing were not the focus of large companies and that it takes time for certain concepts to become mainstream.

## 2.4 Cross-Cutting Sectoral Challenges

The two sectors discussed above illustrate some of the many ways circular business models are being used to drive sustainability. They also highlight different challenges and opportunities for translating CE from theory to practice. These challenges are echoed in other sectors. For example, the fast fashion industry sees many issues similar to those in the polymer and e-waste industries. Poly-cotton blends of fabric are an issue for separation concerning physical or chemical recycling, as polymer recovery is technically challenging and expensive (Zou et al., 2011). Fashion products employ digital information carriers in radio-frequency identification (RFID) tags that record every transaction, an approach that could be scaled up using digital innovations to create an intelligent supply chain equipped to handle big data associated with industry-wide material tracking (Gahletia, 2021). This innovation may enable information sharing and trust between connected stakeholders.

Similarly, polymers offer great assistance in terms of longer shelf life for food, flexibility, strength, resistance to corrosion, insulation (to heat and electricity), and superior mechanical properties such as high strength and modulus to weight ratios (Brinson & Brinson, 2008). The use of thermoplastics especially has become all the more appealing to both producers and consumers due to the ability of their bonds to be separated and rejoined by melting, making them a highly valued commodity. For this reason, Novo Nordisk homogenized their insulin pens to contain just polyoxymethylene and polypropylene so density differences can easily separate them during recycling (Raudaskoski et al., 2019). However, in reality, we rarely find artificial structural materials made of a singular material or a product designed to last several generations. Common consumer plastics are usually some types of composite structure with fibers, metals, or other proprietary plasticizers and additives, making disassembly and removal an expensive feat. For instance, titanium dioxide in polyethylene terephthalate makes opaque bottles less desirable (Kutz, 2016, p.172), and there is a decrease in the internal viscosity every time this polymer is processed (Haynie & Rainville, 2021), increasing chances of breakability and subsequent resource loss during each cycle.

## 2.5 Closing Remarks

Tracing the historical precedents of CE models shows how this concept grew from foundational theories in multiple fields. Economics, systems dynamics, ecology, design, and industrial ecology all contributed to the theoretical basis of what has become a widely regarded field in its own right. This wide array of foundational concepts has shaped the circular economy as holistic and systems-oriented, encompassing economic and environmental perspectives. However, these diverse origins have also led to widely varied approaches to implementation. This variability has been further magnified by regional differences in policy, heterogeneity in consumer responses, and sectoral differences in design, manufacturing, reuse, and recycling practices. These factors help explain why some circular business models have gained traction while others have been unable to surmount economic and technology barriers.

While all fields have much to offer to expand the practical application, validation, and evaluation of CE models, future research in the management field is critical. Marketing to consumers is needed to alleviate perceived concerns about product-service systems and product life extension models. For circular supply, resource recovery, and PSS models, stakeholder theory research is needed to enable collaborations and information sharing to build infrastructure, optimize competing objectives (regulations, costs, and sources of revenues), and reframe waste as a resource. Finally, understanding the flow of information, labor, money, and resource and energy flows is essential to decision- and policy making for all CE models.

The sector-specific examples discussed here underscore the need for more studies exploring the feasibility and outcomes of applying CE in practice. Existing literature emphasizes many examples of resource recovery and circular supply models but has few successful PSS or sharing models. Further, very little knowledge exists about how circular business models interact with one another or effectively bring about the data, policy, and stakeholder collaborations to enable such models to be successful. Expanding such examples will require bringing additional fields into the circular economy domain, including management, organizational theory, and behavioral science. The new paradigm of convergent research can better integrate theoretical conceptualizations of CE that arise from different disciplines and combine the knowledge and expertise of researchers and stakeholders who can translate theory into practice.

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# Chapter 3
# Conceptualization of Circular Economy 3.0: Synthesizing the 10R Hierarchy of Value Retention Options

**Denise Reike, Walter J. V. Vermeulen, and Sjors Witjes**

## 3.1 The Circular Economy as an Evolution in Three Phases

Several authors claim that CE can be traced back as far as Quesnay's "Tableau Economique" (1758) and his assumptions on surplus value from cyclical inputs (Murray et al., 2015). The earliest direct examples at closing material loops date back to the nineteenth century, such as the work by Simmonds (1814–1897) (Cooper, 2011). Besides, historically, there have always been economic sectors evolving from waste usage and by-products like dyes in petrochemicals (Ayres & Ayres, 1996). However, through the industrial revolution, new dimensions of product diversification and material use emerge. After World War II, the global economy accelerates, and waste management becomes increasingly problematic and essential to regulate. The main concerns are controlling and abating pollution, but integrative waste management approaches are still missing (Carter, 2001). At the end of this phase, early warnings of resource depletion and limits to growth emerge. The Club of Rome (1972) publication is decisive in inducing the shift to the next phase. This section details the historical roots of the CE concept, building upon our 2018 published article (Reike et al., 2018a, b). More details of this history can be seen on the online timeline of 70 circularity concepts from the Global South and North (Calisto

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Friant et al., 2021).[1] In the following, we show that CE can be artificially divided into three distinct historical phases.

### *3.1.1 CE 1.0 (1970–1990s): Dealing with Waste*

The 1970s, in Europe, North America, and Japan, are the times of command-and-control policy measures (Otis & Jr, 2000). Alongside environmental movements, the 3R concept of "reduce, reuse and recycling" increasingly gains attention. Governments regulate, businesses mostly follow reactively. Most measures in these decades focus on the "output side"; waste is not prevented, but pollution is limited, through principles like "the polluter pays" and "end-of-pipe treatment becomes the rule" (Gertsakis & Lewis, 2003; Tyler Miller & Spoolman, 2002). Waste management gets importance by regulating landfills and incineration, but there is not yet established thinking in systems, with substantial amounts of waste being treated outside "one's borders" or even dumped in less affluent countries (Moyers, 1991). However, precisely these types of practices, and growing global links through media, like television, nurture a realization that local and global problems are connected and that such problems can ultimately affect solid economic nations. It is in this phase that preventive and life-cycle-thinking-focused concepts like "cleaner production" (CP) and "industrial ecology" (IE) are first introduced and start to contribute to thinking in systems (Gertsakis & Lewis, 2003). Looking at Fig. 3.1, one can see how a large body of literature on waste management and recycling emerges during these decades, which is later accompanied by a rise in the literature which places systems thinking at the center of, for example, CP and IE. Therefore, the roots of CE can be argued to lie in precisely this phase. However, in practice, input and output measures remain insufficiently connected. Successes remain the greatest at the output side, with recycling rates considerably growing between the 1980s and the 1990s, not at last because of further policy measures and voluntary schemes for waste management and recycling by businesses (Bergsma et al., 2014). The scientific literature on the subject also grows steadily in this phase, addressing first improved waste management and later recycling, separation, and collection.

[1] A detailed version of this timeline including definitions, background information and videos can be found at this website

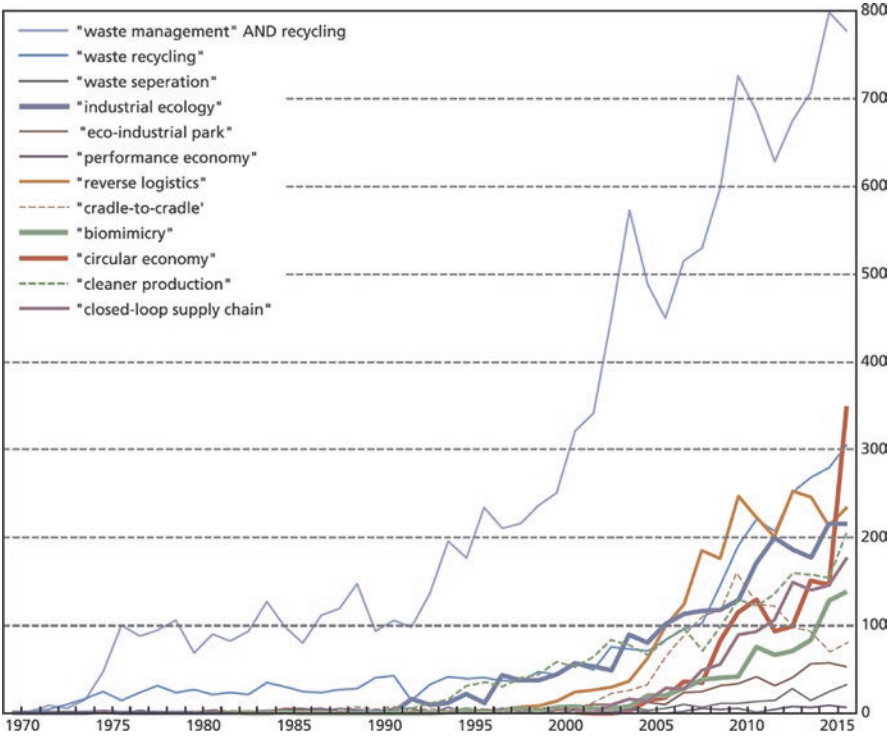


**Fig. 3.1** Scientific publications on circular economy and related concepts. (Source: Scopus)

### *3.1.2 CE 2.0 (1990s–2010): Connecting Input and Output in Strategies for Eco-Efficiency*

In this phase, we see a more robust integration among preventive measures and output measures. The idea of a win-win between the environment and business activity, as laid down in the Brundtland Report (WCED, 1987), gets promoted, often under the motto "pollution prevention pays" (Ochsner et al., 1995). Increasingly, environmental problems are framed as an economic opportunity: pro-active businesses can profit from efficiency gains and reputation gains (see, for more detail, Blomsma & Brennan, 2017). The dominant framing from the end of the 1960s and the 1970s about absolute reduction receives little attention. Concepts like IE and life cycle thinking (Boons & Howard-Grenville, 2009) become principles for action, however only on a limited industrial scale and alongside a very technical discourse (Graedel & Allenby, 1995), with social elements of innovation and implementation largely neglected (Vermeulen, 2006).

Other concepts like Design for the Environment get established in business in CE 2.0, and increasing attention is paid to questions of prevention and efficiency through design – as it is widely realized that a reduction in residuals ultimately asks for a reduction in inputs (Ayres & Ayres, 1996). System thinking is growing, and scientific data on global warming, water shortages, and loss of biodiversity create a new sense of urgency in the early years of 2000, which is aided by more and faster information sharing through digitalization and the Internet, which enable connecting the local to the global environmental issues in unprecedented ways.

Although scholars like Stahel and Reday wrote about a closed-loop economy as early as 1976 (see Bourg & Erkman, 2003), and the concept of CE itself was coined in the 1960s, it is only in this second phase that CE slowly gains prominence (Murray et al., 2015) which is also visible in Fig. 3.1: the first academic literature emerges in the 1990s, but a sharp increase in publications is seen around the year 2000.

### *3.1.3 CE 3.0 (2010+): Maximizing Value Retention in the Age of Resource Depletion*

In terms of framing, from 2010 onwards, several "borrowed" and "older" elements are combined in a new or newly emphasized fashion (Blomsma & Brennan, 2017; see also 3.2). While the rhetoric still stresses economic gains, ultimate threats to the survival of the human race in the light of seemingly insurmountable sustainability challenges are linked to population growth and renewed attention for resource depletion and retaining the value of resources. There is fear that we cannot consume endlessly and that other nations should not catch up with the Western level of exploiting nature – at least not through the same growth path and with similar rebound effects. Against this context, CE's allegedly newly developed idea is celebrated for its potential to decoupling growth from resource use (UNEP, 2011). Thereby, it is phrased as a way out of the "resource trap" (Table 3.1)

## 3.2 Value Retention Options in CE Literature: From a Cacophonic Conceptualization Towards a Synthesis – The 10R Framework

Resource value retention options – also often called Rs, R-options or R-strategies – form one of the circular economy literature and practice fundamental principles. Since the circular economy has reached its third phase (CE 3.0), there has been a growing effort to refine the meaning of this principle further to render its practical applicability and to represent better the complexity confronted by firms and other socioeconomic stakeholders in using resources in a stratified and hierarchical way for attaining a more circular economy. However, these attempts to clarify and deepen the understanding of value retention options have exacerbated an existing

**Table 3.1** Features of circular economy 1.0, 2.0, and 3.0 policies

| | Circular economy 1.0 (1970–1990s) | Circular economy 2.0 (1990s–2010) | Circular economy 3.0 (2010–now) |
|---|---|---|---|
| Focus | *Away from landfilling:* Incinerate and first public recycling efforts | *Connecting input and output side* in eco-efficiency strategies | *Maximizing value retention* in the age of resource depletion |
| Principles/ tools/ instruments | First formulations of waste hierarchies like 3R: Reduce, reuse, recycle/ladder of Lansink | *Input side:* Pollution prevention pays, environmental management systems, design for sustainability; design for disassembly, industrial ecology, cradle to cradle<br>*Output side:* Extended producer responsibility, eco-industrial parks, industrial symbiosis | *Input side:* Replacing all virgin material inputs with secondary resources<br>Relying on new business model incentives<br>*Output side:* More and more profound extended producer responsibility |
| Key challenges | Mostly output side of value chain oriented: What to do with waste after user phase? | Upscaling sustainable business practices<br>Organizing recycling infrastructures | Transfer from downcycling to a higher level of value retention<br>Promote short loop and middle extended loop value retention options |

cacophony around the different categories with different boundaries, meanings, and application contexts. A fundamental development is the increase in the number of the R-options distinguished going from a crude categorization ("reduce, reuse, recycle") towards a more broadened set of categories (e.g., "reduce, remanufacture, reuse, recover, recycle") (Jawahir et al., 2006).

Most value retention options distinguished in literature start with the word "re." The "re-" in Latin means "again," "back," and "afresh," "anew," somewhat well expressing the essence of CE (Sihvonen & Ritola, 2015). The simplicity that makes such terminology attractive may have contributed to confusion in CE literature and related literature strands. Looking at the myriad of words that appear as R-strategies in scientific articles, we note using 38 different "re-"words in varying combinations. In alphabetic order, these are re-assembly, re-capture, reconditioning, recollect, recover, recreate, rectify, recycle, redesign, redistribute, reduce, re-envision, refit, refurbish, refuse, remarket, remanufacture, renovate, repair, replacement, reprocess, reproduce, repurpose, resale, resell, re-service, restoration, resynthesize, rethink, retrieve, retrofit, retrograde, return, reuse, reutilize, revenue, reverse, and revitalize.

This list of words illustrates the variety and confusion found with the different value retention options. Scholars, in combining R-words, present fundamentally different orders and hierarchies, some of which lack an obvious logic. The simple 3R distinction serves well to illustrate that authors remain far from applying the same concepts and meaning. For example, 3R can refer to "reduce, reuse, recycle" – this is a well-known waste management principle and dominant with Chinese scholars as the Chinese national CE policies are based on 3Rs. However, it is also found with many other scholars (e.g., Diener & Tillman, 2015; Ghisellini et al., 2014; Lieder & Rashid, 2015; Yoshida et al., 2007) and can also mean "reuse, remanufacture, recycle" (Gehin et al., 2008; Nagalingam et al., 2013); "reduce, recovery, reuse" (Wang & Hsu, 2010); "reuse, recycle, return" (Hassini et al., 2012); "re-cycling, reuse, revenue" (Larsen & Taylor, 2000); and "reuse, recycle, reduce" (Yan & Feng, 2014).

In our original article, we discuss how the use of higher R typologies leads to wider cacophony regarding the use of R-words in literature. Examples become more diverse and confusing when scholars and practitioners refer to more detailed R-options, which all prompts why scientists – despite a growing body of CE literature – have not focused on clearly defining this key concept related to CE operationalization and an accepted set of definitions. The following section presents such an attempt at clarity and synthesis.

## 3.3 Making Sense of Value Retention Options

Based on an interdisciplinary literature review, we propose a synthesized 10R typology, which we diversify for the two distinct product life cycles of "Produce and Use" and "Concept and Design." The typology consists of eight reutilization options and two preventive options, most notably the R0 – denoting zero use and impact. We coined the term *resource value retention options* (ROs) to attempt a more neutral and "fresh" term not afflicted by the existing confusion, as are other standard terms whose meaning can be viewed as eroded and unsuited as an umbrella notion. As a newly introduced term, it must be clear that it shall refer to the idea of resources carrying an intrinsic value – as applied in the sustainability discourse – as opposed to economic notions of value (see also Campbell-Johnston et al., (2020) for a more detailed discussion of the notion of "value"). Hence, the retention of resource value means conservation of resources closest to their original state and, in the case of finished goods, retaining their state or reusing them with a minimum of entropy to give them consecutive lives. We present the various ROs by distinguishing short loops (where the product remains close to its user and function), medium-long loops (where products are upgraded, and producers are again involved), and long loops (where products lose their original function). Below, we support the outline of the critical points of our comparative analysis and synthesis with Table 3.2 and Figs. 3.2 and 3.3, which show the ROs linked to the two distinct product life cycles. For an in-depth discussion, we recommend reading our original scientific article.

**Table 3.2** 10 Value retention options in (ROs) CE as a synthesis of literature

| | RO # | CE concept | Object | Owner | Function | Key activity customer | Key activity market actor |
|---|---|---|---|---|---|---|---|
| Downcycling | R9 | Remine | Landfilled material | Local authorities, Land owner | New | Buy and use secondary materials | Grubbing, cannibalizing, selling (South)/high-tech extracting, reprocessing (North) |
| | R8 | Recover (energy) | Energy content | Collector, municipality, energy company, waste mgt. company | New | Buy and use energy (and/or distilled water) | Energy production as by-product of waste treatment |
| | R7 | Recycle | Materials | Collector, processor, waste mgt. company | Original or new | Dispose separately; buy and use secondary materials | Acquire, check, separate, shred, distribute, sell |
| | R6 | Repurpose (ReThink) | Components in composite products (new product with old parts) | New user | New | Buy new product with new function | Design, develop, reproduce, sell |
| Product upgrade | R5 | Remanufacture | Components in composite products (old product with new parts) | Original or new customer | Original, upgraded | Return for service under contract or dispose | Replacement of key modules or components if necessary, decompose, recompose |
| | R4 | Refurbish | Components of composite products (old product with new parts) | Original or new customer | Original, upgraded (large complex products) | Return for service under contract or dispose | Replacement of key modules or components if necessary |
| | R3 | Repair | Components of composite products (old product with new parts) | First or second consumer | Original | Making the product work again by repairing or replacing deteriorated parts | Making the product work again by repairing or replacing deteriorated parts |

(continued)

**Table 3.2** (continued)

| | RO # | CE concept | Object | Owner | Function | Key activity customer | Key activity market actor |
|---|---|---|---|---|---|---|---|
| Clients/user choices | R2 | Resell/reuse | Product | Consumer | Original | Buy second hand or find buyer for your non-used produced/possibly some cleaning, minor repairs | Buy, collect, inspect, clean, sell |
| | R1 | Reduce | Product | Consumer | N.a. | Use less, use longer *recent:* share the use of products | See second cycle Redesign |
| | R0 | Refuse | Product | Potential consumer | N.a. | Refrain from buying | See second cycle Redesign |

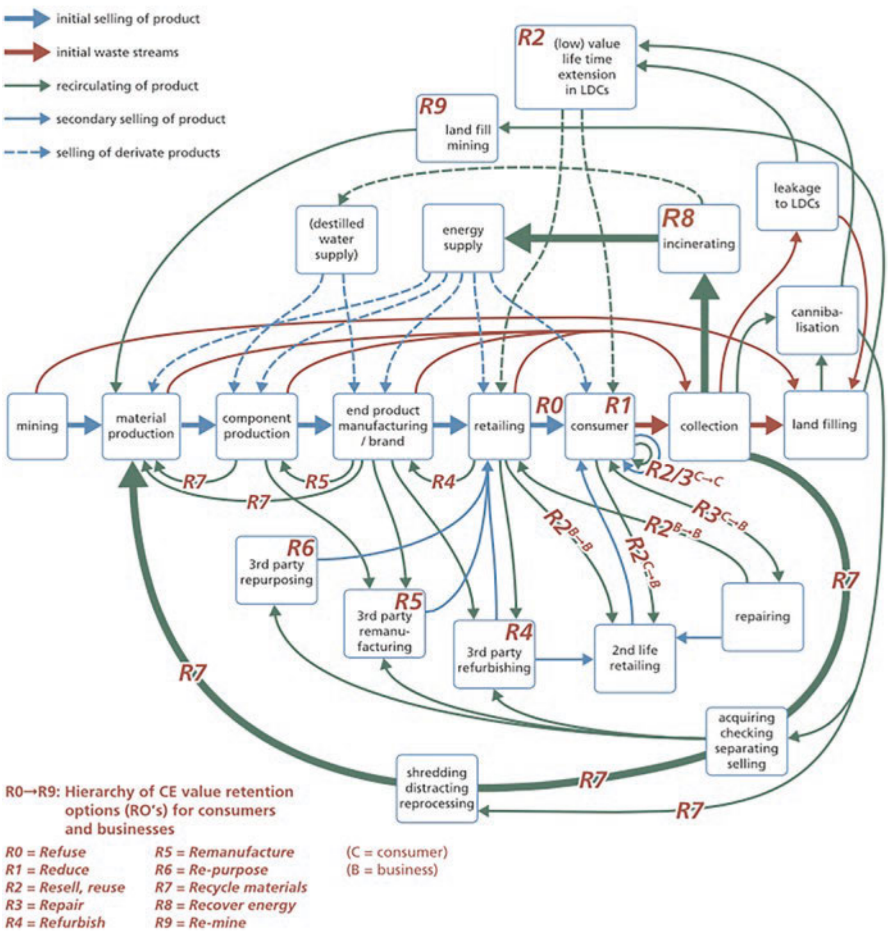


**Fig. 3.2** Mapping circular economy retention options: the Product Produce and Use Life Cycle

### *3.3.1 Shortest Loops: R0–R3 (Refuse, Reduce, Resell/Reuse)*

The first four loops exist close to the consumer and can be linked to a commercial or noncommercial actor engaged in extending the lifespan of products. Scholars applying a clear hierarchy characterize these as the preferable ROs in CE. As the historical overview and the previous section argued, the varying emphasis on the R0 and R1 in literature may be evidence of a paradigmatic division – regarding the issue of the perceived necessity of absolute reduction of inputs and consumption – hence also relating to different motives of different groups in promoting CE.

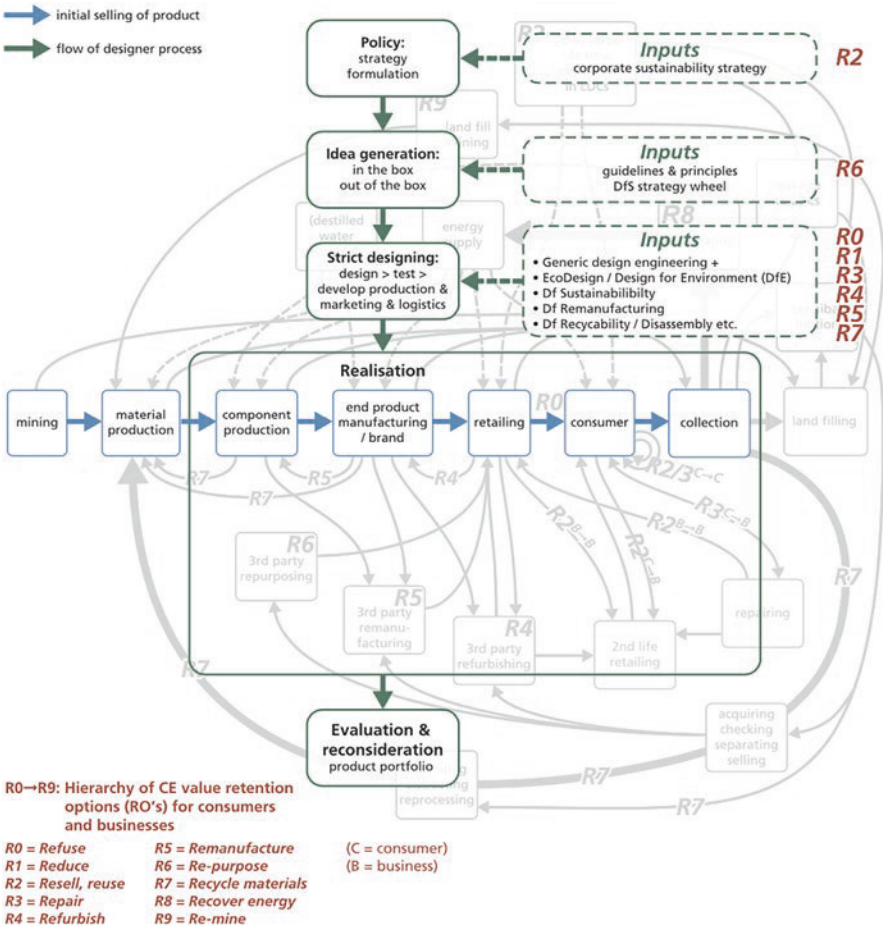


**Fig. 3.3** Mapping circular economy retention options: the Product Concept and Design Life Cycle

#### 3.3.1.1 Refuse: R0

The concept "refuse" is both used in the context of the consumer and the producer. In the consumer case, scholars stress the choice to buy minor or useless, which may apply to any consumption article aiming to prevent waste creation (Allwood et al., 2011; Black & Cherrier, 2010; Tyler Miller & Spoolman, 2002). It refers to a critical position of consumers, shifting towards a post-material lifestyle (Hedlund-de Witt, 2012; Spaargaren, 2003). Refuse is also often used to reject packaging waste and shopping bags (Clapp & Swanston, 2009; Kasidoni et al., 2015). Applied to producers, refuse refers to the Concept and Design Life Cycle, where product designers can refuse the use of specific hazardous materials, design production processes to avoid waste (Bilitewski, 2012), or, more broadly speaking, replace any virgin material.

#### 3.3.1.2 Reduce: R1

The concept "reduce" is used in three ways: consumer-oriented, producer-oriented, or generic. Consumer behaviors linked to "reduce" use purchased products less frequently or use them with more care and longer, or making repairs for life extension, such as consumer-to-consumer support (e.g., repair shops). Den Hollander and Bakker (2012) included participation in the "sharing economy" through pooling (simultaneous use) and sharing of products (sequential use) in this category. In most cases, however, "reduce" is explicitly linked to producers and their role in the pre-market stages of the Concept and Design Life Cycle, stressing using less material per unit of production or referring to "dematerialization" as explicit steps in product design (Jayal et al., 2010; Lieder & Rashid, 2015; Røine & Brattebø, 2003; Sihvonen & Ritola, 2015; Worrell & Reuter, 2014).

#### 3.3.1.3 Resell/Reuse: R2

The concepts "resell" (or "resale") and "reuse" are closely linked, expressing two sides of the market transaction needed to bring products back into the economy after initial use: the offering and the taking sides. Also, in this category, the various explanations of these concepts refer to different positions: consumers, collectors, retailers, and producers. Overall, most commonly "reuse" applies to a second consumer of a product that hardly needs any adaptions and works "as new" (De Brito & Dekker, 2003), "with the same purpose" (Bakker et al., 2014; Ghisellini et al., 2014), "without refurbishment" (Silva et al., 2013), and "without rework" (Srivastava, 2008) or "without repair" (Fleischmann et al., 1997).

From the consumer perspective, this implies buying second-hand or finding a buyer for a product that was not or hardly in use, possibly after some cleaning or minor adaptations for quality restoration by the consumer. In this context, online consumer-to-consumer auctions for used products are increasingly important, like eBay and national equivalents (Worrell & Reuter, 2014). Such "direct reuse" (Agrawal et al., 2015; Loomba & Nakashima, 2012) can also occur as an economic activity via collectors and retailers. Literature suggests that quality inspections, cleaning, and minor repairs are joint here (García-Rodríguez et al., 2013; Hazen et al., 2012; Stahel, 2010). However, direct reuse of unsold returns or products with damaged packaging belongs to this category and producer initiatives that enable multiple reuses of packaging (Agrawal et al., 2015; Romero & Molina, 2013).

#### 3.3.1.4 Repair: R3

The meaning of the concept "repair" may seem to defy misinterpretation. Its common purpose is to extend the lifetime of the product (King et al., 2006). It is described as "bringing back to working order" (Fernández & Kekäle, 2005; Fleischmann et al., 1997), "making it as good as new" (Srivastava, 2008), “recreating its original function after minor defects” (Stahel, 2010), and “replacing broken parts” (Thierry et al., 1995). Despite this apparent clarity, the concept is used variably in different contexts. An important distinction is that different actors can do repairing and with or without change of ownership. Repair operations can be performed by the customer or people in their vicinity, at the customer’s location, and through a repair company. More recently, peer-to-peer noncommercial repair workshops have become a trend (Ecoinnovators, 2015; Hultman & Corvellec, 2012). Businesses may send recollected products to their repair centers, manufacturer-controlled (Thierry et al., 1995), or third-party repair centers (Sherwood et al., 2000). Finally, we can distinguish “planned repair” as part of a longer-lasting maintenance plan (Den Hollander & Bakker, 2012; García-Rodríguez et al., 2013) or “ad-hoc” repairs.

## *3.3.2 Medium-Long Loops R4–R6*

The following two concepts, “refurbish” and “remanufacture,” resemble another. Therefore, some authors seem to use them as synonyms (Blackburn et al., 2004; Defee et al., 2009), yet others mix up the concepts (Mitra, 2007). If we found them both listed among ROs, refurbish appeared as a superior or more desirable option mentioned before remanufacture. However, only a few scholars provide explicit definitions. It is important to note that the medium-long loops are primarily conceived as business activities with indirect links to the consumer, such as commissioner or recipient of refurbished, remanufactured, or repurposed products.

### 3.3.2.1 Refurbish: R4

The use of the concept “refurbish” seems to be adequate in cases where the overall structure of a sizeable multicomponent product remains intact, while many components are replaced or repaired, resulting in an overall “upgrade” of the product (De Brito & Dekker, 2003; Fernández & Kekäle, 2005). In this way, the concept refurbish is also known from the common language in the context of an overhaul of buildings, while in CE literature, airplanes, trains, mining shovels, or engines and machinery are among the examples. The result should be a specified quality (Loomba & Nakashima, 2012; Thierry et al., 1995), bringing the product “up to state of the art due to newer, more advanced components” (Stahel, 2010). In this category, we also find some confusion; for example, Srivastava (2008) speaks of “almost as good as,” yet others mention repairing components that better match the dominant description of remanufacturing.

#### 3.3.2.2 Remanufacture: R5

"Remanufacture" applies where the entire structure of a multicomponent product is disassembled, checked, cleaned, and when necessary, replaced or repaired in an industrial process (Gehin et al., 2008; Lieder & Rashid, 2015). Some scholars also refer to this as reconditioning, reprocessing, or restoration (Den Hollander & Bakker, 2012; Jayal et al., 2010). Compared to refurbishing, the references on retained quality are more tempered, expressed as "up to the original state, like new" (Go et al., 2015; Loomba & Nakashima, 2012), partly because the remaining lifespan is expected to be shorter than for new products and because recycled components are used in the remanufactured product. Gehin et al. (2008) propose that the resulting product might be an upgrade viewed against the original if new parts were added. Another interpretation found in literature is that remanufactured products would entirely consist of recycled components (Badurdeen et al., 2015; Jawahir et al., 2006).

#### 3.3.2.3 Repurpose: R6

The concept of "repurpose" is used to a lesser extent; in total, only three articles included the concept among the ROs (van Buren et al., 2016; Sihvonen & Ritola, 2015; Tyler Miller & Spoolman, 2002); seven other authors seem to mean the same using the concepts "rethink" (Li, 2011) or "fashion upgrading" (Stahel, 2010) or "part reuse" (Den Hollander & Bakker, 2012). Repurposing is popular in industrial design and artists' communities. The material gets a distinct new life cycle by reusing discarded goods or components adapted for another function which seems to denote both low- and high-value end-products. Stahel (2010) gives the example of unemployed workers becoming entrepreneurs by transforming defective microchips into jewelry, glass bottles into mugs, textile waste into quilts, or plastic sheeting into handbags.

### *3.3.3 Long Loops R7–R9*

At first view, the long loops are purely denoting traditional waste management activities as this category includes recycling, different forms of energy recovery, and re-mining – which could be viewed as an "upgrade to landfill management." All scholars applying clear hierarchies with their ROs agree that these options are the least desirable. Still, materials or particles obtained through longer loop recycling can serve as input for shorter loop ROs (see "remanufacture"). We added "re-mining"; despite a sheer lack of attention to this RO in the analyzed contributions, a growing body of literature emerges on this subject. We view it as an essential addition to the RO hierarchy as it is directed at obtaining a use for existing waste stock and materials and flows that seemed irreversibly lost as untreated waste.

#### 3.3.3.1 Recycle Materials: R7

The concept "recycling" is at the bottom of ROs but the maximum use and confusing use. It is either used for any form of avoiding the use of new mining materials or resources (Ayres & Ayres, 1996; Ghisellini et al., 2014): "any recovery for any purpose" (Bakker et al., 2014), or it is explicitly described as an option beyond the shorter routes of R0–R6. Commonly, it means the processing of mixed streams of post-consumer products or post-producer waste streams using expensive technological equipment (Yan & Feng, 2014), including shredding, melting, and other processes to capture (nearly) pure materials (Graedel et al., 2011). A clear difference with the higher ROs is that recycled materials do not maintain any of the original product structure and can be re-applied anywhere (Graedel et al., 2011; Jawahir et al., 2006; King et al., 2006), wherefore recycled materials are also called "secondary" materials (Worrell & Reuter, 2014).

#### 3.3.3.2 Recover (Energy): R8

Like some of the other ROs, "recover" has a mixed use with three types dominating. First, it describes "collecting used products at the end of life, and then disassembly, sorting and cleaning for utilization" (Yan & Feng, 2014). Elsewhere, we found the second R in a 3R ranking: reduce, recover, reuse (Wang & Hsu, 2010). This use is widespread in the reverse logistics literature (De Brito & Dekker, 2003). It may also mean the extraction of elements or materials from end-of-life composites (Stahel, 2010). In Worrell and Reuter's *Handbook of Recycling*, we see a mixed use of the word, both connected to the collection of recyclable products and materials and the "energy recovery" from waste streams (Worrell & Reuter, 2014). However, in 20 of the analyzed articles, recovery means capturing energy embodied in waste, linking it to incineration in combination with producing energy (Hultman & Corvellec, 2012; Sihvonen & Ritola, 2015) or use of biomass (Stahel, 2010). In Fig. 3.2, we placed it among the lower value ROs referring to its dominant use.

#### 3.3.3.3 Re-Mine (R9)

A RO that is mostly forgotten or ignored in operationalizing CE is retrieving materials after the landfilling phase. In the Global North and the South, taking valuable parts from disposed of products forms a more or less informal sector that emerged under very different conditions. In developing countries, people try to earn a living by scrapping valuable materials and items from landfills which often involves freeing hazardous substances, thereby posing significant health risks for the "scavengers." Focusing on the most valuable parts, it is named "cannibalization" (Fernández & Kekäle, 2005; Fleischmann et al., 1997; Masoumik et al., 2014; Schenkel et al., 2015; Thierry et al., 1995). However, the concept is also used more generally to denote selective retrieval of parts (De Brito & Dekker, 2003) which can be used in other products or components (García-Rodríguez et al., 2013).

In developed countries, with a long history of controlled landfilling, recently, entrepreneurs started to "mine" the valuable resources stored in old landfills and other waste plants, which is called "landfill mining" or "urban mining" (Cossu & Williams, 2015; Frändegård et al., 2013; Johansson et al., 2012; Jones et al., 2013; Quaghebeur et al., 2013; Van Passel et al., 2013).

This R9 receives the least attention in policymaking and business with the medium-long loops of refurbishing and repurpose. It may change status in the decades from an unpopular "R" towards a widely known and practiced activity once technological progress allows for lucrative re-mining. With a view on this, we have included it as R9 activity in Figs. 3.2 and 3.3.

## 3.4 The Comprehensiveness of 10R Typology

With this exposé, the mapping of CE options in the Product Produce and Use Life Cycle is complete. Three clusters can be formed (see Table 3.2): ROs closely related to consumer/customer alternatives (R0–R3), ROs referring to various forms of upgrading of used products on the side of users but dominantly carried out by business actors (R3–R5), and the options referring to aggregate material flows, often resulting in downcycling, hence lower value re-applications (R6–R9). The three categories can also be labeled "user choices recycling" (R0–R2), "product upgrading" (R3–R5), and "downcycling" (R7–R9). Moving along the options, up to the higher-numbered ROs, we also see changes in ownership and changes in functions, summarized in Table 3.2.

## 3.5 Systematic Integration of Value Retention Options: A Visualization

Above, we have indicated that shorter and longer loops can be distinguished among the value retaining activities in CE. Taking the insights from the various scholarly contributions together, a depiction of the RO loops and flows is possible through integration into a synthesized visualization (see Fig. 3.2).

Comprehensive visualizations that are closer to depicting the complexities of CE need to distinguish various shorter loops between stages, for example, links between retailers and end producers or between the end producer and component manufacturers which also means that a variety of new stakeholder groups need to be acknowledged, for example, third parties (profit or nonprofit organizations) engaged in specific recirculation activities (repairing, re-retailing, refurbishment, etc.). Some of the R-activities may be either consumer-to-consumer, consumer-to-business, or business-to-business activities in the shorter loops. Many of the 3R, 4R, 5R, 6R, etc., descriptions and visualizations do not consider these differences. They are essential because, in all cases, they refer to interactions between different societal actors, each of them dealing with their interpretations, abilities, limitations, and contextual situations.

In our discussion of the ROs, we briefly referred to the second type of product cycle: the Product Concept and Design Life Cycle. Ideas on prevention and prolonging product life through design relate to much older approaches (see Sect. 3.3). In the 1990s, material choices and improving recyclability represented three out of seven elements in the Life Cycle Design Strategies (LiDS) wheel (Brezet & van Heme, 1997; see also Tukker et al., 2001). The same premises can be found in the "Design for Environment" approaches (Ehrenfeld, 1997; Kurk & Eagan, 2008).

As we stated earlier, the idea to "design out waste" is crucial in CE. In the articles analyzed, we saw that the authors used different ideas to denote ROs as part of products' (re-)design. Notably, "refuse," "reduce," and "re-purpose" represent different ideas in different contributions. Mapping CE options as industrial design activity requires a perspective where all the RO steps are considered long before a product is mass-produced. This distinctive life cycle aims at prevention and starts with the design process, resulting in a realization of the design, which entails all the ROs in Fig. 3.3. Design is also aimed at long-lasting economic lifespan and the most effective, repeated production and sale of a successful product concept. Industrial design scholars vary in their design process descriptions, but it commonly includes design task definition: function analysis and module structure configuration – material selection and part design – preliminary evaluation (Xing & Luong, 2009).

The various steps in literature can be summarized as five core activities in the Product Concept and Design Life Cycle to which the different ROs can be attached: (1). policy (strategy formulation), (2). idea generation (using creativity), (3). the strict designing (see steps given above by Xing et al., 2003), (4). realization (which is the timespan of producing the product), and (5). evaluation and reconsideration. The last two steps directly link to the Product Produce and Use Life Cycle, as shown in Fig. 3.1. In Fig. 3.2, we linked R2 and R6 to design conceptual ideas; the other ROs are traditionally related to strict designing in literature; for example, Design for Remanufacturing relates to R5. The Product Concept and Design Life Cycle can hence be mapped on top of the first figure, as shown in Fig. 3.3, taking the role of (re-)designers in the lifespan of a product concept as the focus.

Taking insights on the ROs together, it becomes clear that we need to think about two related life cycles, the Product Produce and Use Life Cycle (Fig. 3.2) and the Product Concept and Design Life Cycle (Fig. 3.3). Previous life cycles are a fundamental insight that a particular author group has so far only stressed within reverse logistics/closed-loop supply Chain (RL/CLSC; see Kuik et al., 2011; Nagalingam et al., 2013).

Another essential consideration we point to regards agency and ownership. Most scholars lack attention to the role of consumers in refusing, reducing, and consumer-to-consumer arrangements for reselling goods. Although firms remain the central actor in our visualization, the connection to government, consumers, and other parties for a functioning CE system becomes more explicit. We also show that even a more circular economy will have low-value life extension and leakages, affecting developing countries.

Finally, within our typology, we focused on neglected or under-addressed ROs through the inclusion of “refuse” and “re-mine” among the ROs. “Refuse” is critical to include because prevention is always more desirable than minimizing. Overall, merging “stocks and flows” perspectives as known from IE visualizations and complementing it with established ideas of value retention of goods and materials found in RL/CLSC, CP, and the design and waste management literature result in a completer and more systemic picture of ROs in CE.

## 3.6 Conclusion and Reflection

Our review of the historical evolution and controversies on the value retention imperatives (ROs) shows that conceptualizing what circular economy constitutes is still ongoing. Since the first publication of our review presenting the CE history in three phases (see Table 3.1), we have built on this work and further characterized CE 3.0.

Also, other scholars have used our work to distinguish CE phases (e.g., Kristensen & Mosgaard, 2020; Morseletto, 2020; Ngan et al., 2019) and apply the 10Rs for their research. For example, Finnish researchers used it to map how young adults perceive the circular economy (Korsunova et al., 2021). Scholars from the northeast of Europe applied the framework to analyze the integration of circular economy into environmental reporting practices in EU manufacturing companies (Dagiliene et al., 2020).

Building on our constitutive work, we have further explored the more extensive societal debate, where we see different framings of what the CE 3.0 entails, ranging from more “reformist” to more “transformist” approaches. The work of Calisto Friant et al. (2021) proposes a two-by-two typology discussing four different schools of thought in more detail. It distinguishes reformist CE, transformational CE, technocratic CE, and fortress CE. The reformist Circular Society discourses argue that the current system can be deeply reformed towards circularity, and using social and economic innovation can lead to a sufficient level of eco-economic decoupling, preventing a widespread ecological collapse. The transformational CE discourse expects a general economic downscaling and philosophy of sufficiency leading to shorter, slower, and more meaningful lives. Local production is primarily emphasized through cooperative and collaborative economic structures, agroecological techniques, and open-source innovations and technologies. The technocratic CE proposes an era of green growth and technological advancements that increase prosperity levels while reducing humanity’s ecological footprint. Lastly, the fortress CE advances a future vision where scarce resources, overpopulation, and biophysical limits require strong, cohesive measures. Hence, the discourses suggest sufficiency, population controls, or resource efficiency imposed top-down can rationally confront global scarcity and limits, showing that current discourses pay insufficient attention to wealth distribution and social justice questions.

Which type will come to characterize the CE 3.0 retrospectively? Arguably, the choice of specific framings by policymakers, businesses, and other societal actors will impact the potential that circular economy carries as a concept in moving forward the more significant sustainability debate. So far, the EU circular economy policy has been characterized as technocratic CE (Calisto Friant et al., 2021). In practice, recycling and incineration, lower forms of value retention of materials, still dominate policies and practice. Further, tools for measurement and validation of CE impacts are still under-developed, and the absence of such demonstration effects, in turn, makes long rendered wider uptake of more disruptive circular economy solutions and business models unattractive. Data on higher-ranking ROs is still hardly systematically collected by business and private actors to date, and public datasets likewise often provide reliable data mainly on "recollection and recycling rates" rather than product reuse rates and other ROs, which also further complicates measurement and validation by researchers and other independent parties.

Our analyses conclude that policymakers and businesses should focus their efforts on realizing the more desirable, shorter loop retention options, like remanufacturing, refurbishing, and repurposing – yet with a view on feasibility and overall system effects. On the other hand, scholars should assist business and policy actors in contributing to an increased circular economy in practice by taking up a more active role in attaining consensus in conceptualizing the circular economy. We have tried to publish our historical analysis and 10R typology in various popular magazines (e.g., Reike et al., 2018a, b; Reike & Bosch, 2017; Vermeulen et al., 2019).

A continuously growing number of companies and public organizations have more recently demonstrated that applying higher-ranking R-strategies is possible and profitable (see Chap. 4). It should be critically noted that measurement of real "net effects" (Korhonen et al., 2018) of circular solutions remains a severe issue, and impact measurement is generally lagging behind the application of higher-ranking R-options. More recently, studies and measurement tools allowing for more accurate tracking, assessing, and monitoring of the circular solutions applied in the CE 3.0 are being developed with great zeal by public and private actors (see Chap. 4).

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# Chapter 4
# Working with the New Conceptualization of Circular Economy 3.0: Illustrating the Ten Value Retention Options

**Denise Reike, Walter J. V. Vermeulen, and Sjors Witjes**

## 4.1 Introduction

In providing descriptions and illustrative videos, we demonstrate in Sect. 4.2 that individual businesses successfully apply various retention options in their portfolio – even simultaneously. While start-ups tend to enter the market with more disruptive business models, in various sectors also incumbents experiment with circular business models, inspiring other prominent players to follow their examples and thereby support broader dynamics for industry transformation. The latter can be seen particularly from recent examples in the fashion and clothing sector (Sect. 4.2).

In Sect. 4.3, we show how the 10R framework has been applied in policy development and evaluation, and how it can be used for monitoring the implementation of circular economy at various levels (national, regional, and organizational). In the Netherlands, an active circular economy policy push has fostered implementation since the mid-2010s, starting with public procurement objectives. These evolved from voluntary initiatives into challenging policy targets which are arguably among the most ambitious worldwide – the Dutch government aims to move towards the reduction and even phasing out of primary raw material inputs altogether (described in the Dutch policy as a 50% reduction in the use of primary raw material by 2030

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and 100% circularity by 2050) (Ministerie van Infrastructuur en Waterstaat, 2020). Dutch policies also focus on enabling research on the transformation of sectors for circular operation and the realization of pilot projects in the market (Ministerie van Infrastructuur en Waterstaat, 2020; PBL, 2021) which has supported the emergence of a wide variety of innovation practices, some of which are discussed in this chapter.

## 4.2 Applying the 10Rs in Market Contexts

This section illustrates the *value retention options* (ROs) with various examples from sectors in and around the Netherlands. They often go beyond just one option, as single companies and public actors may apply a set of ROs in combination. Taking a sector perspective, we seek to illustrate mutual responses of companies to each other's initiatives and front-running actions by start-up companies and incumbents. We added a video link to many of the examples described here to fuel the imagination. When arriving at these unique elements, the reader is invited to leave the pages of the book for a moment, for gaining additional insights as a viewer, into the circular processes that we can only summarize rather briefly in the text (see also the recommendations how to display videos in multiple languages, at the end of the chapter).

Many of the RO illustrations are changes in the product's composition, materials used, or the way products are presented. The ROs include examples of "product services systems" (PSS), where consumers do not buy the product but lease them and/or only pay per use. For more details about "product services systems" see Tukker (2015) or Kjaer et al. (2019). Notably, such PSS approaches are also frequently linked to the "sharing economy" (see for more details Hobson and Lynch (2016)).

The notion of "market" applied in this chapter includes commercial businesses and the government as a buyer. In the European Union, government purchases make up about 16% of total GDP, enabling governments to act as crucial launching customers for innovative products and services, such as provided in the circular economy, This can play a crucial role during the first phases when market penetration is yet too low for enabling upscaling through regular demand-supply market dynamics (Aschhoff and Sofka, 2009). Specifically, in the context of upscaling sustainability, the Netherlands and many other countries re-structured the order and steps of their procurement process into an open and more collaborative innovation process (Witjes & Lozano, 2016), which national, regional, and local authorities can apply.

In this supportive environment, many initiatives for the circular economy have emerged in almost every section of the market. Below, we discuss the developments in three different sectors, not intending to present a complete or representative picture but rather to demonstrate how the 10R framework can be applied in practice.

### 4.2.1 Illustrations in the Mobility Sector

The capital intensity of final goods in the mobility sector is generally relatively high for some mobility modes. In sub-segments, where the capital intensity of producing and using the final product is immense, for example for train manufacturers and service providers, these products are traditionally used for long periods. This is typically the context in which refurbishment takes place. The Dutch railway company *NS* has a special workshop called “Haarlem Train Modernisation Workshop” where 15–20-year-old trains are stripped and given a completely new and more modern interior and external painting. The refurbished train is an upgraded version, with higher service standards than the original train. In the process of modernization, 65% of the materials are recycled. The modernized trains are expected to be used for another 15–20 years. Such refurbishment is cheaper and faster than buying new trains. The company also runs the “Tilburg Component Factory” for its more regular maintenance, where components get renewed and stored. In this way, the Dutch railway company NS systematically combines *R3 Repair* with *R4 Refurbish* (NS, 2020; van Dongen, 2017)[1].

Another interesting and inspiring case is the aircraft recycling company *AELS*. Aircrafts are used even longer than trains, their end-of-life is often reached after up to 30 years. AELS stands for “aircraft end-of-life solutions” and has operated since 2006 at Twente Airport in the Netherlands (AELS, 2020). The company buys aircrafts at their end-of-life, disassembles them, stores all components that can still be re-used, and sells them for urgent repairs, including speed delivery all over the world. They offer over 10,000 different parts of Boeings 737, 747, and 757 and Airbus A320, A330, and A340. All come with 6–12 months’ warranty, and the history of previous use is carefully registered (this is a standard procedure in the airline industry). This is an alternative model to the many aircraft graveyards around the world. Selling aircraft components to be used in existing aircraft is their primary business model, but anything still usable is also sold for individual repurposing by interested customers in online auctions.[2] In this way, old cockpits are used as flight simulators. seats become pub or home interior, and life jackets become fashion items. Finally, the central aluminum structure of a plane is sold for recycling. In this way, AELS combines *R2 Resell/re-use* with *R6 Repurpose* and *R7 Recycling of materials* systematically.

Such examples complement the recycling strategies implemented during the circular economy 2.0 (see Chap. 3), which primarily relied on the instrument of *extended producer responsibility* (EPR). EPR applies for passenger cars but also to car components like tires. Under Dutch and European legislation, producers, importers, and retailers of these products are responsible for maximizing their recycling

[1] Watch this video (Video <InternalRef RefID=”MOESM1” >4.1) for a detailed overview of the disassembly and refurbishment process at NS.

[2] Watch this video (Video <InternalRef RefID=”MOESM2” >4.2) to learn how AELS dismantles the aircraft, separates parts, and applies the various R-strategies.

after the use phase. They can choose to organize this either individually or collectively. In passenger cars, the producer responsibility organization (PRO) *Autorecycling Nederland (ARN)*, operating since 1995, has achieved collection rates of 98.5% in 2019, of which 87.2% is *R7 Recycling of materials* and 11.2% is *R8 Energy recovery.* The costs for this are covered by the market actors, approximately € 160 per car (ARN, 2019).

A comparable PRO for car tires, *RecycBEM*, even reported a 100% collection rate leaving 0% for landfilling and incineration. Thanks to EPR, process optimization takes place, and costs are meager at €1.30 per tire and are covered by producers. A recent evaluation of this, applying the 10R approach, showed that the current regulations only generally describe the targets as any form of "recycling" and "energy recovery," not specifying the 10R options. This can be viewed as a clear shortcoming of the EPR instrument. In practice, the majority of "recycling" has been *R7 Recycling of materials* (~65–70%), mainly in the form of granulate fillings for artificial sport and playing fields. Such re-usage of tires has been shown in studies to cause adverse health and ecological issues, yet governments act upon this in different ways (see Dürkop et al. 2001, Campbell-Johnston et al., 2020a). The share of *R8 Energy recovery* decreased from ~20% to ~5% (in the form of pyrolysis), while the *R2 Resell/re-use* option grew from ~15% to 30% over time recently. However, this last option partly includes export to countries with weaker recycling policies than Europe. The exports to African countries after multiple use phases remain common practice (Campbell-Johnston et al., 2020a).

The Netherlands also seeks to foster mobility as a service (MAAS) and sharing services for mobility that contribute to the circular economy (KiM, 2020; Zijlstra & Durant, 2019). A user gains temporary access to mobility through MAAS platforms and contracts which are typically based on access fees and subscriptions or a pay-per-ride model instead of ownership. These services are not new in the circular economy, yet, the diversity in the available modes of transportation, using software for advanced customization, and in particular advertising the environmental efficiency of the service (infra) structure, as a value proposition in the business model, is arguably a more recent phenomenon. When the latter is included, MAAS can be viewed as an example of *R2 Resell/re-use*, in line with the definition of this retention option as including multiple successive or simultaneous uses of a good.

Dutch start-ups have been successful in offering consumers direct mobility services or in linking consumers, offering each other access to mobility (C2C)[3] via platform technologies. *Green Wheels* is a business-to-consumer (B2C)[3] car-sharing company that applies *R2 Resell/re-use* and has tied environmental objectives to its service offering and actively advertises the reduced impacts attained by its users (*R1 Reduce*) (Goudappel Coffeng, 2019). The Dutch company *SnappCar*[4] started from the founders' idea to lend out their private cars during idle time, and it has become one of the leading peer-to-peer sharing platforms in Europe (The Guardian, 2017; Snappcar Blog, 2016).

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[3] (C2C) = consumer-to-consumer; (B2C) = business-to-consumer

[4] Watch this video (Video <InternalRef RefID="MOESM3" >4.3) to see how offering one's car on SnappCar works for car owners.

Looking at the Dutch number one form of mobility, biking, *Swapfiets* has captured a large part of the bike rental market (*R2 Resell/re-use*). With its distinctive design is particularly famous among students (AD, 2019; marketing facts, 2018). The company offers *R3 Repair* services, and as indicated by the term "swap," the user receives another bike during repair time. With illegal re-use (stealing) of bikes being one of the leading crimes in the country, insurance is an additional service highly valued by customers, yet it has also turned out as a considerable threat for the business model operators (CCV, 2021; Fietsersbond, 2019). For shorter-term rental, most consumers continue to use *OV-fiets*. This bike rental service is easily coupled to the available train card used by all Dutch citizens across the country and offer efficient and effortless access (NS, 2019). These commonly shared bikes have a lifetime of about 4 years. Together with ***Roetz-Bikes***, the operator (*NS*) developed the "OV-fiets Recycle" – despite the name it includes more than only *R7 Recycling of materials*, as 70% of OV-materials are given a second life as part of a new OV bike in applying various R-strategies (*R2 Resell/re-use*, *R3 Repair*, *R4 Refurbish, R5 Remanufacture*) by people with a distance to the labor market.[5]

Together with other countries, like Sweden and Denmark, the Netherlands has been leading Europe in the development cargo bikes and other electric cargo vehicles ("stints") as a new model for last-mile delivery in cities.[6] The cargo fleets use an entirely new vehicle design (see Rs of the "concept and design cycle") and are meant to couple health benefits for the driver with public benefits through reduced delivery truck emissions in inner cities (*R1 Reduce*). Eventually, this new mode of transportation may replace trucks in cities, entirely contributing to *R0 Refuse*. However, initially "famed" offerings, such as the *Stint*,[7] which combines a Segway and a hand wagon design, were temporarily banned from the market through the Dutch government, as they fell short of basic security features (Holland Times, 2019).[8] Increasingly, innovative companies enter the market with improved designs and expanded services, such as *FoodLogica*[9] which is a fully electric logistic company focusing on refrigerated last mile solutions for food producers and brands (Foodlogica, 2021). *Urban Arrow* is a company that focuses on the consumer market and developed an intelligent, multipurpose designed bike to make a single bike's user phase as long as possible through expanded functionality (*R2 resell/re-use*).[10] The latter cargo bikes come with different mountings and can hence be re-designed to switch from carrying persons, e.g. several children to carrying a pet or groceries (Urbanarrow, 2021).

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5 Watch this video (Video <InternalRef RefID="MOESM4" >4.4) to learn about the design and the different R-strategies applied by the "OV Recycle" program.

6 Watch this video (Video <InternalRef RefID="MOESM5" >4.5) on the International Cargo Bike Festival in Groningen (2019).

7 Watch this video (Video <InternalRef RefID="MOESM6" >4.6) to hear challenges of the Stint founders in maintaining the company and redesigning Stint in response to a tragic accident with small children.

8 See van Dongen (2017).

9 Watch this video (Video <InternalRef RefID="MOESM7" >4.7) to see what a day tour for Foodlogica employees looks like.

10 Watch this video (Video <InternalRef RefID="MOESM8" >4.8) to learn about design (security and health supporting features) and use of the Urban Arrow.

The illustrations described so far are all private business initiatives and not yet including the *R0 Refuse* option. This option is still frequently regarded as business cannibalization as it can imply lower income. However, there are joint government and business initiatives promoting *R0 Refuse*, where this serves both parties' interests. One such Dutch joint initiative is the promotion of reduced individual car use. To this end, the Dutch government collaborated with employers' organizations, addressing the commuting behavior of employees by public and company campaigns. An evaluation of this program showed that this resulted in a daily reduction of 80,000 cars used during the rush hours, of which 74% is attained by having employees work from home or change to cycling, public transport (Ministerie van Infrastructuur en Waterstaat, 2018).

### *4.2.2 Examples in the Clothing Sector*

The clothing *sector* is characterized by short user phases and affluent buying behavior for clothes in the more prosperous world as practice of unsustainable lifestyles. Impacts from producing garments are disproportionately high for their short lifecycle. Globally, in 2014, 60% more garments were bought compared to 2000, while consumers kept the clothes for only half as long (WEF, 2021). The World Economic Forum (WEF) estimates that 85% of clothes retain no second life and are dumped (ibid). The sector is also responsible for an estimated 10% of global carbon emissions (ibid). The Netherlands is generally considered a front-runner in textile recycling (*CoR*, 2020), and this includes many start-ups offering an alternative to the incumbent fast fashion multinationals.

One such start-up practicing *R2 Resell/re-use* is *United Wardrobe*,[11] founded in 2014 by two students, creating an online platform for consumers selling their used or dispensable clothes to other consumers. In 5 years, they grew to four million users and are also active in Belgium, France, and Germany (RetailDetail EU, 2020). The platform ensures safe exchange between seller and buyer and payment via the website. Its business model is based on 10% seller's fee and a buyer's administrative fee (United Wardrobe, 2020). Others noticed the success, and in October 2020, it was taken over by *Vinted*, founded in Vilnius, Lithuania, in 2008. *Vinted* is now the largest online marketplace for second-hand fashion goods in Europe, creating a community of sellers and buyers of 34 million people in 11 European countries (RetailDetail EU, 2020).

In response to these bottom-up initiatives, large fashion companies also started to enable circular solutions. *R2 Resell*, *R3 Repair*, *R5 Remanufacture*. Linking to the *R2 Resell/re-use* examples, the German online fashion shop *Zalando*, which ranks third in terms of market share in the Netherlands and was initially only selling

[11] Watch this video (Video <InternalRef RefID="MOESM9" >4.9) to see how United Wardrobe works and how the company was created.

new clothes, also started selling second-hand clothes and enabling customers to sell items still of good quality in exchange for vouchers or philanthropic gifts (Zalando, 2020). Customer returns from online shops are also a growing issue, some companies are selling these returns as second hand. Amsterdam-based Tommy Hilfiger, for example, started "Tommy for Life," which offers clothes from the application of various R strategies simultaneously: recommerce of second-hand clothing handed in by consumers and of unsold and restored clothing items from stationary shops, and renewed sale of e-commerce returns or products that could no longer be repaired, but are now part of new designs (FashionUnited, 2020). *They use marketing concepts like "Reloved," "Refreshed," and "Remixed," respectively, to exemplify R2 ResellR2 Resell, R3 RepairR3 Repair, and R5 Remanufacture.R5 Remanufacture.*

With this strategy, Tommy Hilfiger is not the first in the market with a business model combining several RO. They copy a well-known and celebrated example set by *Patagonia*, which launched their circular business model in an advertisement on the day before the "consumerism holiday" Black Friday, as early as 2011, with bold headings: "DON'T BUY THIS JACKET." They promote *R1 Reduce* by stressing that their products are designed to last longer, *R2 Resell/re-use* suggesting customers to sell their second hands on eBay, *R3 Repair* promoting customers to repair if damaged, and *R7 Recycle* with their take-back system and selling products made of 100% recycled materials (Patagonia, 2011). Later, they developed an online brand for returning, repairing, and (re)selling second-hand Patagonia products (*Worn Wear*) in the USA and Europe.

Conscious consumption aiming for *R0 Refuse* and *R1 Reduce* lies at the heart of many successful start-ups in the Netherlands and elsewhere in Europe. Its founders describe the company *Asket* in Sweden[12] as immune to the biggest drivers of both business risk, overconsumption, and overproduction in the clothing sector by refraining entirely from seasonal collections and limited offerings, focusing instead on a single permanent collection of timeless items (Bard Bringéus 2019). In the Netherlands, various start-ups collaborate with researchers for a different endeavor of permanence – not only related to clothing design but to virgin material supply. *Neffa* is a Utrecht-based award-winning start-up working on MycoTEX, a seamless production technology to create clothes made from mycelium (mushroom roots) (Neffa, 2021). Mycelium needs to be combined with base material yarns for obtaining high-quality clothes, but it offers high potential as it can be grown anywhere globally, at low cost, and without impacts on land use. Further, it reduces the cost, waste, and labor intensity of cut and sew operations during the production process, and it could potentially contribute to replacing polymers and leathers used for clothing (ibid).[13]

[12] Watch this video (Video <InternalRef RefID="MOESM10" >4.10) of the Asket t-shirt including the vision of its founders and the t-shirt design challenges.

[13] Watch this video (Video <InternalRef RefID="MOESM11" >4.11) for a documentary about growing mycelium and its potential uses and experiments of Neffa.

The fashion industry is also a breeding ground for PSS business model examples, forms of *R2 Resell/re-use* and *R1 Reduce*. *MUD Jeans* offers jeans, partly made with recycled denim, as a service, with a year's contract, after which the consumer returns the jeans. Throughout the year, repairing is offered if needed (MudJeans, 2021a). After use, the denim is mechanically recycled into new denim fibers for *MUD Jeans* at *Recovertex* in Spain through mechanical fiber-to-fiber recycling – to date this process includes adding virgin organic cotton material[14] (Mud Jeans, 2021b).

Platforms and shops renting baby and maternity clothes form one of the more successful PSS in the Netherlands and can be considered an *R2 Resell/re-use* subcategory. At shops like *Hulaaloop*,[15] *Circos*, and *Bieby*, customers can select sustainable baby clothes from different quality/price categories. Customers pay a minimum amount per rented item or item package and additionally a fee for the rental period, often decreasing costs for increased rental periods (Hulaaloop, 2021; Circos, 2021, Bieby, 2021). Other models include fixed 'exchange rates' which makes the predictability of the return flow higher for the PSS offeror. Return models vary; typically, rented clothes are brought back to a local shop or collection point, shipped by post, or recollected by the rental service provider (Hulaaloop, 2021, Circos, 2021).

Successful PSSs have also evolved around the rental of luxury clothing items as another category of clothes where customers find temporal access instead of ownership attractive. So far, Dutch platforms offering access to luxury designer brand items like *Spinning Closet* and *WauW Closet* focus exclusively on female customers. Luxury PSSs are usually distinct from other rental models in allowing only short rental periods, and including high fees for delayed or failed returns. While some offer subscription services for a regular overturn of items, others use pay-per-use and pay-per-item models (Wauw Closet, 2021; Quotenet, 2020).

Next to increasing offers of PSS, fashion libraries are a growing niche in the Netherlands. These arguably carry a much higher potential for positive environmental impact (*R1 Reduce*), but the economic viability of these local *R2 Resell/re-use* entities is typically lower. *LENA the fashion library* (2021) is a shop focused on selling and renting (new) clothes by upcoming designers and sustainable brands in addition to vintage items.[16] In contrast, the *Outfit Library LESS* (2021) focuses mainly on selling, renting (subscription model with fixed price), and repairing second-hand/vintage clothes and accessories. Lastly, The Hague-based *Bij Priester* (2021) shows the viability of combining the use of various R-options for small enterprises (SMEs); this SME is simultaneously a fashion library, a shop, a learning center for clothes and leatherware repair and refurbishing, and a provider of jewelry

[14] Watch this video (Video <InternalRef RefID=”MOESM12” >4.12) to see how old MUD Jeans are turned into a new fabric in the mechanical recycling process.

[15] Watch this video (https://biteable.com/watch/embed/hulaaloop-pitch-kleding-die-met-je-kleintje-meeg-1542403) for an impression of the offerings of maternity clothes rental services like Hulaaloop.

[16] Watch this video (Video <InternalRef RefID=”MOESM13” >4.13) to see how rental at LENA library rental works and how they support other clothing libraries.

and accessories remanufacturing, thus exemplifying *R2 Resell, R3 Repair*, *R4 Refurbish*, and *R5 Remanufacture*.

Using the medium to long-loop strategies, *R7 Recycle* takes a vital role in the textile sector. *R7 Recycle* occupies, in general, a low position in the hierarchy of R-strategies, as it predominately stands for "downcycling" of products and materials. However, innovative clothing recycling strategies (mechanical and chemical recycling) can form an essential bridge between end-of-life value recovery in the product "*produce and use" lifecycle* and designing a new product in the "*concept and design" lifecycle*. There are a handful of highly innovative companies that can recycle worn post-consumer textiles into new garments with minimal to no virgin material inputs (*R0 Refuse*).

A unique example of *R0 Refuse* combined with *R7 Recycle* is the chemical recycling company *SaXcell*, a spin-off from Saxion University. Most chemical recycling companies use wood pulp or other virgin material in conjunction with recycled fibers for making new fibers with sufficient quality for clothing. SaXcell[17] developed a patented technology whereby cellulose fibers are recovered from high cotton content post-consumer textiles and converted into new fibers, replacing the need for virgin material (SaxCell 2021, see also "Worn Again" (2021), a similarly innovative UK start-up building the first chemical recycling plant in the Netherlands with a focus on polyester rather than cotton).

A Dutch SME focused on refusing virgin material (*R0 Refuse*) through mechanical recycling is *Blue Loop Originals*.[18] Together with researchers and manufacturers, they developed a method for post-consumer denim recycling into new yarn for denim. Yarn spinning from recycled fibers happens in Italy, and all other steps in the Netherlands, e.g., shredding old jeans at their end-of life and designing and weaving new jeans (Outdoorbrands, 2021). While both companies contribute to absolute resource use reduction, there are more limits to optimising mechanical recycling as 'repurposing' materials other than for orginal use (clothing) or adding high volumes of virgin material eventually becomes necessary for a consecutive recycling and reuse loop. Chemical recycling, however, is only environmentally and economically viable when applied at much larger scale.

The Dutch government actively supports the move towards shorter loop re-use and recycling practices with a transition agenda "Circular Textiles" and a set of subsidies. In the RegioDeal (Regional Deal) "Circulair Textiel" in Twente, national, regional, and local government and local businesses have combined investment of 11 million euros in order to foster the transition towards more circular textiles – similar regional programs exist for three other Dutch regions (Board Twente, 2021). Within the Twente Circular Textiles Programme led by the nonprofit Stichting TexPlus, "triple helix" partners (government, universities, and industry) cooperate in order to attain a commercially viable closed-loop system wherein collected

[17] Watch this video (Video <InternalRef RefID="MOESM14" >4.14) for insights into SaXcell's chemical recycling process and facts on clothing impacts.

[18] Watch this video (Video <InternalRef RefID="MOESM15" >4.15) to see the mechanical recycling process from denim to fabric at Blue Loop Originals.

post-consumer textiles are turned into new clothing with ultimately no virgin input (*R0 Refuse*) (CoR, 2020). Partnering organizations (e.g., collectors, sorters, mechanical and chemical recyclers, fabric producers) are spread across the region, yet together form one closed-loop supply chain realizing various R-strategies to date and making one partner's outputs another's inputs. The interdependence built into this system warrants constant high coordination among the partners and has earned the project a place among the 200 best transition practices honored by the EU Committee of the Regions (2020) (Mahy & Janssen, 2020).

As another striking initiative, the rollout of a nationwide program for setting up "craft centers" for circular textiles tied to local recycling facilities, is underway 2020–2025 (Rijksoverheid, 2020). Worn textiles arriving at the municipal recycling facility[19] are first checked and selected by shop owners for direct re-commerce at local (nonprofit) second-hand shops (*R2 Resell/re-use*). Another part goes to craft shops that repair, "remanufacture" (i.e., re-sew, re-cut, and customize anew) and refurbish (e.g., upgrade with the incorporation of new fiber, fabrics) clothes, or repurpose them (e.g., using fabrics as a padded cover for a chair). (*R3-R6*). A final proportion of clothes is intended for mechanical and chemical recycling into new clothes, with only a small proportion being traditionally recycled, i.e., for using the textile material anew with a lower value purpose (e.g., insulation).[20] In this initiative, shops are locally tied together avoiding environmental impacts from transport. Moreover, the hierarchical principle implied by the 10Rs in the RO framework that can guide the implementation of circular solutions is thoroughly respected.

### *4.2.3 Examples in the Electronics Sector*

The electronics sector attracts much attention in the context of the circular economy. On the one hand, there is a growing use of the wide variety of electronic devices, partly with short life spans, contributing to growing sustainability impacts. On the other hand, the sector has been affected by detailed regulation, resulting in many sustainability initiatives in the last two decades (Evans and Vermeulen, 2021), many of which aim at recycling and circularity. Based on European regulations, the sector is also one of the few where EPR applies, this means the financial and logistic responsibility for collection and recycling, lies with the producers (Ongondo, Williams, and Cherrett, 2011). In the Netherlands, this has resulted in collection of 58% post-consumer electronics in 2018 and 2019. From the collected e-waste, 96% is processed for recycling, among this 15% is incinerated for energy recovery. In this way, 65% of the collected electronic equipment is recycled (*R7 Recycle*).

[19] In the Netherlands all municipalities have drop-off points where recyclable items of all kinds can be handed in, including clothes. Sorting takes place using long conveyor belts; see a video of the general process at footnote 21.

[20] Watch this video (Video <InternalRef RefID="MOESM16" >4.16) to see how Ambachtscentra works and how former waste is repurposed for a second lifecycle.

For comparison: washing machines are recycled to 77% and refrigerators to 92%.[21] The 42% of e-waste, which is not separately collected but disposed of via the general household waste, is either incinerated or exported abroad (National (W)EEE Register, 2020).

Next to this collective approach in the electronics sector, we also see increased engagement with circular solutions by individual companies. There is experimentation with circular business models, especially PSS for household equipment (e.g., washing machines, kitchen equipment). Multiple providers exist and compete, including start-ups promoting sustainable alternatives, such as choices for second-hand or refurbished electronic equipment[22] offering pay-per-use. Some of the examples are closely linked to retailers or producers, like *Bosch*,[23] and are presented as a more conscious consumer choice: "Recycle, refurb, reuse: do good for the environment, we recycle your old machine, and give it a second life. Do away your energy eaters".[24] However, in this case, the adherence to circularity principles in re-use and recycling is arranged anyhow through the sector-wide EPR extended producer responsibility instrument. While this type of corporate initiative can be understood as misleading, the Dutch consumer association Consumentenbond also warns consumers to be careful and be critical before accepting these initiatives because of the higher costs (Consumentenbond, 2021).

In response to the sector-wide initiatives, the mobile phone sector in the Netherlands has shown several attempts to contribute to enhanced circularity. Linking to *R0 Refuse* and *R1 Reduce* examples, *Fairphone*, an Amsterdam-based mobile phone assembler, has optimized the supply chain of the phones they deliver, aiming to use conflict-free precious metals and, therefore, reduce use of conflict materials.[25] *R1 Reduce* examples can also be found in the supplier code of conduct of Dutch service provider *KPN*: as a mechanism to contribute to their overall sustainability vision, *KPN* requires suppliers of mobile phones to "reduce the use of (virgin) raw materials and resources." The mobile phone's sales on the national second-hand online buyer market website *Marktplaats* can be linked to *R2 Resell/re-use*: private owners of mobile phones try to find a following buyer/user for their phone.

Regarding *R3 Repair* examples, *Fairphone* phones are designed on a modular base enabling easier repair and more extended use of the phones: *Fairphone* batteries and cameras can be easily replaced by newer versions enabling owners to expand use time. The Netherlands has at many places mobile phone repair shops in different

21 Watch this video (Video <InternalRef RefID=”MOESM17” >4.17) for an in-depth outline of material separation and electronic equipment recycling.

22 For more information on second-hand or refurbished electronic equipment: www.bundles.nl or https://www.homiepayperuse.com

23 For more information on Blue Movement of Bosch: https://www.bluemovement.com/nl-en/about-us

24 More information can be found on their website: https://www.bluemovement.nl/hoe-werkt-het

25 Watch this video (Video <InternalRef RefID=”MOESM18” >4.18) for Fairphone's quest for conflict-free mobile phones.

organizational settings offering the repair of several parts of mobile phone parts. Besides the brand-linked repair possibilities linked to product guarantee, electronic stores also offer screen reparation, battery renewal, etc. (see, e.g., *Saturn* or *MediaMarkt*). Several smaller nationwide or local shops enable mobile phone users to extend the life of their mobile phones by a variety of reparation options. An example of *R3 Repair* are also initiatives for consumers entirely focusing on repairing mobile phones through Do-It-Yourself. One of these is *iFixit*,[26] operating online and in many languages. They and support, with user guidelines, repair sets, and they conduct lobbying for easier repair. In this, they cooperate with some of the PSS offering companies mentioned earlier, even across sectors (like *Patagonia*).

As another trend over the last few years, the Netherlands has seen attempts of developing business models aiming for re-selling (*R2 Resell/re-use*) almost-new mobile phones combined with *R4 Refurbish*. For example, *LEAPP* buys Apple products displayed in the Apple Stores and upgrades the batteries and other necessary product parts to sell the products at several quality levels, finally at a lower price than the original 100% new Apple products.[27] Originally, *LEAPP* started with physical stores, yet they have entirely moved towards online business. The offerings of mobile phone manufacturers, like Apple and Samsung[28] to trade in old phones for reducing the price of a new phone, can be seen as another example aimed at *R5 Remanufacturing* as both brands state to use parts and materials of old phones for the production of new phones.

The above mentioned Dutch companies are taking the described actions as part of a corporate strategy to contribute to a more circular economy, which in some cases leads to motivating actors in the supply chain and sector or market to do the same. For example, *KPN* signed the *KPN* Circular Manifest in 2017, together with supply partners like *Nokia*, *Cisco*, *Huawei*, etc., joining forces to attain 100% re-useable and recyclable parts and resources by 2025.[29] The waste separation company *DAR* was one of the initiators of a regional initiative targeting enhanced circularity in the electronics sector. After having sorted three million kilos of electronics waste, *DAR*, with a subsidy from the province of Gelderland, started an electronics hub. Here, electronic equipment 1. handed in as waste is 2. checked for the possibility of a second life; when possible, 3. the equipment is refurbished or remanufactured, and 4. brought back to the market. *DAR*'s own logistics and infrastructure is used for collecting the electronics. The checks occur in collaboration with *Road2Work*, an organization that helps people with a distance to the labor market. The refurbishment and remanufacturing of electronics is organized in collaboration with *Wecycle*, an organization that manages recycling activities for major electronic brands (set up to comply with extended producer responsibility

[26] More information can be found on their website: https://nl.ifixit.com/Info/index

[27] Watch this video (Video <InternalRef RefID="MOESM19" >4.19) to see the business case of LEAPP.

[28] Watch this video (Video <InternalRef RefID="MOESM20" >4.20) to see the take-back system of Samsung.

[29] See this link to download the Circular Manifest

regulations). Finally, collaboration with second-hand shops and regular retail stores brings back electronics to the market. For upscaling knowledge and experience on the circularity of electronic equipment, the *Electronics Hub* aims to connect to significant electronics Dutch sales platforms like *Coolblue* and *Bol.com* and with the product development departments of electronic producers.[30]

### *4.2.4 Overview of the 10R Application per Sector*

The previous sections presented circular economy approaches specifically for the Dutch mobility, fashion, and electronics sectors. As shown in Table 4.1, different ROs are applied in each of these three sectors, with *R1 Reduce* and *R2 Resell/re-use* among the most commonly applied options. Similar examples can likely be found in other (European) countries. As indicated, it is interesting to observe the interactive dynamics between start-ups and incumbent firms initiating circular initiatives. In some sectors, through voluntary or legally required action, front-running and resourceful incumbents drive changes towards circular practices (e.g., electronics). In contrast, in other sectors, start-ups and their innovative approaches influence incumbents to follow suit (e.g., clothing).

Moreover, Table 4.1 outlines that it seems to make sense for companies to apply a mix of ROs, rather than focusing on a single strategy. In some cases, companies address almost all options. However, companies tend to focus on the retention options of the "*product and use lifecycle*," and only a few begin their search for circularity with the "*concept and design lifecycle*" by engaging in re-designing their product with all the supply chain partners for completely closing the loop and replacing all virgin materials used by recycled materials. This also relates to the application of Extended Producer Responsibility. We saw some related activities (for cars, tires, and e-waste) in the examples. In its original intention, making producers responsible for collecting and recycling post-consumer waste would create a strong incentive for eco-design. In practice, this has not worked out this way. In a recent whitepaper[31] for the Dutch government, we designed a revision of this policy instrument (Vermeulen et al., 2021).

In line with this finding, there is little dedication to the R0 Refuse option by producers across sectors, i.e., material substitution and avoiding impacts altogether. We also see relatively few original producers enabling a second lifecycle for a product or even supporting the *R0 Refuse* option. However, all three sectors provide relatively ample examples of products given an entire second lifecycle (in original or modified form). One of the issues here is that ownership of products moves to the buyer in the linear economy, and producers are not in control of the end-of-life

[30] More information on the Electronica Hub of DAR: https://theeconomicboard.com/nieuws/elektronicahub-dar-circulariteit/

[31] Watch this video (Video <InternalRef RefID="MOESM21" >4.21) on our advice for revised EPR.

**Table 4.1** Overview of the 10R application per sector

| Examples | Video available | R0 Refuse | R1 Reduce | R2 Resell/ re-use (incl. rental) | R3 Repair | R4 Refurbish | R5 Remanu-facture | R6 Repurpose | R7 Recycle | R8 Recover energy | R9 Re-mine |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mobility* | | | | | | | | | | | |
| NS | https://www.youtube.com/watch?v=ppxtqDW7joU | | | | √ | √ | | | | | |
| AELS | https://www.youtube.com/watch?v=hV70bX6p7Fo | | | √ | | | | √ | √ | | |
| ARN | | | | | | | | | √ | √ | |
| RecycBEM | | | | | | √ | | | √ | √ | |
| Greenwheels | | | √ | √ | | | | | | | |
| SnappCar | https://www.youtube.com/watch?v=sK3zJwiUq5Y | | √ | √ | | | | | | | |
| Swapfiets | | | √ | √ | √ | | | | | | |
| OV-fiets | | | √ | √ | √ | √ | √ | | √ | | |
| Cargobikes | https://youtu.be/wEbm2otrjoo | | √ | √ | | | | | | | |
| Stint | https://www.youtube.com/watch?v=MuNoTuGc8_0 | | √ | √ | | | | | | | |
| FoodLogica | https://www.youtube.com/watch?v=uSrfAKw9Kiw | | √ | √ | | | | | | | |
| Urban arrow | https://www.youtube.com/watch?v=pye09heBqfY | | √ | √ | | | | | | | |
| Government support: car use reduction programs | | | √ | | | | | | | | |

| Examples | Video available | R0 Refuse | R1 Reduce | R2 Resell/ re-use (incl. rental) | R3 Repair | R4 Refurbish | R5 Remanu- facture | R6 Repurpose | R7 Recycle | R8 Recover energy | R9 Re-mine |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Clothing* | | | | | | | | | | | |
| United Wardrobe/ Vinted | https://youtu.be/ Ar3X9RKT-JI | | | √ | | | | | | | |
| Zalando | | | | √ | | | | | | | |
| Tommy Hilfiger | | | | √ | | | √ | | | | |
| Patagonia | | √ | √ | √ | √ | | | | √ | | |
| Asket | https://youtu.be/ Ar3X9RKT-JI | √ | √ | | | | | | | | |
| Neffa | | √ | √ | | | | | | | | |
| MUD jeans | | √ | | √ | √ | | | | √ | | |
| Hulaaloop/Circos / Bieby | https://biteable.com/watch/ embed/ hulaaloop-pitch-kleding-die-met-je-kleintje-meeg-1542403 | | | √ | | | | | | | |
| The spinning closet/ Wauw closet | | | | √ | | | | | | | |
| LENA the fashion library | https://www.youtube.com/ watch?v=iVYUHHTY-vw | | √ | √ | | | | | | | |
| Outfit library LESS | | | √ | √ | | | | | | | |
| Bij Priester | | | √ | √ | √ | √ | √ | | | | |

(continued)

**Table 4.1** (continued)

| Examples | Video available | R0 Refuse | R1 Reduce | R2 Resell/ re-use (incl. rental) | R3 Repair | R4 Refurbish | R5 Remanu-facture | R6 Repurpose | R7 Recycle | R8 Recover energy | R9 Re-mine |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SaXcell/worn again | https://youtu.be/p4fdhgcfANE | √ | | | | | | | √ | | |
| Blue loop originals | 🎥 https://youtu.be/RblPTsBIH0w | √ | | | | | | | √ | | |
| Government support: circular textile craft center (“Ambachtscentra”) | https://www.youtube.com/watch?v=AZyommgWmOI | √ | √ | √ | √ | | | | √ | | |
| Government support: Twente Circular Textiles Programme | | | √ | √ | √ | √ | √ | √ | √ | | |
| Extended producer responsibility | https://youtu.be/SLuBuX2QYEc | | | | | | | | √ | | |
| *Electronics* | | | | | | | | | | | |
| EPR system | https://youtu.be/wa4nTB2fPGI | | | | | | | | √ | √ | |
| Fairphone | https://youtu.be/QRi4srOjtSM | √ | √ | | √ | | | | | | |
| Refurbished shops | | | √ | | √ | | | | √ | | |
| Bundles/ Homie | | | √ | | √ | | | | √ | | |
| iFixit | | | | | √ | | | | | | |
| Saturn/MediaMarkt | | | | | √ | | | | | | |
| KPN | | | √ | | | | | | | | |
| Marktplaats | | | | √ | | | | | | | |

| Examples | Video available | R0 Refuse | R1 Reduce | R2 Resell/ re-use (incl. rental) | R3 Repair | R4 Refurbish | R5 Remanu-facture | R6 Repurpose | R7 Recycle | R8 Recover energy | R9 Re-mine |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LEAPP | https://www.youtube.com/watch?app=desktop&v=AfW6w8PomQQ&feature=youtu.be | | | √ | | √ | | | | | |
| Samsung | https://youtu.be/MaPLucASIVk | | | | | | √ | | | | |
| DAR Electronics Hub | | | | √ | √ | √ | √ | | √ | √ | |
| *Post-landfilling* | | | | | | | | | | | |
| Machiels | | | | | | | | √ | | | √ |

phase. They may still be liable for malfunctioning but easily lose track of the product (like with cars if they are sold to second, third, etc., users). This is where PSS have advantages, with ownership remaining in the hands of producers. These are displayed in the table as combinations of *R1 Reduce* and *R2 Resell/re-use.*

We note that the original 10R hierarchy of ROs posed in our scientific article includes *R9 Re-mining,* missing in Table 4.1. This option concerns new developments in the field of dismantling old landfills, allowing for the re-use of discarded raw materials long after landfilling. It is still in its experimental phase, mainly in affluent countries, and worldwide only a few projects systematically test this RO's viability. In the Dutch city of Den Helder[32] a landfill was uncovered, and previously dumped construction waste was re-mined (i.e., inventoried, taken apart, or dismantled and separated) for re-use and recycling. After that, the area was changed into a breeding ground for coastal bird species, combining *R9 Re-mining* for the spot of land with *R6 Repurpos*e.

Additionally, there is a series of European subsidized pilot projects just across the Dutch border.[33] In Belgium, the company *Machiels* is seen as a front-runner in *R9 Re-mining.* Findings suggest that this method can be cost-effective, especially in places where old landfills are meant to be repurposed, for example, if converted into construction sites.

In the Netherlands, a saying poses that "one bird does not yet bring springtime". In other words, for attaining a breakthrough and mainstreaming circularity, it is essential that individual front-runners, applying whichever of these ROs, can upscale their activities to enhance their contribution and impact, as well as and function as an inspiration for others. The national circular economy policy implemented since the mid-2010s, with the help of 'transition agendas', has supported these initiatives aimed at innovation and market creation and upscaling, and furthermore enabled research on the transformation of sectors for circular operations. In the next section, we outline how governments are applying the 10R framework.

## 4.3 Applying the 10Rs for Policymaking and Evaluation

The development of the 10R framework, as presented in Chap. 3, took place in the context of the emerging Dutch circular economy policies, which we shortly described in Sect. 4.1. Our first version of the framework was developed in a study on request by the regional Economic Board of Utrecht (Vermeulen, Witjes, and Reike, 2014) but needed further systematic elaboration, which we provided in the 2018 article in *Resource Conservation and Recycling*. The framework has been

[32] More information can be found on their website: https://www.interregeurope.eu/policylearning/good-practices/item/3269/the-bird-rock-den-helder/

[33] The Belgian government stimulates this actively; see https://www.ovam.be/landfill-mining). It is involved in two EU Interreg projecten: COCOON en RAWFILL. One of the front-running companies from Belgian Brabant is Machiels group

taken up in policymaking later and has been recognized at other policymaking levels. Besides, it also serves for policy evaluation, and we give insights into these forms of application in the Dutch context below.

### *4.3.1 The 10R Framework for Policymaking and Evaluation*

We developed the 10R hierarchy framework in response to questions from, for example, government agencies on how to measure the implementation or claim assurance of circular economy initiatives. In the Netherlands, the National Environmental Assessment Agency (PBL) is the official policy advisor for the government that feeds policymaking with problem analyses studies and it conducts regular evaluations of the progress made in implementing sustainability policies. PBL closely collaborates with universities, among this the Copernicus Institute of Sustainable Development at Utrecht University. They have published various reports about the circular economy since 2016, addressing issues as how to measure the circular economy and how to specify targets and impact assessments of planned policies.

First versions of applying the 10R framework were given in a joint report on how to gear up innovation for the circular economy (Potting et al., 2016). In later reports on measuring circular economy implementation, PBL works with a slightly adjusted version of the 10Rs, adding a Rethink R, which replaces our second lifecycle related to *concept and design* and omits our *R9 Re-mining* (PBL, 2018). This version was used by PBL to systematically map the activities of the national government and show the limited attention to the shorter loop value retention options (see Fig. 4.1).

They justified this alteration and a further adaptation by arguing that they left out hardly used options while further combining our *R4*, *R5*, and *R6* (Kishna, Rood, and Prins, 2018, p. 8). Nonetheless, the basic reasoning of our framework was adopted to measure which type of activities Dutch businesses are currently engaged in, as shown in Fig. 4.2 (Rood et al., 2019). The figure shows that companies generally apply less value retention activities than parties inside government programs (Fig. 4.1), except *R3 Repair* and *R4 Refurbish* (see Fig. 4.2). However, studying the report details, the high score can be explained through sectors where repairing has been common practice for a long time (e.g., bicycle repair shops and car dealers). This type of monitoring of differences in market activity and circular activities from policy programs as executed by PBL is helpful for governments in evaluating implementation effects and feeds into adjustments in the policy programs.

Conclusively, these examples illustrate the usefulness of the 10R framework and highlight the tendency in policymaking to adjust and simplify the problem of defining and conceptualizing circular economy and its fundamental principles, as we tried to address in our scientific article.

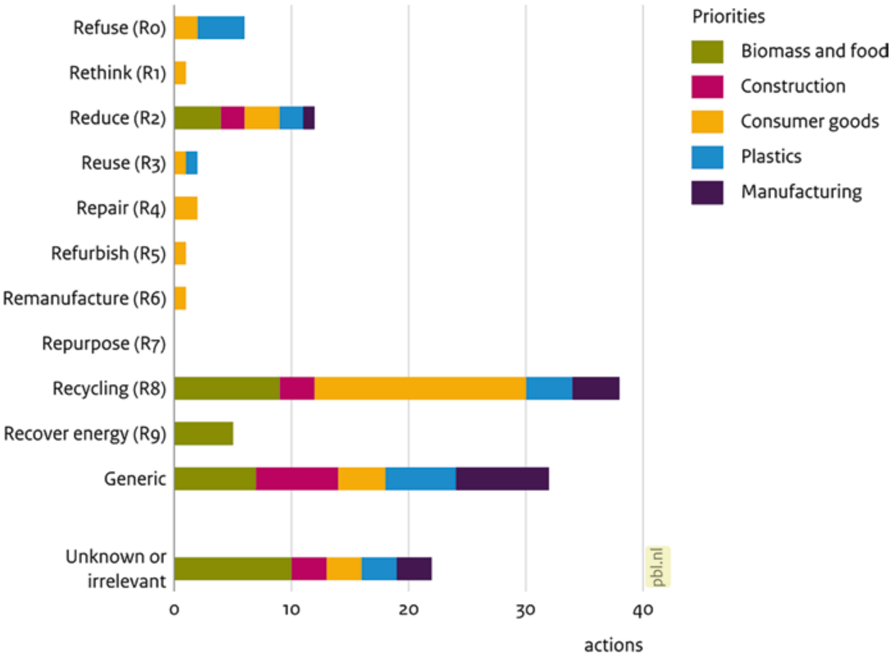


**Fig. 4.1** Actions government-wide policy program circular economy, per retention option (RIVM, 2017)

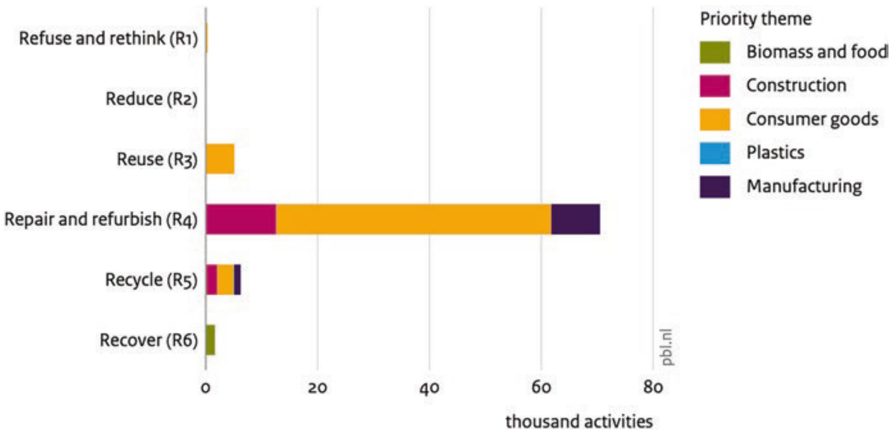


**Fig. 4.2** Circular activities per retention option in the Netherlands in 2018 (PBL, 2019)

### 4.3.2 The 10R Framework for International Policymaking

The framework has also been taken up at other governmental levels in line with the original publication. The UN Environment Programme presented the 10R framework at a G7 meeting on resource efficiency in 2019 (Noronha, 2019), where more vigorous attention to the shorter loop value retention option was promoted. In 2020, at the UN 10th, Regional 3R, and Circular Economy Forum in Asia and the Pacific, the 10Rs and the distinction between the two types of lifecycles were discussed and endorsed (UN CSD, 2020), which may lead to a broader application of the 10Rs in both policymaking and evaluation.

## 4.4 Conclusions

In this chapter, we presented the application of the 10R framework by businesses and in a political context. We showed that the Netherlands could be regarded as a front-runner in circular economy implementation through our overview of the many diverse and innovative initiatives by businesses – partly jointly with the government – in applying the 10Rs. At the same time, our chapter illustrates that studies conducted for assessment of the broader implementation of the 10Rs across the Netherlands show a more critical picture with a dominant focus on *R7 Recycling* and too little attention for the shorter and medium-long loops, which are regarded as preferred ROs in the 10R framework.

Positively, we see the use of the shorter loop options increasing; there is much experimentation, particularly with *R2 Resell/re-use* models. As highlighted by our business illustrations and the policy data, there is also an increase in the implementation of *R1 Reduce* and *R0 Refuse* options, although the latter is often focused on substitution rather than avoidance of any (virgin) material inputs. Interestingly, the option of *R9 Re-mining* discussed in Chap. 3 is almost absent in practice with a few infant business initiatives existing and no systematic measurement by business or government. It remains to be seen if this option increases in importance in affluent countries such as the Netherlands.

Overall, we have presented our examples on the application of the 10Rs in a value-free manner rather than taking an entirely critical perspective on the notion of the circular economy and its relation to sustainability as demanded by scholars such as Campbell-Johnston et al. (2020b) and Corona et al. (2019). In our scientific article, we pledge a holistic, system-oriented perspective that embeds circular economy as a concept among other sustainability-related concepts. Accordingly, we reflect on sustainability considerations in several of our examples in this chapter.

This chapter provided “working illustrations” of CE without much consideration for their net environmental impact. The value retention option *R2 Resell/re-use* best illustrates possible dilemmas and adverse environmental effects from circular economy implementation. It is regarded as a highly ranked R strategy, as the product is maintained in its current state and for current use purposes, ideally without extra energy input for modifications. However, if products are shared or re-used consecutively by different users, their lifetime may go down compared to regular use by a single user.

Car sharing is a good example where idle time is economically undesirable and environmentally unsustainable as space is blocked without use. Still, the car's lifetime can be higher when it has higher idle times than a shared car with high use frequency. However, if we add to the calculation the benefits from "refused cars" (i.e., not bought) due to the possibility of using a shared car in the vicinity, the balance sheet may once again look positive – this shows the sheer complexity of defining system boundaries and calculating circular net effects.

There are also *R2 Resell/re-use* examples implemented by large companies that potentially do more harm than good. For example, where consumers are not incentivized to alter their shopping behavior, multi-national companies like Zalando or other platforms implementing *R2 Resell/re-use* and rental models for clothes may attain circular business models with economic feasibility that are causing more adverse environment impacts simply through extra shipping and re-packaging of textiles.

Regarding economic considerations of sustainability, we have focused on economically viable initiatives or retain viability through policy support or mandate rather than describing grassroots initiatives that shall not suggest a view of circular initiatives subordinate to current market practices. As the term circular economy suggests, we view the circular economy as a means for overturning the market and the economy more fundamentally. We recognize there is often a trade-off or even conflict between environmental, social, and economic objectives in the circular economy.

Finally, we have largely left out social aspects as essential in the scientific literature (Geissendoerfer et al., 2017). Some of our business illustrations include social sustainability objectives ("Circular Ambachtscentra," the "OV-fiets," and DAR's electronics hub). These are circularity initiatives aimed at all three sustainability dimensions since they include integration into work of people with a distance to the labor market. However, it remains a reality that social aspects are under-addressed in circular economy business initiatives as well as in policy assessment to date (Walker et al., 2021).

Japan uses the term sound material society instead of the circular economy. Their terminology suggests a more vital link with the social dimension and the need for understanding humans less as "accepting consumers" but as citizens shaping their economy and the associated institutions. Regardless of the choice of the term – which matters without a doubt – we hold that consumer and citizen involvement is required at the outset to integrate social, economic, and environmental objectives in attaining circular outcomes in our global societies. First, scientific work on this has been provided by Campbell-Johnston et al. (2020b), proposing how the notion of value in R-strategies used in technical cycles and "cascading options" used in biological cycles can be conceptualized to include the social dimension. Specifically, the authors developed a theoretical framework that considers the socio-organizational necessities for a CE-cascading system.

| Video | Source | URL | Language |
|---|---|---|---|
| Mobility | | | |
| NS Nedtrain | NS Nedtrain, 2015 | https://www.youtube.com/watch?v=ppxtqDW7joU | Not applicable |
| AELS | AELS, 2018 | https://www.youtube.com/watch?v=hV70bX6p7Fo | Dutch |
| SnappCar | Snappcar, 2017 | https://www.youtube.com/watch?v=sK3zJwiUq5Y | English |
| Cargobike festival | BicycleDutch, 2019 | https://youtu.be/wEbm2otrjoo | English |
| OV recycle | NS, 2014 | https://www.youtube.com/watch?v=5-0UBh9mH2k | Dutch |
| Stint | Kinderopvangtotaal, 2020 | https://www.youtube.com/watch?v=MuNoTuGc8_0 | Dutch |
| Urban arrow | Propel, 2019 | https://www.youtube.com/watch?v=pye09heBqfY | English |
| FoodLogica | Bijbanaan, 2018 | https://drive.google.com/file/d/1NhlAPmPEDnxI3J97nlTrt0_ccKFK7_P/view?usp=sharing | Dutch |
| *Clothing* | | | |
| Asket | Asket, 2015 | https://www.youtube.com/watch?v=n8S0AXD8VSY | English |
| Neffa | Aniela Hoitink, 2018; Aniela Hoitink, 2015 | https://youtu.be/HFwvYkJyaRg; https://www.youtube.com/watch?v=nVJv4bWnOCM | English (short); Dutch |
| MUD jeans | Earthackers, 2018 | https://www.youtube.com/watch?v=iM9gkv2vxWo | English |
| Hulaaloop | Hulaaloop, 2021 | https://biteable.com/watch/embed/hulaaloop-pitch-kleding-die-met-je-kleintje-meeg-1542403 | Dutch |
| LENA the fashion library | ING, 2018 | https://www.youtube.com/watch?v=iVYUHHTY-vw | English subtitles |
| SaXcell | Eloop Digital, 2020 | https://youtu.be/p4fdhgcfANE | English |
| "Circular Ambachtscentra" | MEO Filmt, 2020 | https://www.youtube.com/watch?v=AZyommgWmOI | Dutch |
| Extended producer responsibility | Utrecht University, 2021 | https://youtu.be/SLuBuX2QYEc | English subtitles |
| *Electronics* | | | |
| EPR in electronics | WEEE Nederland, 2018 | https://youtu.be/wa4nTB2fPGI | Dutch |
| Fairphone | Fairphone, 2021 | https://youtu.be/QRi4srOjtSM | English |
| LEAPP | De Ondernemer, 2016 | https://youtu.be/xe2LTznD29s | Dutch |
| Apple/Samsung | Samsung, 2021 | https://youtu.be/MaPLucASIVk | German |

Conceptualization of circular economy in line with all three sustainability dimensions remains a challenge in theory, let alone in practice. In this chapter's examples from the three Dutch sectors, start-ups tend to enter the market with more disruptive and sustainability-minded business models. However, even incumbents have started to include the 10R hierarchy in their strategic considerations and experiment with circular business models. These experiments can inspire other large players in the sector to follow their example and thereby support broader dynamics for industry change needed to transition towards a circular economy. We hope this chapter contributes inspiration to support such broader societal change dynamics by putting some examples in the spotlight.

## 4.5 List of Illustrative Videos

**Tip** In the text, we referred to use short videos available on YouTube. Some videos are in Dutch. Please use the settings button (⚙) to enable subtitles and to set subtitles to your language of choice. All videos are combined in this YouTube CE 3.0 Playlist: https://tinyurl.com/10R-Examples4Uplaylist.

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# Chapter 5
# The Circular Economy: A Critique of the Concept

**Keith R. Skene**

## 5.1 Introduction

The circular economy is an increasingly influential school of sustainable economic thinking, dominating recent five-year plans in Chinese policy while increasingly featuring in the sustainability policies of the European Union. It is a contested concept, with questions surrounding its theoretical and practical feasibility (Korhonen et al., 2018; Skene, 2018; Millar et al., 2019). Furthermore, recent developments in Eastern and Western interpretations and applications differ significantly, which leads to confusion in terms of any global conversation and delivering a sustainable transition that is urgently needed. Furthermore, questions about whether it should be a global development or a myriad of small, local circles are being asked (Prendeville et al., 2017; Real et al., 2020). Currently, the global economy is only 9% circular (with Europe 12% and China 2%), and the linear model is still systemically "baked in" (Circle Economy, 2019).

Over 100 different definitions of the circular economy were identified in a review by Kirchherr et al. (2017). In this chapter, we adopt the definition of Murray et al. (2017), which defines the circular economy as "an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being."

We begin by contextualizing the circular economy through its historical development, since the history of a concept often tells us as much about it as does the concept itself. We then compare and contrast the two dominant geopolitical versions of the circular economy, the Chinese and Western models, identifying differences and

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issues in underlying principles. In order to explore the current and future prospects for the circular economy, we explore the Earth system, on which, ultimately, our species relies upon. By teasing apart its functionality, two levels of organization emerge: local and global. The chapter ends with exploring what this means for any concept of sustainable economics and concludes by identifying the essential critical characteristics of such a concept.

## 5.2 Origins and Context

Desrochers (2002, 2008) pointed out that concepts such as re-use, recycling, and resource and habitat management have played important roles throughout the history of manufacturing. The circular economy was a recognized concept in meaning if not in name two millennia in the past. Back then, rather than environmental damage, resource scarcity drove the pursuit of reducing, re-using, and recycling resources (the 3R concept).

Such approaches also reflected a much more localist approach in terms of short supply chains. Short supply chains bring with them responsibility, accountability, and transparency. If you chop the local apple tree down for wood, there will be no more apples. Thus, Hardin's (1968) tragedy of the commons is rarely, if ever, seen where short supply chains exist and where a functional society operates, which is particularly relevant to First Nations people. For example, the Ogiek people of the Mao forests in Kenya need agreement from the council of elders before cutting down even one tree (Skene, 2019), which has been lost as we externalize our supply chains, which disappear across the horizons to distant lands, where the true impact is not felt by the consumer halfway around the world.

Figure 5.1 lays out the conceptual development of the circular economy in terms of its more recent, post-linear economy evolution. Many of the major schools of sustainable economics share much in common. The circular economy is merely a re-expression of concepts that have been around for many years. What is of more interest is how it is interpreted in different nations and trading blocs. We will take two examples, China and the European Union.

## 5.3 The Circular Economy in China

Given that the population of China represents around 19% of the global population and given its important position in trade and raw material supply, particularly in terms of the rare earth metal and graphite, the economic practices of China are of vital interest to the rest of the globe.

The history of the adaptation of the circular economy as a central theme in policy in China dates back to 1973, when the first National Environmental Protection Conference formulated environmental protection policies and guidelines (Zhang &

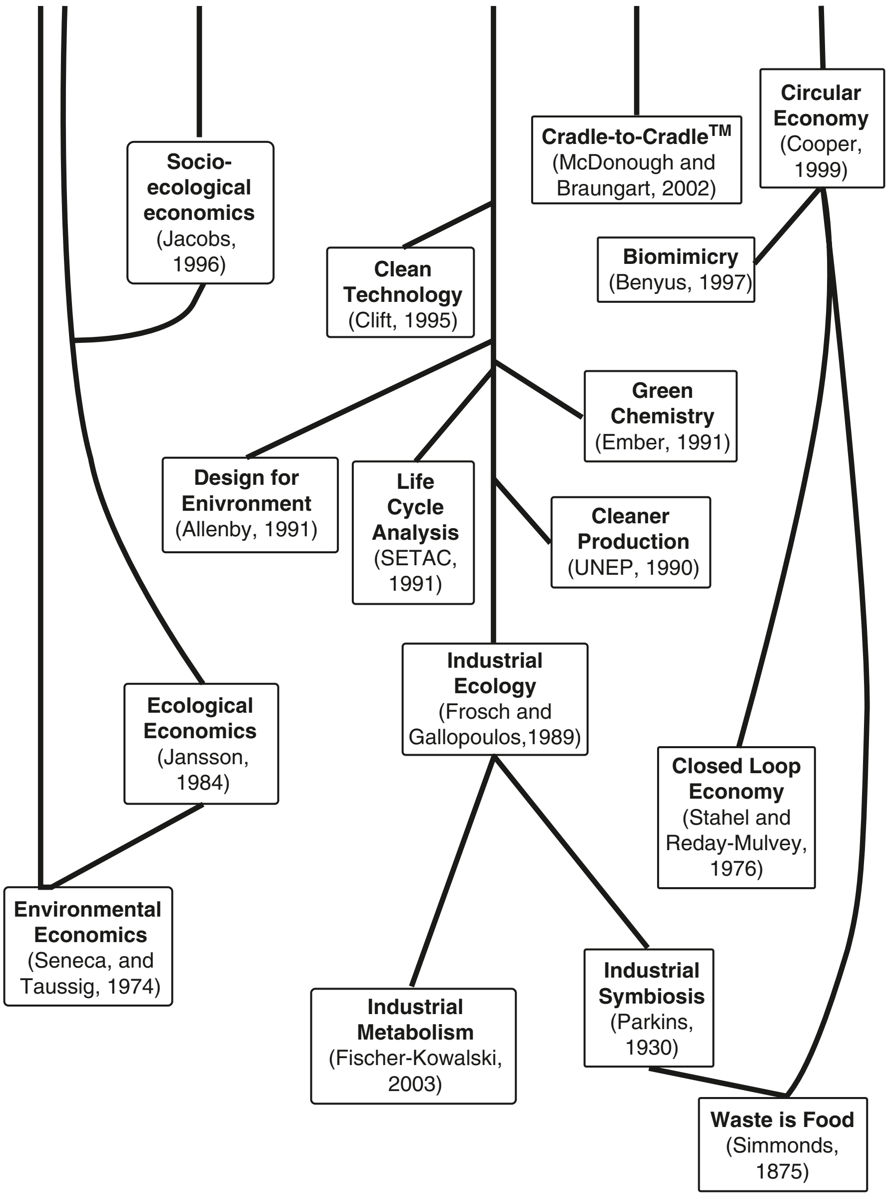


**Fig. 5.1** A chronological map of the inter-relatedness of sustainability concepts, tracing the emergence of current schools. The references record the early appearance of each concept. Skene and Murray (2017) developed it

Wen, 2008). In 1983, the second National Environmental Protection Conference was held, making environmental protection a core national policy. In 1989, the Environmental Protection Law of the People's Republic of China was enacted.

In 2002, the 16th National Congress of the Communist Party of China set out an ambitious development plan involving social equality, the recovery and protection of the environment's integrity, and quadrupling of GDP, which was called a circular economy underpinned by a cleaner production strategy. The circular economy is defined in legislation as a generic term for reducing, reusing, and recycling activities conducted in production, circulation, and consumption. Interestingly, these three goals embrace the three pillars of sustainability: economics, society, and the environment. Thus, the Chinese model formally attempted to address all three pillars of sustainability, unlike most other schools of sustainability at the time. Three new laws were introduced to move the agenda forward:

- The Cleaner Production Promotion Law (passed on June 29, 2002, and put into effect on January 1, 2003)
- The Law of the People's Republic of China on Appraising Environmental Impacts (passed on October 28, 2002, and put into effect on September 1, 2003)
- The Law on Pollution Prevention and Control of Solid Waste (April 2005)

Planning for societal development in China targeted realizing a healthy, equitable, and functional society by the year 2020. These laws appear to be the first in the world to make the circular economy a national economic and social development strategy. The Ministry of Environmental Protection initiated eco-industrial parks (EIPs) as early as 2002, releasing an EIP standard. Currently, 50 such parks exist.

Guiyang was chosen as the pilot city for implementing a circular economy. In 2004, the Guiyang Circular Economy Development Plan focused on six sectors: coal, phosphorus, aluminum, herbal medicine, tourism, and organic agriculture. The People's Republic of China Law on Renewable Energy was enacted in January 2006, marking an important step in terms of sustainable energy production, which was followed by the Energy Conservation Law of the People's Republic of China, enacted in January 2008.

## 5.4 Five-Year Plans

The five-year plans, focusing on social and economic development, lie at the heart of policy in China. In 1953, under Mao Zedong, they were inspired by the Soviet economic and industrial development model.

### *5.4.1 11th Five-Year Plan (2006–2010)*

Incorporating a circular economy into the Outline of the 11th Five-Year Plan for National Economic and Social Development meant increased support and focused on sustainability (Wu et al., 2014). The plan was based on the 3-2-1 model (Tan, 2008), which refers to three industrial systems (the eco-industrial system, the eco-agricultural system, and the eco-service system), two domains (production and consumption), and one industrial chain of renewable resources. The Law for the Promotion of the Circular Economy, which came into effect on January 1, 2009, promoted resource utilization efficiency, natural environment protection, and sustainable development. It operated at three levels: individual firms (focused on eco-design and cleaner production), eco-industrial parks (utilizing the waste-is-food concept), and the eco-city and eco-province level (creating a recycling society).

Key objectives were:

- Close monitoring of energy consumption and pollution emissions in heavy industries by government
- Promotion of recycling, energy efficiency, and waste-reutilization standards by government departments and policy development to diversify capital into environment-friendly industries
- Introduction of water-saving technologies in new buildings and projects
- Switch from oil-fired fuel generators and boilers to alternative green energy fuels in power generation, steel, and iron production plants
- Adoption of renewable technologies, such as solar and geothermal approaches, to be used by enterprises and government departments in new buildings
- Recycling and re-use of coal ash, coal mine waste, and other waste materials
- Recycling straw, livestock waste, and farming by-products to produce methane

As of 2011, tax incentives were expanded, including variable rates of VAT on specific products. Construction materials made from construction waste became VAT-exempt, recycled graphite now could claim a 50% VAT refund, and, more eclectically, wigs made from human hair would now earn an 80% VAT refund (Skene & Murray, 2017).

### *5.4.2 12th Five-Year Plan (2011–2015)*

China's 12th Five-Year Plan dedicated enormous resources (around US$ 470 billion) towards the implementation of a circular economy. In the 12th Five-Year Plan (2011–2015), Chap. 22 is dedicated to the circular economy (Mathews & Tan, 2016). Policy shifted from resource efficiency of heavy industries to remanufacturing and recycling metals and minerals, focusing upon the exchange of materials between companies (Preston, 2012). The development of the internet-of-things to track the resource history of products was implemented, as was research into a green economic growth strategy.

### 5.4.3 13th Five-Year Plan (2016–2020)

In the 43rd Chapter of the 13th Five-Year Plan (2016–2020), the importance of CE both as a national policy and as a fundamental pillar of the Chinese economy is clearly stated (Central Committee of the Communist Part of China, 2016, p. 219). It was recognized that a market-based approach could encourage Chinese businesses to pursue a more sustainable path, rather than using incentives such as tax rebates, which did not always provide the expected outcomes (Zhang, 2013).

### 5.4.4 14th Five-Year Plan (2021–2026)

In the most recent Five-Year Plan, the Chinese government has set out its so-called Dual Circulation Strategy (DCS) to boost domestic spending. The main idea behind this strategy is to strengthen China's vast domestic market (domestic circulation) while balancing its foreign trade (external circulation). This significant policy changed from an economy previously focused on export-oriented development since the launch of Deng Xiaoping's reforming policies of 1978.

The DCS represents a new development pattern where domestic and foreign markets can boost each other, with the domestic market as the mainstay. Supply chain issues now take the central stage in terms of sources and sinks. By localizing, there is less uncertainty and less externalization. The "dual-circulation" strategy avoids asynchrony between cycles and feedback loops and government policies by applying flexible, adaptive, institutional, and structural approaches.

China's 14th Five-Year Plan sets technological autonomy as one of the country's top priorities and signals a shift from pure economic growth to social and climate-friendly development. It is hoped that a new urbanization strategy, more equal distribution of public goods, and increased investment in environmental technologies will deliver new sources for sustainable growth by improving economic efficiency and by increasing domestic demand (Yang, 2020). It is also envisioned that an increasingly inward, domestic focus of the DCS will protect China in extreme scenarios (such as global pandemics) while reducing China's vulnerability in trade war scenarios (such as with the Trump administration). It is not only the market that is shifting internally. Made in China 2025 (MIC25) aims to achieve independence from foreign suppliers (Liu, 2016), essential in domestic cycling and supply chain integrity.

China has developed a system of indicators to provide feedback on progress in the circular economy, based around resource output, resource consumption, integrated resource utilization, and waste disposal/pollution emission (Geng et al., 2012). Macro-level indicators are used to analyze progress at the national and regional levels, guiding development and planning, while meso-level indicators operate at the eco-industrial park level. Eco-city indicators cover such aspects as local ecosystem value, greening land rate, and biodiversity. Finally, $CO_2$ indicators provide feedback on climate mitigation policies.

## 5.5 Issues with the Dual Circulation Strategy

Some issues arise from the DCS. The re-orientation of the economy towards a domestic market creates many challenges. For Chinese consumption to be equivalent to that of other developing economies, ordinary households would need to recover at least 10–15 percentage points of GDP at the expense of businesses, the wealthy, or the government (Pettis, 2020), which would require a massive shift of wealth and power to ordinary people. The success of China's international circulation has been built on low material and labor costs. An interesting point to note here is that with advancing robotic manufacturing, the cost of production, in terms of labor, will soon decrease as a consequence of the loss of the human workforce, which is seen to impact the manufacturing geography, making it cheaper to bring manufacturing back to Europe and the USA as transport costs would now dominate over labor costs (Skene, 2019). Thus, a decreased reliance on international markets may well become a necessity anyhow.

The aim of zero net carbon by 2060 becomes more problematic when viewed alongside the DCS, as domestic economic growth will pose considerable challenges in terms of the green growth strategy as initially outlined in the 12th Five-Year Plan. Furthermore, fundamental issues related to the core nature of manufacturing in China revolve around a coal-based energy sector, a heavy chemical industry-centered industrial structure, and a heavily road-based transportation structure. Li et al. (2020) point to the challenges of urban-rural development, whereby the desire is to move more of the population into cities, raising energy intensity and green agriculture issues.

Economic growth coinciding with absolute reductions in resource use and emissions is called "absolute decoupling," while economic growth increasing less than resource use and emissions is referred to as "relative decoupling" (Skene & Murray, 2017). Whether green growth is possible through either absolute or relative decoupling is highly questionable (Albert, 2020; Hickel & Kallis, 2020). Haberl et al. (2020), having assessed over 800 studies, reported that few delivered absolute decoupling. Ward et al. (2016) report that there is little evidence that GDP growth can be decoupled in the long term.

## 5.6 The European Approach

While China has led the way in adopting a circular economy, Europe had been initially world leaders, with eco-industrial parks such as Kalundborg in Denmark established in the early 1970s and Germany's recycling laws providing essential inspiration in China. However, more recently, the EU has fallen behind in terms of national policy, which is understandable, as the EU comprises 27 nations, with qualified majority voting, but, for several key issues, unanimity is required. These nations pursue quite different political and economic agendas while often coming from very different historical contexts. There are significant differences between individual nations within the EU, both in industrial profile and pollution production. Some nations are fundamentally agrarian, others industrial, while yet others are firmly in the Information Age. Poverty levels vary widely. Previous heterogeneity is a big challenge for the EU, as exemplified by the difficulties in approving the EU budget for 2021–2027 and the membership of North Macedonia.

The origins of a circular economy strategy in Europe can be traced back to 1972. With global environmental awareness growing, the European Commission chairperson, Sicco Mansholt, stated that new economic thinking was needed to prevent resource waste, increase product lifetimes, and reduce resource use per capita (Vonkeman, 1996). As early as 1975, a European Communities Council directive emphasized taking "appropriate steps to encourage the prevention, recycling and processing of waste, the extraction of raw materials and possibly energy from that place and any other process for the re-use of waste" (European Communities, 1975, p. 40). Since the 1970s, the approach of the EU has been criticized as resembling an incremental policy layering of closed-loop thinking rather than some form of paradigm-shifting transformative thinking (Fitch-Roy et al., 2020).

Finally, on December 17, 2012, the EU released the following statement: "In a world with growing pressures on resources and the environment, the EU has no choice but to go for the transition to a resource-efficient and ultimately regenerative circular economy" (EU, 2012).

They identified six action points (EU, 2012):

1. Encouraging innovation and accelerating public and private investment in resource-efficient technologies, systems, and skills, also in SMEs, through a dynamic and predictable political, economic and regulatory framework, a supportive financial system and sustainable growth-enhancing resource-efficient priorities in public expenditure and procurement.
2. Implementing, using, and adopting intelligent regulations, standards, and codes of conduct that (a) create a level playing field, (b) reward front-runners, (c) accelerate the transition, and (d) consider the social and international implications of our actions.
3. Abolishing environmentally harmful subsidies and tax breaks that waste public money on ancient practices. Also, taking care to address affordability for people whose incomes are hardest-pressed—shifting the tax burden away from jobs to encourage resource-efficiency and using taxes and charges to stimulate innovation and development of a job-rich, socially cohesive, resource-efficient climate-resilient economy.
4. Creating better market conditions for products and services that have lower impacts across their life cycles and are durable, repairable, and recyclable. Also, progressively taking the worst-performing products off the market; inspiring

sustainable lifestyles by informing and incentivizing consumers, using the latest insights into behavioral economics and information technology, and encouraging sustainable sourcing, new business models, and the use of waste as raw materials.

5. Integrating current and future resource scarcities and vulnerabilities more coherently into broader policy areas, at national, European, and global levels, such as in the fields of transport, food, water, and construction.
6. Providing clear signals to all economic actors by adopting policy goals to achieve a resource-efficient economy and society by 2020, setting targets that give a clear direction and indicators to measure progress relating to the use of land, material, water, and greenhouse gas emissions, as well as biodiversity. Such indicators must go beyond conventional economic activity measures, help guide all actors' decisions, and assist public authorities in timely action. All organizations above a meaningful size and impact must be held accountable to measure and report critical non-financial progress indicators on a comparable basis.

By 2015, the circular economy had become a foundational concept in Europe, exemplified by the report "Closing the Loop – an EU Action Plan for the Circular Economy" (European Commission, 2015), and is now recognized by the European Union (EU) as an "irreversible, global megatrend" (COM, 2019a, p10). It is a critical component of the European Green Deal and the Von der Leyen Commission (2019–present) (European Commission, 2020). Hill (2015) provides an excellent review of the emergence of circular economic concepts within the European Union.

The EU views the circular economy as an economic tool, primarily. The idea of green growth and the decoupling of economic growth from environmental degradation pervade, which is quite a reversal from the environmental Kuznets curve that underpins much of sustainable development thinking and espouses that economic growth will deliver environmental sustainability and economic equity over time (see Stern, 2004). However, in terms of economic growth delivering social justice, the Kuznets curve is acknowledged when the Council of members writes, "member states will work towards ensuring inclusive and sustainable growth in the EU, a necessary condition to reduce inequality" (COM, 2019b, p.96). Thus, there is a tension here. As Friant et al. (2021) observe: "By focusing on growth and competitiveness rather than human well-being and ecosystem health, the EU might be creating new business opportunities from some while doing little towards addressing the core socio-ecological challenges of the 21st century."

The EU has also set out a straightforward program for auditing pollution costs, a key externality related to market failure, as identified early in the twentieth century by Pigou (1920). To do this, they set up ExternE, which concentrates on damage from energy and transport sectors upon the environment. Such audits are essential if a circular economy is to be assessed and implemented in Europe and based on material flow accounting (MFA) (Bringezu, 2001). The European Environment Agency's reports include assessments of policy progress and analysis of crucial material flow trends.

In 2013, the European Union (EU) Environment Commissioner, Janez Potocnik, set out a parallel path with China, undoubtedly with the hope of encouraging trading relations with China through a shared sustainability approach: "When I look to China's 12th five-year plan and compare it with the EU's political documents, I see many similarities ... It is an excellent basis for cooperation" (Potocnik, 2013); however, apparent differences exist between the approaches in Europe and China. While China set out its principles to guide government and in order to communicate the rationale and implementation of their program to its citizens as ipsum factum, setting up new EIP projects continuously and funding from central funds, Europe relies much more on the private sector, which they must convince of the merit of such a thing.

The private sector is predominately profit-driven. Hence, the emphasis on the financial benefits of the circular economy lies at the heart of European approaches. Western governments are also elected, and so attractive political references relating to jobs, living standards, and the environment playing well on national and European stages. Europe also faces the difficulty of significant differences between its member states. One joint facet between Europe and China is the dependency on external sources for much of their material and energy needs. However, China's new DCS points to a separation of pathways here also.

## 5.7 Indigenous Economics

While the Western economic model, founded on neo-liberalism, globalization, and a production/service dichotomy (where developing nations produce goods while developed nations buy and service these products), dominates global trade, a very different approach also exists, modeled on localism, post-development, and indigenous thinking. Here, many of the circular economy principles have been practiced for millennia, explaining why such approaches have underpinned the long-term survival of ancient people in even the harshest of landscapes. Indeed, many indigenous civilizations today are primarily limited to the regions of the planet that are not inhabited by industrialized populations, such as tundra, semi-arid plains, and high-altitude environments. The Ogiek people of the Mau forests in Kenya have, for centuries, embraced most of the principles of the sustainable development goals, with the exceptions of goals 8 (Economic Growth), 9 (Industry, Innovation, and Infrastructure), and 11 (Sustainable cities) (Njeru, 2018; Skene, 2020).

However, the foundations of these essential practices have not emerged from economic theory, nor is the emphasis on green growth and development targets. Instead, these principles emerge from a holistic approach, wherein humans are bound within their social and environmental contexts. The 'more-than-human relational self' lies at the heart of this (Gould et al., 2019), wherein society recognizes the Earth system as the unit of sustainability, with all players as components of that system, contributing to its resilience and functionality.

Many argue that unless we recognize the Earth system as the alpha and omega of our existence, within which we find our evolutionary, ecological, social, economic, and individual context and meaning, we cannot possibly hope for a sustainable future. While the Earth system will continue with or without us until the Sun eventually expands and consumes it, we, as all species before us, face extinction at some point or another. How we interact with the Earth system is critical. Economics governs the intensiveness of our exploitation of the Earth's resources, the flow of energy through ecosystems (due to fertilizer application), and the sink issues in terms of waste. Therefore, contextualizing our economic activity within the Earth system in such a way as to reduce our footprint to an appropriate size must surely be the priority.

In many ways, the Chinese policy of DCS can be seen to embrace the benefits of this localized indigenous approach. By developing the domestic economy, China hopes to be less impacted by issues elsewhere on the planet, whether political or pandemic. Ironically, the Trump administration also emphasized a version of this, in terms of nationalism first, internationalism second, creating one of the issues that encouraged the development of the DCS in China, where self-sufficiency and domestic production and consumption can shield from shocks while raising living standards within the nation through increased employment.

However, problems arise in terms of how to implement the profound changes needed. In a low-wage structure such as China, increased spending power requiring increased wages, increased wages requiring increased business profitability, and increased profitability requiring increased consumer spending all lead to a very different form of circular economics. Meanwhile, production at home costs much more in any given Western nation than production in a developing nation, requiring a sharp increase in prices and further wage increases simultaneously, thus driving up inflation. You can make your cake and eat it, but you have to pay a lot more for it. Fundamentally, globalized economics still dominates, and our supply chains are deeply embedded within this approach. Thus, any attempt to change direction brings with it enormous challenges. However, more significant challenges exist regarding the environmental crisis, impacting such necessities as food production, water supplies, climate, and health. The planetary card trumps any economic card, and therefore, we must shape our economies to support the Earth system if we are to continue as a species.

## 5.8 The Earth System

In terms of the local/global balance, we can learn much from the Earth system. Firstly, the business of the planet is partitioned into biomes, determined by temperature and precipitation. The main biomes, moving from the equator towards either pole, are tropical rain forest, tropical dry forest, tropical savanna, desert, temperate grassland, temperate woodland and shrubland, temperate forest, boreal forest, and tundra. Each has evolved, with species adapted to the conditions and natural economies matched to these conditions. These biomes, differing in soils, topography, and climate, have shaped the ecology and evolution of life within them. A tropical rainforest functions entirely differently from an area of tundra, and a desert consists of very different organisms than a temperate rainforest. For millennia, human cultures have also differed across these landscapes, adapting to the local conditions and resonating with the functioning of these landscapes.

## 5.9 Local and Global Realities

Indigenous people living in these biomes, whether the Ogiek in the tropical dry forests, the Sami in the boreal and tundra, or the Masai in the savanna, each have economies and cultures adapted to their ecological environment settings. While trade between tribes from different biomes does occur (e.g., honey and milk traded between the Ogiek and Masai (Njeru, 2018)), for the most part, these tribes have localized economies. Supply chains are short and immediate, while accountability is high. Cutting down a fruit tree for fuel is a strategy of doubtful value and would immediately affect the local community.

Thus, the idea of local solutions for local communities is an ancient and emergent concept within the Earth system. Furthermore, a rainforest does not strive to convert a desert or a savanna into a rainforest. Each biome functions in the most appropriate way relative to the biogeochemical context within which it finds itself. In other words, the concept of development is not found within the Earth system. However, global issues exist in atmospheric gas levels, ocean and air circulation (such as El Niño and El Niña), and long-term glacial (Milankovitch) cycles, driven by changes in the Earth's tilt and orbit around the Sun. These impact upon most if not all parts of the planet. Indigenous human populations have both globalized and local identities. Thus, we would suggest that a sustainable future requires some balance, but to identify this, we need to reflect on the origins of global issues within the Earth system.

In ecology, localism is easily accounted for, reflecting the tight relationship between any given organism and the biome level differences in climate, biogeochemistry, and topography. However, global issues, such as the albedo effect, ocean, and atmospheric circulation, tectonic plate movements, atmospheric chemistry, and long-term cycles in solar radiation (leading to intermittent ice ages), impact the planet. Anthropogenic impacts can affect both local and global ecology. Global patterns, particularly across human cultures, are emergent yet shared across the world, be it the Inuit and Sami of the Arctic, the Pila Nguru of the deserts of Western Australia, or the Pumé people of the Venezuelan savanna. Common themes include equitable societies based on indigenous communalism and the gift economy, where resources are shared. Furthermore, activity (economics) is firmly rooted within societal and environmental contexts. The tragedy of the commons (Hardin, 1968) is not an issue here because accountability is a survival skill, not an option.

It has been proposed that the study of local, place-based socio-ecological research allows an insight into the interplay between global and local scales (Norström et al., 2017). Transformations towards sustainability are often triggered at the local scale. It has been suggested that regions may form a helpful go-between, connecting the local with the global (Paasi, 2003; Jonas, 2012). Resilience stems from local biocultural diversity, where indigenous knowledge plays a vital role in resonance with landscape (Ruiz-Mallén & Corbera, 2013). Resilience is a system-level property that cannot be built or constructed but emerges in a functioning ecosystem. However, with 7.5 billion people currently on the planet, dematerializing and localizing the supply chains, reducing waste to appropriate levels, economic degrowth, and environmental revitalization pose untrivial challenges. Fundamental to all of this is accountability, wherein our decision-making is well informed in terms of its environmental and social consequences. By thinking global and acting local, we do not merely focus on our spatial localities but instead consider all of the planet as our locality while preventing environmental and social damage wherever our supply chains lead.

Shortening supply chains bring transparency, accountability, and awareness. It also brings resilience, resistance, and security against the winds that blow elsewhere. Circularity is much easier if you can see the perimeter of the circle. Global supply chains disappear into the mist and are anything but transparent. An example would be the horrific child labor in the mines of the Democratic Republic of the Congo (DRC), with children as young as 6 years of age forced to work at gunpoint or drugged, underpinning the supply of 50% of the world's cobalt, which plays a crucial role in electric vehicle batteries (ILO, 2017; Cheruga et al., 2020).

Indeed a consumer in Europe who is considering buying a car with cobalt from DRC must be given the information that allows them to decide if they wish to contribute to the maltreatment of these children. Because whether they know it or not, their consumer decision contributes to this cruel form of slave labor. Consumer awareness will prevent us from facilitating such cruelty.

Artificial intelligence and the internet-of-things can provide feedback and information on our supply chains and the impacts on human and ecological communities across the globe and allow us to act for the global good while in our localities (Skene, 2019). The indigenous people who live within these biomes have cultures, economies, and behavior tightly tied to their specific habitats and share familiar global narratives, even though they may never have met. We may have lost much of the ecological intelligence of indigenous people, but our decision-making can still be informed, allowing us to make the decisions that can provide the basis for a sustainable future, one informed decision at a time. Given the advanced technologies now available to us, where remote sensing satellites such as Copernicus can monitor the heartbeat of the Earth system from space, collecting data on every facet of the functioning biosphere, we have unequaled access to the health of our planet and the consequences of our actions.

## 5.10 Conclusions

China and Europe have pursued the circular economy principles as mainstays of policy for much of the twenty-first century. However, significant differences exist, both in terms of the political contexts and more recent policy agendas. The DCS has been announced as the subsequent significant development in economic thinking in China. In terms of supply chains, production, and consumption, the domestic economy will be promoted, thus building resilience, mainly through a decreasing dependence on international markets, which pose increasing risks. The Trump administration has recently promoted a similar, nation-centric approach in the USA. Both of these strategies pose significant problems and require significant economic growth. How this fits in with a sustainable transition is less than clear. While these approaches and the policies of Agenda 30 for sustainable development all embrace economic growth, it is unclear how the planet can heal and where any form of circular economy can persist, given the elephant of complex supply chains tied up and gagged out of site in the cupboard across the corridor and the discordant harmony of economic growth, environmental damage, and social inequality.

Recent upheavals, including the interruption of international trade caused by COVID-19 and the rise of populist politics with concomitant nationalism, are likely to drive nations further towards domestic and regional production and consumption, further undermining a globalized economy that offers opportunities as well as challenges, in terms of a more localized approach to sustainability and economics. So, what type of sustainable economic strategy should we practice to fulfill our objective of continuing to exist, where existence must be within the Earth system, which provides our sustenance, fresh air, water, and context? We would suggest that the following characteristics should define any systems-based pathway:

(a) Complementarity, wherein our activities contribute to the functioning of the Earth system, allowing it to repair itself and self-organize.
(b) Resonance, wherein our activities' temporal and spatial patterns are in tune with the Earth system, material and waste cycling, renewable resource use, and appropriate, landscape-sensitive care of the commons. Resonance also informs decision-making.
(c) Feedback, where we are monitoring our impact in real time and adjusting it where necessary, thus being alive to the emergent and nonlinear nature of the Earth system while understanding our impact upon it.
(d) Sub-optimality, where we optimize for the Earth system while sacrificing our excesses, and where trade-offs are central to planning, design, and lifestyles, rather than problems that need to be overcome.

These key characteristics describe social and environmental interactions. Then the path to sustainable economics will reveal itself, most likely at a local level but governed by global, Earth-system thinking. Almost all of our time on Earth as a species has been governed by the socio-ecological relationship rather than the socio-economic relationship. Economics emerges from the former relationship at a fundamentally local level. Universal to this approach is systems theory, wherein the individual is embedded within a social construct, and the social construct is embedded within its broader ecology, embracing ecological ethics. Here the context is everything, and all elements within a given landscape are, in a sense, "globalized," circular, resonant, and accountable.

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# Part II
# Circular Economy: Business Applications

# Chapter 6
# Waste Management and the Circular Economy

**Aldo Alvarez-Risco, Shyla Del-Aguila-Arcentales, and Marc A. Rosen**

## 6.1 Introduction

Daily life in the world has changed since the onset of the COVID-19 pandemic, with various adverse effects. Negative effects have been reported on the health system (Alvarez-Risco et al., 2021a; Chen et al., 2020; Román et al., 2020; Yáñez et al., 2020a; Zhang et al., 2021a; Zhang et al., 2021b; Zhang et al., 2020), education (Alvarez-Risco et al., 2021b; Alvarez-Risco et al., 2020a; Alvarez-Risco et al., 2021c), citizens (Alvarez-Risco et al., 2020b; Quispe-Cañari et al., 2021; Yáñez et al., 2020b), and firms (Alvarez-Risco et al., 2020c; Yan et al., 2021).

As a consequence of these changes, it has also been possible to report variations in consumer behavior, generating different demands regarding products and services with greater use of technology. The latter point leads to increasingly frequent disposal of cell phones, laptops, and other technological equipment and a greater inclination towards ecological products (Boz et al., 2020; Canavari & Coderoni, 2020; Iqbal et al., 2021; Wojciechowska-Solis & Barska, 2021). However, higher consumption usually leads to more waste (Islam & Huda, 2020), leading to health impacts (Li & Achal, 2020; Singh et al., 2020).

All companies, regardless of their sector, generate wastes (Fig. 6.1). A few decades ago, companies had to take charge of waste during the production process,

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https://doi.org/10.1007/978-3-030-94293-9_6

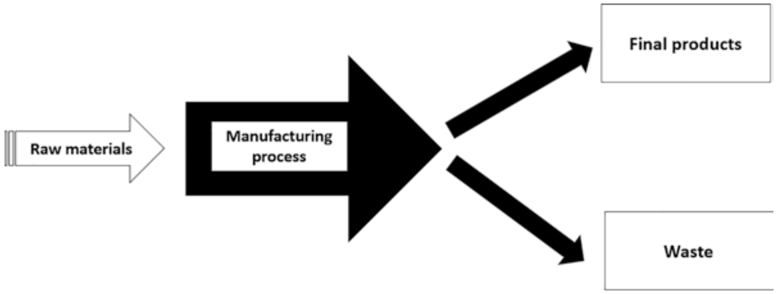


**Fig. 6.1** Manufacturing process and generation of waste

but various legal restrictions generated a considerable expense for this waste management process, discouraging companies from doing so. The negative impact on the environment was maintained due to waste generation and the high cost of treatment incurred by companies.

## 6.2 Waste Management and Circularity

### *6.2.1 Waste of Food*

According to the Food and Agriculture Organization (FAO) (2021), globally, between a quarter and a third of the food produced annually for human consumption is lost or wasted, which represents approximately 1300 million tons of food (30% of cereals; 40% of roots, fruits, vegetables, and oilseeds; 20% of meat and dairy products; and 35% of fish). These amounts are enough to feed 2 billion people. Due to the pandemic, there has been a profound social and economic crisis, which translates into a decrease in access to food, especially by the most vulnerable people (Laborde et al., 2020; Niles et al., 2020; O'Hara & Toussaint, 2021). For this reason, the circular economy approach is suitable because it ensures that the limited resources available can be maximized; that is, there is minimal or no waste (Wuyts et al., 2020).

This issue is critical in companies responsible for producing hazardous components, such as chemical companies. Over the years, global pressure grew to control companies' waste, generating environmental pollution both individually and collectively (Ball et al., 2011; Oliveira et al., 2013). However, the pressure on companies, especially in developed countries, added a notable waste management charge to companies. These companies have, over the years, improved in the management of various types of wastes (Fig. 6.2).

However, there is also a benefit to be had with the circular economy on an individual level. For instance, the consumption of fruits by consumers allows them to dispose of the residue and generate compost. This compost can be used to fertilize

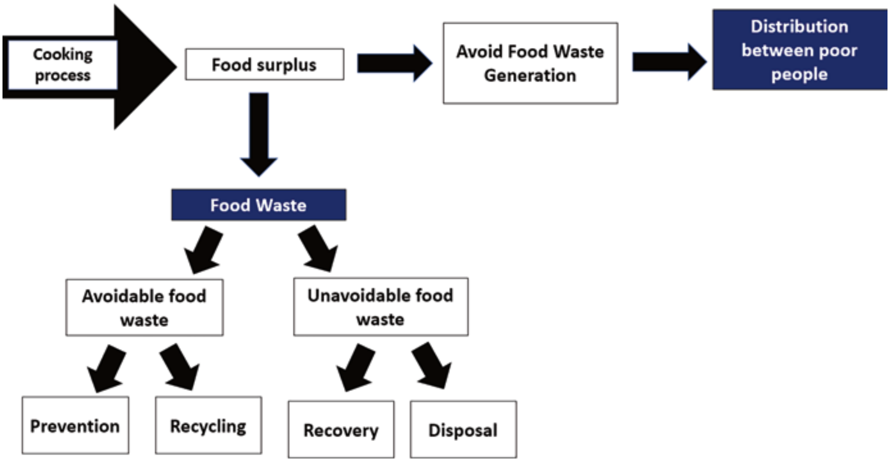


**Fig. 6.2** Management of food waste

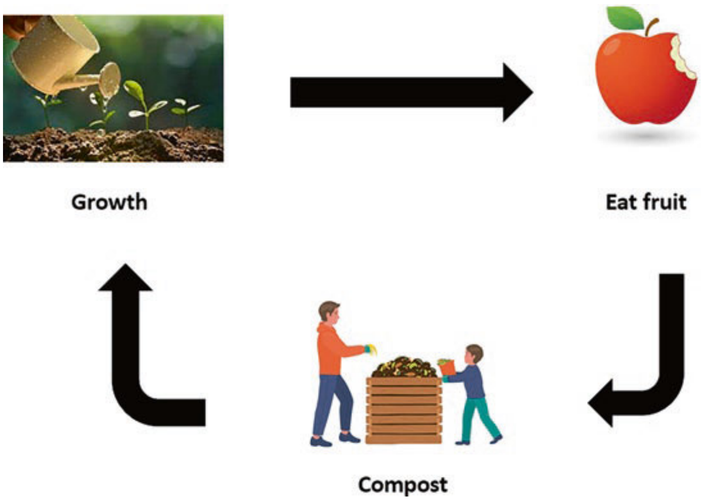


**Fig. 6.3** Circular economy circle in food

the land that allows the consumed fruit to be sown and that will generate a new fruit that can be consumed and continue with the virtuous circle (Fig. 6.3).

Various kinds of countries have problems with food waste. Both developing and developed countries have similar problems in managing waste food. The top 15 countries in terms of food waste in 2021 are shown in Fig. 6.4. Nigeria, Greece, Iraq, Saudi Arabia, and Australia lead in this ranking, clearly demonstrating that various countries are involved in such food problems.


**Fig. 6.4** Annual per capita household food waste (in kg per year). (Source: Food Waste Index Report 2020)

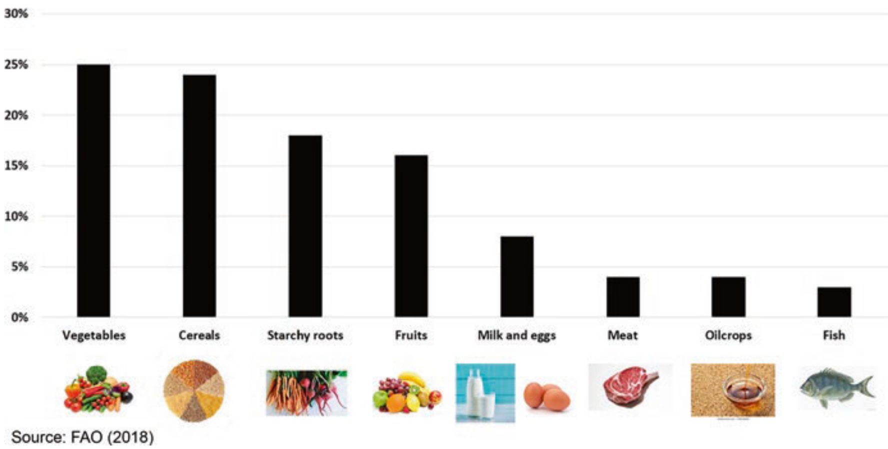


**Fig. 6.5** Contribution of food to carbon footprint and food wastage. (Source: FAO (2018))

When generating circular economy plans, the type of processed food must be considered to recognize which ones generate a larger carbon footprint and food wastage (Fig. 6.5).

Food wastage is responsible for around 6% of global greenhouse gas emissions (OurWorldInData, 2020). In addition, Conrad (2020), in a report that included more than 40,000 Americans, found that the average person spends about $1,300 a year on food that is not eaten.

The data subsequently show that the problem is not only in the processing of foods in a noncircular manner but also in the process of consumption that is not carried out sustainably, which leads to a significant loss of food while there is a considerable number of people in the world who do not have access to food for their survival. This situation is a paradox.

### 6.2.2 *Waste of Water*

The use of water and wastewater is one of the most significant challenges for the circular economy as numerous industries depend on water (Mauchauffee et al., 2012; Navarro et al., 2020; Nicolaidis & Vyrides, 2014). Wastewater disposal causes environmental damage, and more than half of the world's freshwater usage (2212 $km^3$ per year) is released to the environment as wastewater in the form of municipal water and industrial and agricultural drainage water (UNESCO, 2017).

The lack of availability of water is a problem of enormous dimensions. In recent decades, water scarcity, largely due to increasing urbanization and climate variability, has forced people to reduce pressures on water resources, mainly by reducing water demand. Water.org (2021) reports the following data regarding water availability:

(a) 785 million people lack access to safe water.
(b) 2 billion people lack access to adequate sanitation.
(c) Women and girls spend 200 million hours collecting water daily.
(d) one million people die yearly from water, sanitation, and hygiene-related diseases.
(e) Every 2 minutes, a child dies from a water-related disease.
(f) 1 in 3 schools lacks access to essential water and sanitation.
(g) 260 million USD is wasted through lost productivity each year globally due to a lack of essential water and sanitation.

These statistics show the urgency of circular measures in water management and efforts to reduce the pressure on water resources while limiting wastewater and to use effective and efficient treatment methods to protect people's health and lives and the environment.

It is interesting to understand how much an individual can contribute environmentally with consumption measures, like the meat-free Mondays initiative (www.meatfreemondays.com), which proposes avoiding meat consumption by consumers one day a week. For example, based on the calculator on the Meat Free Monday website, when four people (a typical family) stop consuming meat once a week for a year, the following results are achieved:

Animal agriculture uses water.
(a) 3157 full bathtubs worth of water usage is avoided. The average meat-eater requires 16 Olympic swimming pools of water to produce the meat they will eat over their lifetimes.

(b) The equivalent of 2434 $m^2$ of marine reserves are created. By avoiding seafood consumption, global demand is reduced, and marine and freshwater species are saved roughly at the rate of 11.7 $m^2$ marine reserve every meat-free day.
(c) The equivalent of 11.9 tennis courts on the forest floor are saved. Anthropogenic activity destroys the forests, which act to a large extent like the world's lungs, and global oxygen levels are dropping. Every meat-free day each person causes a slightly reduced global habitat destruction.
(d) People gain 6.67 days of extra lifespan. Compared to someone who eats 100 g of processed red meat per day, a person who does not eat any processed red meat could extend their life by 46.2 minutes per meat-free day.

An approach based on reduction and reuse (2R) can be taken as a strategy for sustainable use of water (Sakai et al., 2017). Such a strategy permits the generation of wastewater to be avoided precisely by reducing the use of water and pollution at the source. Reuse involves reusing wastewater as an alternative source of water supply. A 3R (reduction, reuse, and recycling) approach has also been previously proposed, involving recovering wastewater and treating it to be used as drinking water (Huang et al., 2018; Moriguchi, 2007). Finally, a 4R (reduction, reuse, recycling, and recovery) approach has been proposed, wherein resources such as nutrients and energy are recovered from wastewater (Yu et al., 2021; Zand et al., 2020).

There are various initiatives worldwide that are focused on the circular economy. Selected strategies developed in countries in Europe are as follows:

Albania: Country Specific Report on Circular Economy (POLIS, 2021). Other efforts were reported, too (UNECE, 2020; World Bank, 2020).
Germany: 2020 Status Report on the German circular economy (IFAT, 2020).
Andorra: Borgen Project outcomes (Borgen Project, 2017).

Also, the Organisation for Economic Co-operation and Development (OECD) has produced various reports from its countries related to circular economy efforts: Spain (OECD, 2021), Sweden (OECD, 2020b), and the Netherlands (OECD, 2020a). Furthermore, based on reports by organizations, we have numerous World Bank reports about circular economy implementation, as follows: Bolivia (World Bank, 2018f), Brazil (World Bank, 2018d), Chile (World Bank, 2019a), Egypt (World Bank, 2018c), India (World Bank, 2019c), Mexico (World Bank, 2018a), Peru (World Bank, 2019b), South Africa (World Bank, 2018b), and USA (World Bank, 2018e).

### *6.2.3 Organic Waste Management*

Most organic waste materials can be composted, requiring extensive material shredding before adding it to a compost pile. Certain materials can begin to decompose in a storage pile; however, complete composting occurs when it is mixed and handled in the correct proportions of carbon and nitrogen, with adequate airflow and humidity. The materials considered unacceptable for composting include: chemically treated wood products, plastics (bags, bottles, film sheets), raw grass and chunks of soil, and large bulky volumes (concrete and asphalt). The materials considered acceptable for composting include green and woody plant clippings, soil, plant media, untreated wood, and uncoated paper scraps.

Indicators of good compost are as follows (University of Missouri, 2021):

(a) The producer can give details of the composting process.
(b) Raw materials must not be recognizable.
(c) There should be no unpleasant odor.
(d) The compost temperature is not more than 11 °C above air temperature after delivery.
(e) The C/N ratio is 15:1 to 20:1.
(f) The pH is not higher than 8.0 (ideal 6.5) before mixing.
(g) The value of CE (soluble salts) is less than 6.0 mmho/cm before mixing with other components. The CE of the final potting mix should be less than 1.0.
(h) The ammonium level is low.

## 6.3 Firms Involved in Waste Management

Some examples of leading companies in waste treatment are Biffa (https://www.biffa.co.uk) since 1912 in the UK, Cleanaway (https://www.cleanaway.com.au) since 1979 in Australia, Clean Harbors (https://www.cleanharbors.com) since 1980 in the USA, Covanta (https://www.covanta.com) since 1986 in the USA, Waste Connections (https://www.wasteconnections.com) since 1997 in the USA, Bingo Industries (https://www.bingoindustries.com.au) since 2005 in Australia, and Renewi (https://www.renewi.com/nl-nl) since 2017 in the Netherlands.

When efforts are made to encourage consumers to participate in recycling, garbage and recycling bins of different colors are used, as has been done for many years in many jurisdictions. However, there has been strong criticism of the initiative's efficiency (Peng & Zhou, 2019). Thus, some institutions have colored garbage bins to facilitate appropriate disposal, but there is no differentiated collection of classified garbage in several institutions, which means the classification effort remains without any impact. In this sense, waste management initiatives must be comprehensive to achieve the expected effect on waste management.

Many companies identify waste as a critical environmental impact, which they address via their Environmental Management System (EMS). The ISO 14001 Environmental Management System is the most widely recognized standard for environmental management. Companies set their objectives and develop processes to achieve them. As such, ISO 14001 can be used to help minimize waste and move towards closed-loop recycling. With certification from Bureau Veritas, companies can demonstrate and verify their commitment to sustainable business (BureauVeritas, 2021).

Due to the coordination of efforts required for waste management processes, artificial intelligence is increasingly being proposed. In this way, garbage generation can be predicted, considering the type, origin, and destination. This type of intelligent management achieves better waste management results (Zhang et al., 2019), although some barriers have been identified (Sarc et al., 2019).

It is still important to be aware of the countries' initiatives to identify the best strategies for circular economy implementation. Countries have reported widely on efforts for circular economy implementations, including the following: Europe (Malinauskaite et al., 2017), Croatia (Luttenberger, 2020), India (Sharma et al., 2020), Italy (Isernia et al., 2019), Togo (Salguero-Puerta et al., 2019), Russia (Plastinina et al., 2019), Poland (Smol et al., 2020), Cyprus (Symeonides et al., 2019), Nigeria (Ezeudu & Ezeudu, 2019), South Korea (Kim & Park, 2018), Vietnam (Schneider et al., 2017), Switzerland (Haupt et al., 2017), Brazil (Ferreira et al., 2021), China (Bao et al., 2019), and Austria (Van Eygen et al., 2018).

## 6.4 Closing Remarks

Implementing the circular economy is a gradual process and can be based on waste management by organizations, especially companies. The generated waste requires concrete and efficient strategies that allow waste management to achieve the expected results, which can contribute to the SDGs, the Paris Agreement, and various climate commitments. Initiatives for the implementation of a circular economy should be incentivized through facilities and tax bonds for companies. Also, universities and colleges should be required to develop comprehensive training programs so that the circular economy is understood and future citizens and professionals develop sound actions for waste management.

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# Chapter 7
# The Circular Economy and Energy

Marc A. Rosen

## 7.1 Introduction

The circular economy is an economic system that reduces the continual use of resources and generation of waste linearly and instead envisions a closed-loop system. Thus, the circular economy employs activities such as repair and refurbishment, reuse, and recycling. Doing so helps reduce resource use and the creation and emission of wastes, including pollutants and carbon, and keeps products and systems in use longer, improving productivity. With this regenerative approach, waste energy and material should often become be an input for other processes. For example, Alvarez-Risco et al. (2020a) describe a new regulation in Peru for supporting a circular economy in the plastic industry. The circular economy is somewhat akin to industrial ecology, which is focused on finding ways to lessen the environmental impact of industrial systems by mimicking the behavior of natural systems, in part by reducing the use of natural resources and generating less waste (Graedel & Allenby, 1995, 2010; Zvolinschi et al., 2007).

Design is the creation of a product or process to satisfy a needed service. Design is usually complex and involves many steps and factors (Walker, 2010; Jonker & Harmsen, 2012; Lindow et al., 2012; Rosen & Kishawy, 2012; Lau, 2010; Nagel et al., 2012). Some of the factors considered in design include the ability to function and meet its purpose, safety, manufacturability, maintainability, economics, materials and equipment requirements, efficiency, reliability, lifetime, legal/regulatory compliance, customer satisfaction, and environmental impact. The inclusion of

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environmental considerations is often referred to as Design for Environment (DFE) (Graedel & Allenby, 1995, 2010).

DFE considers environmental concerns throughout a design process and varies in comprehensiveness and rigor. The lengthy lifetimes of some products, often decades, make DFE decisions early in the design process very important. As it is usually more straightforward, more effective, and efficient to alter designs for better environmental performance in the initial stages of a design, DFE is best addressed early. For example, it is often cheaper and simpler to reduce lead emissions by removing lead compounds from feedstocks rather than adding capture and treatment steps to the back end. Energy is used in most aspects of living and is an essential factor in the environment's design. DFE activities related to energy strive to use sustainable and environmentally benign energy resources and do so efficiently.

More broadly, since sustainable development involves the efficient utilization of only energy resources that cause little or no environmental impact, energy is directly linked to sustainable development (Adams et al., 2016; Anderson et al., 2016; Rosen & Abu Rukah, 2011; Zijp et al., 2015; Kuhlman & Farrington, 2010; Stock & Burton, 2011; Waas et al., 2011; Burns, 2012; Clifton, 2012; Abbott & Marchant, 2010; Yigitcanlar & Dur, 2010; Zavrl & Zeren, 2010; Bettencourt & Kaur, 2011; Kates, 2011; Orecchini et al., 2011). Sustainable development usually implies reliable and secure access to energy, good economics, and little environmental, health, and societal harm. The latter terms suggest it reduced or no use of energy resources that are finite and nonrenewable resources (e.g., fossil fuels) and increased use of renewable resources that are sustainable over the relatively longer term (e.g., falling water, biomass, wind, sunlight, and tides). Sustainable engineering also plays a vital role in sustainable development (Rosen, 2012, 2013; Allenby, 2011; Bell et al., 2011; Pearce et al., 2012; Armand, 2012; Rutkauskas, 2012; Bi, 2011). This chapter describes energy fundamentals and activities and design for energy selection and design for energy efficiency. Many facets of energy link to the circular economy and industrial ecology and design for the environment.

## 7.2 Fundamentals of Energy

### *7.2.1 Energy*

Energy resources are obtained from the natural environment and come in two main forms (Evans et al., 2009; Gomez-Echeverri et al., 2012):

- Renewable (or relatively renewable) resources, such as wind, solar energy, falling water, tides, geothermal heat, wood, and other biomass fuels (when the growth rate exceeds or meets the rate of use). For instance, geothermal energy has received much attention recently (Rosen & Koohi-Fayegh, 2017).
- Finite resources, including fossil fuels, fossil fuel-containing substances such as oil sands, peat, and uranium.

Energy carriers (or currencies or vectors) are the energy forms that we transport and utilize. They come into two types:

- Secondary (or processed) energy forms (e.g., electricity, work, heat, and diesel fuel). These are not typically found in the environment.
- Some energy resources (e.g., fossil fuels).

The difference between energy carriers and sources sometimes leads to confusion. Hydrogen and electricity, for instance, are energy carriers, even though hydrogen is often erroneously referred to as an energy source, as is electricity sometimes. However, hydrogen and electricity must be produced, as is commonly done from various resources via energy-conversion processes.

### *7.2.2 Energy Conversion*

Energy can be converted from one form to another. Desired energy carriers are produced from energy resources through energy conversion. The appropriate energy-conversion technology depends on the initial (or source) and final (or desired) energy forms. Energy-conversion technologies can be loosely separated into two types:

- Traditional energy-conversion technologies include fossil fuel, hydroelectric, nuclear electrical generating stations, motors, heaters, coolers, and fuel refineries.
- Alternative (or nontraditional) energy-conversion technologies, including wind generators, solar photovoltaic and solar thermal systems, electrochemical devices like fuel cells that generate electricity from hydrogen and oxygen, and polygeneration systems (e.g., cogeneration and trigeneration) that simultaneously produce multiple energy products.

Energy-conversion technologies can have varying efficiency and environmental attributes. Clean-coal systems include coal gasification integrated with carbon capture and sequestration devices. High-efficiency systems include combined-cycle systems for electricity generation.

### *7.2.3 Energy Use*

Generally, energy use involves:

- Production of helpful energy forms via energy-conversion processes
- Energy storage, transport, and distribution
- Utilization of energy (resources and secondary forms) to provide services and products

Various energy efficiencies can be defined for assessing energy use. Some examples are as follows:

- Conventional energy efficiencies (and inefficiencies or losses) often are determined based on energy flows. Note that a weakness of energy methods is that, for meaningful assessments, different energy forms must be assessed differently.
- Energy intensity reflects the energy use per some output unit, e.g., energy consumption per monetary unit of gross domestic product for a country or region. Primary processing activities (e.g., petroleum/coal production, chemical production, metal processing) generally have higher energy intensities than secondary processing activities, which usually is because the former tend to deal with raw materials and the latter finished products.

Energy use by an economy (e.g., city, region, country) can be assessed to provide helpful information, and many examinations of cities have been reported (Alvarez-Risco et al., 2020b). The energy use breakdown by the sector of an economy, in a simple sense, can be divided into two main groupings:

- Primary energy entering the economy is supplied directly to end-use sectors (transportation, industrial, commercial, institutional, residential).
- Primary energy entering the economy is processed into secondary energy forms (e.g., heat, electricity, processed fuels) and then supplied to end-use sectors.

Sustainable energy use is becoming increasingly of interest and plays a large role in the circular economy (Frangopoulos & Keramioti, 2010; Gnanapragasam et al., 2011; Hacatoglu et al., 2015; Hacatoglu et al., 2016; Khalid et al., 2015; Rosen, 2021; Gnanapragasam et al., 2011; Tomkiewicz, 2010; Tonn et al., 2010).

Energy use is usually significant in all sectors, although the energy forms supplied to sectors of an economy usually vary by jurisdiction. Sectoral energy use is often complex, involving a wide variety of activities (e.g., operating mechanical drives; lighting, process, space, and water heating; process and space cooling; and transportation). Activities in the industrial sector are often diverse, including pulp and paper processing; metal processing; clay, stone, and glass production; manufacturing; chemical and petrochemical processing; and food production (Graedel & Allenby, 1995). End-use energy consumption, broken down by sector and energy type, is illustrated for a hypothetical but not atypical region in Table 7.1.

## 7.3 Energy and a Circular Economy

Plans and actions for a circular economy for a jurisdiction *usually* aim to be both cleaner and more competitive economically, which necessitates a shift to a regenerative growth model that extracts less from the Earth. A necessary action to support a circular economy is sustainable and efficient energy and other resources. Other actions include reducing waste and contributing to climate change; reducing or limiting single-use products; enhancing utilization of more recycled materials in

**Table 7.1** Hypothetical energy usage in a region, broken down by sector and energy type

| Sector | Energy type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Electricity | Petroleum products | Natural gas and liquids | Coal | Wood and wood-related energy | Uranium | Hydraulic energy | Renewable energy (geothermal wind, solar, etc.) |
| Residential | ■ | | ■ | | ■ | | | ■ |
| Commercial | ■ | ■ | ■ | | | | | ■ |
| Institutional | ■ | ■ | ■ | | | | | ■ |
| Transportation | ■ | ■ | ■ | | | | | ■ |
| Industrial | ■ | ■ | ■ | ■ | | | | ■ |
| Energy conversion utilities | ■ | | ■ | ■ | | ■ | ■ | ■ |
| Non-energy use | ■ | ■ | | | | | | |

manufacturing; improving product durability, reparability, and recyclability; and keeping producers responsible for their products' performances throughout their life cycles.

Energy is clearly a key player in a circular economy because circular activities such as material processing normally require the energy of various types (fuel, electricity, heat, etc.), sometimes in significant quantities.

Some important energy options for enhancing a circular economy are now considered:

- One important energy option for enhancing a circular economy is to make sustainable energy technologies, especially those based on renewable energy, part of the circular economy itself.
- A related means of enhancing energy use to support a circular economy is to make energy use more sustainable by integrating sustainable energy into production, manufacturing, transport, storage, and consumption processes.
- An additional way to manage energy to support a circular economy is to expand the reuse and recycling of energy wastes, materials, components, and products.
- An important contribution to a circular economy can be made by decoupling economic growth from the use of energy and other resources. Of course, practical reasons suggest this needs to be done while maintaining economic competitiveness.

The World Bank projects annual waste generation to increase by 2050 by about 70%, rising from 2.0 billion tonnes in 2016 to 3.4 billion tonnes in 2050 (Kaza et al., 2018), and it is primarily driven by countries, regions, and cities growing in population, urbanization, and economic development. Much of this increase is linked to energy processes. Also, global consumption of materials such as biomass, fossil fuels, metals, and minerals is expected to more than double from 79 Gt in

2011 to 167 Gt in 2060, according to the Organisation for Economic Co-operation and Development's Global Material Resources Outlook to 2060 (OECD, 2019). Again, a large proportion of this increase is derived from energy processes. Furthermore, predictions for energy use in the next 30–50 years suggest that the transition to sustainable forms of energy needs to speed up to meet increasing energy demands if a circular economy is to be achieved. Together, these trends indicate how important it is to establish and scale up the circular economy. Note that energy technologies and systems themselves should be designed to consider circular economy principles. It is the case for conventional fossil fuel technologies and sustainable energy technologies such as wind turbines, solar energy systems, biomass plants, and batteries. They often utilize materials that cause notable environmental impacts during their extraction and manufacturing.

Consider the case of batteries. Batteries are important for many devices and systems, especially for electro-mobility through electric cars and other technologies. Large-scale battery use has major environmental impacts in terms of both resource extraction and waste releases. Li-based batteries are common at present, but efforts are being expended to develop new battery technologies, e.g., sodium-ion (Na-ion)-based batteries. Managing battery usage within a circular economy requires careful consideration of various factors:

- Measures for the collection and recycling of batteries
- Requirements for the use of recycled battery materials
- Actions for reducing or eliminating non-rechargeable batteries in favor of superior alternatives
- Sustainability characteristics and requirements for batteries

## 7.4 Factors Affecting Energy and a Circular Economy

Since the circular economy reduces the use of resources and generation of waste linearly and instead envisions a closed-loop system, it is important to understand the environmental impact of energy use, design for energy selection and energy efficiency, methods and technologies for energy efficiency, and use of advanced tools. These topics are covered in this section and are illustrated in Fig. 7.1.

### *7.4.1 Reduction of Environmental Impact of Energy Use*

Energy use often leads to environmental impacts (Nazzal et al., 2013; Kilkis et al., 2020). Some examples are as follows:

- Combustion of fossil fuels, wastes, and biomass leads to climate change and other forms of pollution via carbon dioxide, sulfur dioxide, nitrogen oxides, methane, and particles.

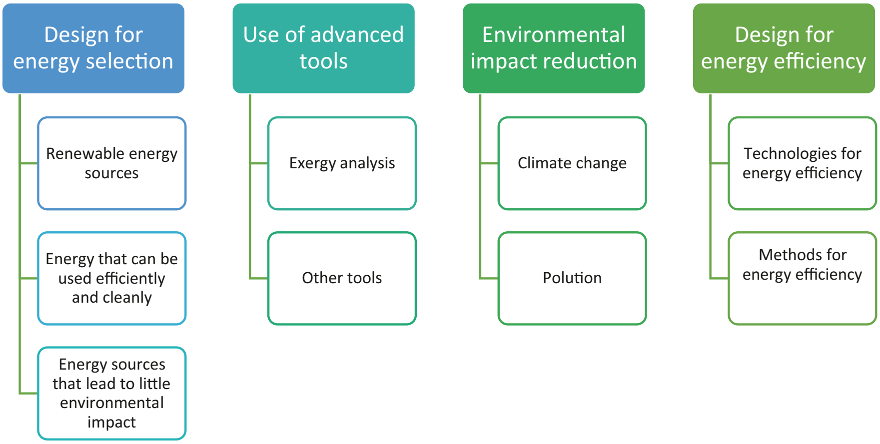


**Fig. 7.1** Various energy factors affecting the circular economy

- Water reservoirs and dams used by hydroelectric generation can change water flows and flood lands.
- Spent uranium from nuclear electrical generating stations has remained radioactive for thousands of years.

Environmental impacts associated with energy use occur over the entire life cycle of a product or process, not only during the operating phase. Thus, environmental impact is often best assessed using life cycle assessment (Curran, 2012; Finkbeiner et al., 2010; Russell-Smith et al., 2015; Sørensen, 2011), which analyzes the entire life cycle.

Fossil fuel combustion processes are often responsible for significant environmental impacts. Various approaches exist to reduce combustion emissions and their impacts. Some of the main approaches are as follows:

- Clean the fuel before combustion, e.g., desulfurize fossil fuels like oil and natural gas.
- Treat the combustion gases, e.g., remove particulate matter and acidic gases.
- Modify the combustion process, e.g., use dual combustion systems to reduce the production of pollutants like oxides of nitrogen.
- Substitute for a different process than combustion, e.g., carry out electrochemical oxidation via a fuel cell.

### 7.4.2 *Design for Energy Selection*

In energy selection activities, the selection of both energy sources and carriers should be considered carefully. The selection of energy sources and carriers often depends on the energy-conversion technologies available and the energy service to be provided.

Actions to mitigate or prevent environmental impact through energy selection consider the following approaches:

- Using renewable energy. Renewable energy sources usually are relatively benign and sustainable, although they are often more costly than nonrenewable energy sources.
- Utilizing energy sources that lead to little or no environmental impact. The use of renewable energy avoids many environmental impacts, although resources are needed to construct the technologies, and large land tracts are often required. Spent fuel is released due to the regular operation of nuclear power plants, although no other emissions occur. Fossil fuel utilization leads to emissions, like carbon emissions being more notable for coal than petroleum and then natural gas, based on the fuel's hydrogen-to-carbon atomic ratio.
- Exploiting energy sources and carriers that can be used more efficiently and cleanly. Some energy selections involve energy or fuel substitution.

### *7.4.3 Design for Energy Efficiency*

Designs can be developed to achieve high energy efficiencies. Some limitations are important to acknowledge:

- Theoretical limitations. Understanding the theoretical limits to efficiency is critical to decision-making when efficiency options are considered. This situation can be confusing because energy efficiencies generally do not measure how nearly the efficiency of a process of device approaches the theoretical upper limit, which has led to excessive resources to be dedicated to increasing energy efficiencies that are in fact near the upper limit while ignoring glaring efficiency improvement opportunities for devices far from the upper limit. The problems with energy efficiencies stem from ignoring energy quality, considering only energy quantities. Exergy efficiencies can overcome the problems associated with energy efficiencies since they account for the degradation of energy quality during real processes.
- Practical limitations. The practical aim when selecting energy sources and utilization processes is not the upper limit efficiency. Instead, optimal trade-offs are sought among efficiency and other relevant factors: environmental impact, economics, sustainability, health and safety, and acceptability. The optimum depends on many factors that can be utilized to encourage or discourage increased efficiency, e.g., governments can disincentive some activities through taxes and regulations and incentivize others through financial inducements to enhance the economic attractiveness of efficient technologies.

In brief, theoretical limitations establish the maximum efficiency theoretically attainable, while practical limitations include further factors that limit energy efficiency.

### 7.4.4 *Methods and Technologies for Energy Efficiency*

Numerous methods and technologies exist for energy-efficient designs and retrofits. These are discussed here, broken down by type.

#### 7.4.4.1 High-Efficiency Technologies

The first type of methods and technologies is based on high-efficiency technologies:

- High-efficiency devices. High-efficiency devices can generally be used to increase energy efficiency, e.g., high-efficiency furnaces, air conditioners, boilers, home appliances, and motors. In the latter case, it is pointed out that variable-speed motors and drives can be used with pumps, fans, compressors, heat pumps, and process lines in the industry to increase efficiency.
- High-efficiency building envelopes. The energy efficiency of a building can be improved using such measures as increased insulation to reduce heat gains in summer and losses in winter. Also weatherstripping and caulking to reduce air leakages into and out of buildings, high-efficiency windows with multiple glazing and low-emissivity window coatings, and window shades or blinds equipped with sensors that adjust to keep out excessive sunlight can be used.
- High-efficiency lighting. Lighting is a significant energy consumer. New bulbs have significantly higher efficiencies and longer lives than older equipment, e.g., the efficiencies (in lumens of light delivered per watt of electricity) (DOE, 1986) are 10–30 for incandescent, 20–55 for mercury, 20–60 for fluorescent, 50–130 for high-pressure sodium, and 80–155 for low-pressure sodium lights and even higher for LED lighting. Other measures to increase lighting efficiency and effectiveness include reducing lighting intensities, the use of task lighting, and the use of timers and occupancy sensors.

#### 7.4.4.2 Technologies Incorporatable into Systems to Enhance Efficiency

The next type of methods and technologies is based on technologies that can be incorporated into systems to enhance efficiency:

- District energy. District energy involves both, e.g., buildings in some cities are often connected by pipes through which hot water or steam flows to provide space and water heating, and through which cold water flows to provide cooling. District heating uses centralized heating facilities to produce a heated medium that is transported to many users via a network, while district cooling is the central production of a cold medium, which is transported to users for cooling.

- Polygeneration. Generating more than one product simultaneously sometimes increases efficiency compared to separate processes for each product. Cogeneration, or combined heat and power (CHP), is used by many industries and utilities (Rosen & Koohi-Fayegh, 2016). Trigeneration extends cogeneration by adding cooling. Polygeneration involves the generation of multiple products in general (Mehr et al., 2021).
- Integrated energy systems. Efficiency can be increased by linking separate systems advantageously to create integrated energy systems (El-Halwagi, 1997), e.g., using wastes from one or more processes as inputs to others so as to link them beneficially.
- Energy storage. Energy storage can be used to improve system efficiency by storing energy between times when it is available and when it is needed, if these are not coincident, e.g., solar thermal energy collected in the day for space heating at night using thermal energy storage (Dincer & Rosen, 2021b).

#### 7.4.4.3 Methods for Enhanced Efficiency

The final category of methods and technologies for energy-efficient designs and retrofits is based on methods that can enhance efficiency:

- Improved matching of energy supplies and demands. Instead of supplying energy of a much higher quality than required for a demand, it is usually more efficient to supply an energy form of a better-matched quality, e.g., supplying heat at 45 °C to space heat a building to 22 °C, rather than furnace combustion gases at 600 °C.
- Energy loss prevention and waste recovery. Efficiency can be improved by preventing energy losses and recovering energy wastes, inspecting periodically to detect and mitigate losses, and using technologies and processes to avoid losses (e.g., insulating). Energy wastes can be recovered, e.g., waste heat recovery from hot fluids, leading to increased efficiency by avoiding the additional external energy input that would otherwise be necessary.
- Maintenance, monitoring, and control. Equipment's efficiency and life span can be enhanced via maintenance and related actions, e.g., regular equipment cleaning, replacing consumable items, lubrication of moving parts, periodic equipment overhauls, and periodic calibration, tuning, and testing of equipment. Careful monitoring and control can also improve efficiency.
- Use of passive technologies. Passive, as opposed to active, methods can be used to reduce energy use, e.g., utilizing daylight harvesting to offset artificial lighting and using solar energy to heat buildings by exploiting the thermal energy storage capacity of buildings, and placing trees, windows, and window shades to keep buildings cool during summers.

### 7.4.5 *Use of Exergy Analysis and Other Tools*

Exergy can be viewed as a measure of the usefulness or quality of energy. It is defined as the maximum amount of work that a stream or system can produce when brought into equilibrium with a reference environment. Exergy is consumed during real processes due to irreversibilities and conserved during ideal (reversible) processes, whereas energy is a conserved quantity.

Exergy analysis is based on the second law of thermodynamics and has several advantages over energy analysis, which is based on the first law of thermodynamics and the principle of conservation of energy. More meaningful efficiencies are evaluated with exergy analysis since exergy efficiencies are always a measure of the approach to the ideal. Process inefficiencies (types, causes, and locations) are better identified and measured with exergy analysis. Many applications of exergy analysis have been reported (Dincer & Rosen, 2021a; Kotas, 1995; Szargut et al., 1988). Other analysis methodologies are also based on the second law of thermodynamics, e.g., lost work analysis and pinch analysis. Many suggest that thermodynamic performance is best evaluated and improved using exergy analysis in addition to or in place of energy analysis.

## 7.5 Advances and Developments on Energy and a Circular Economy

Several important reviews have been published recently on the circular economy in general. For instance, a systematic review has been done on circular economy performance assessment methods (Sassanelli et al., 2019). Circular economy definitions and future research paths have also been reviewed (Alhawari et al., 2021). The relation of energy to the circular economy has been examined from various perspectives. Energy infrastructure and modularization have been investigated (Mignacca et al., 2020), as have energy markets and the roles of enterprises within them (Gitelman et al., 2019). Sustainable, renewable, and green energy have received considerable attention concerning the circular economy (Klemeš et al., 2019; Olabi, 2019; Gallagher et al., 2019; Hao et al., 2020), which has included much work on biomass energy (Sherwood, 2020) and solar photovoltaic technology (Heath et al., 2020; Mathur et al., 2020).

Advances have also been made about energy system design and the circular economy. For instance, the use of eco-design has been examined for stand-alone renewable energy technologies (Gallagher et al., 2019). In addition, there has been effort expended on improving the circular economy through process integration (Klemeš et al., 2019) as well as energy recovery in general (Halkos & Petrou, 2019; Zohar et al., 2021) and heat recovery in particular (Khayyam et al., 2021). Individual energy technologies that have a significant role in the circular economy have also received attention. For instance, the energy and environmental benefits of circular economy strategies have been applied to reusing used batteries (Cusenza et al., 2019), hydrogen energy technologies (Sharma et al., 2020), and electric vehicles (Cusenza et al., 2019). A circular economy approach to energy has been the focus of studies for various industries. For example, the olive oil industry and its thermochemical conversion processes have been examined (Nunes et al., 2020), as have the following industries: carbon fiber manufacturing (Khayyam et al., 2021), agrochemicals (Zohar et al., 2021), buildings (Kosanović et al., 2021), and sewage sludge (Zohar et al., 2021). More generally, the water-energy-food nexus has been the focus of advances in recent years in relation to the circular economy (Del Borghi et al., 2020; Sharma et al., 2020). Focused studies for individual countries and regions have also been undertaken regarding energy to the circular economy. For example, a meta-analysis reported circular economy practices in India (Priyadarshini & Abhilash, 2020), while the energy refurbishment of family houses in Serbia was carried out following circular economy principles (Kosanović et al., 2021). More broadly, the energy efficiency of EU member states has been investigated in line with the circular economy (Halkos & Petrou, 2019). Finally, circular economy principles for clean energy transitions and opportunities under the COVID-19 pandemic have been studied recently, as have energy transitions (Su & Urban, 2021). It is noted that advanced tools have been employed to support some of this work, such as machine learning (Khayyam et al., 2021).

## 7.6 Example

Consider electric space heating (Fig. 7.2). The energy efficiency of space heating with an electric resistance heater is often 98% or higher, suggesting that the maximum energy efficiency possible for this heating device is 100%. However, this is incorrect, as the energy efficiency neglects that a low-quality product (warm air) is obtained using a high-quality input (electricity) in this process. The exergy efficiency of space heating recognizes this difference in energy qualities and is 6%. Since thermodynamically reversible (ideal) space heating has an exergy efficiency of 100%, the same space heating can, in theory, be achieved using about 6% of the electricity used in conventional electric resistance space heating. In practice, one can achieve space heating with a significantly reduced electricity input using a high-efficiency electric heat pump (Fig. 7.2), using 20% of the electricity that electric resistance heating would require, for a heat pump with a "coefficient of performance" of 5.

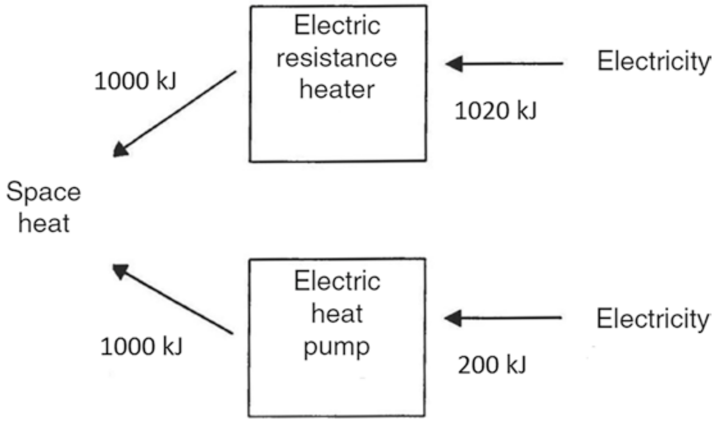


**Fig. 7.2** Comparison of the electricity required for the same electrical space heat using a resistance heater (top) and a heat pump (bottom). To produce 1000 kJ of space heat, an electrical resistance heater with an energy efficiency of 98% requires 1000/0.98 = 1020 kJ of electricity, while an electric heat pump with a coefficient of performance of 5 requires 1000/5 = 200 kJ of electricity

## 7.7 Closing Remarks

Designing for appropriate energy efficiency and selection is essential in the circular economy and its regenerative approach. It can support efforts to reduce processes and systems' environmental impact by reducing natural resource use and waste generation. These are important elements of the circular economy. Designing for appropriate energy efficiency and selection topics will likely become more significant in the future, as part of the circular economy and, in general, as technology advances. Potential future energy-related trends include increased efficiency to reduce resource consumption and environmental impacts, increased utilization of more environmentally benign and sustainable energy forms and sources, decarbonization, and greater use of clean technologies. Although this chapter is technically focused, nontechnical matters such as energy system management, economics, and law are also important and must be addressed for a holistic consideration of the relation of energy to the circular economy.

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# Chapter 8
# Supply Chain and Circular Economy

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## 8.1 Introduction

Supply chain management (SCM) and its processes aim to maintain a desired flow of materials. Standardized operating procedures (SOPs) have been developed in many industries to ensure that these processes are carried out correctly. Also, organizations that support supply chain management activities, such as the Association for Supply Chain Management (www.ascm.org), have developed guidelines to help companies attain the certifications required or sought after globally.

Similarly, certifications are provided to professionals based on the specific competencies developed in supply chain-related processes. Some examples of such certifications and the institutions that provide them are as follows:

– National Contract Management Association (www.ncmahq.org).

  Certified Professional Contract Manager.

– The International Society of Logistics (www.sole.org).

  Certified Professional Logistician.

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**Fig. 8.1** Supply chain traceability

– Institute for Supply Management (www.ismworld.org).

Certified Professional in Supplier Diversity.

– Association for Supply Chain Management.

APICS Certified Supply Chain Professional.

Professionals, organizations, and companies' efforts and certifications aim to provide useful and consistent supply chain processes. In particular, the efforts and certifications help ensure traceability through the processes, as shown in Fig. 8.1. Each of the processes shown in this figure covers stakeholders' various responsibilities, starting from purchasing raw materials to the final delivery to the consumer. Note that these processes require transparency so that the details of each action in the supply chain process are known and understood, as this is a fundamental requirement to ensure the successful implementation of the circular economy.

## 8.2 Supplier Standardization

The point of entry to a system shown in Fig. 8.1 involves purchasing raw materials to start the manufacturing process, which is a critical step because it implies external contact, and the operation of the production cycle depends on it. Failure or deficiency in raw material supply usually directly impacts the production process and the ultimate delivery times to the consumer, economically impacting the company.

Achieving standardization of suppliers should be a standard process in companies, regardless of when they have been affiliated with previous suppliers, especially when developing new suppliers. Detailed knowledge of the suppliers allows the necessary adjustments to be made in the circular economy implementation process. Hence, for example, if a company wants to improve the packaging material to be derived via clean production or biodegradable, it is a great advantage to have approved suppliers because this process can then be carried out transparently and fluidly. The improvement of packaging material is usually fulfilled by large companies in the world and some medium-sized companies and in sporadic cases by small companies. For this reason, the homologation process is essential for traceability in the production process.

### 8.2.1 Advantages of Supplier Standardization

Activities by companies for standardization of their suppliers provide various benefits:

(a) Strengthening the relationship between both companies since they typically work very closely in the process of standardization.
(b) Exhibiting a better image of the company.
(c) Better purchasing decisions, based on reliable information about the weaknesses and strengths of suppliers (times, quality, prices).
(d) Improved supplier processes due to homologation, which can improve relations with all clients.
(e) More fluid communications, allowing more efficient/optimal delivery times.
(f) Better knowledge of other products or services the supplier offers, which can be beneficial for the company at present or in the future.
(g) A better understanding by the company's supplier, providing the possibility to explore and offer new and better products/services.

In the circular economy, supplier standardization can help ensure that raw material is obtained by eco-efficient means, noting that it is not enough that the raw material is ecologically sourced but that it also has to be produced in an ecologically acceptable manner. Likewise, if a product pollutes more than others, supplier standardization assists in quickly finding eco-friendly alternatives. When companies seek to implement the circular economy in their processes, supplier endorsement gives them the ability to detect processes that can be improved and achieve these changes in a controlled and efficient way (Ávila-Gutiérrez et al., 2019; Brenner et al., 2018; Shamsuyeva & Endres, 2021).

### 8.2.2 Circular Economy Framework

Processes usually have five relevant stages that need to be considered in the circular economy: material input, design, production, consumption, and end-of-life resource management. The types of actions involved in these stages are outlined in a report from the Ellen MacArthur Foundation (Ellen MacArthur, 2015) as building blocks: circular product design and production, business models, cascade/reverse skills, and cross cycle and cross-sector collaboration.

A European Environment Agency report (EEA, 2016) details the main requirements for the implementation of the circular economy that should be foci:

(a) Reducing inputs and use of natural resources.
(b) Reducing emission levels.
(c) Reducing valuable material losses.
(d) Increasing share of renewable and recyclable resources.
(e) Increasing the durability of products.

One of the most relevant aspects of planning to implement the circular economy within the supply chain management involves having accurate process data to ensure that expected impacts are achieved in economic and environmental terms. Failure at this stage can lead to general business setbacks and not achieving the expected environmental impact reduction (Dewick et al., 2020).

## 8.3 Contribution of Internet of Things

The Internet of things (IoT) is a recent technology that increasingly has personal (Blythe & Johnson, 2021; Hoffman & Novak, 2018; Novak & Hoffman, 2019; Gligoric et al., 2019) and business use. IoT also has been the subject of increasing use in the implementation of the circular economy (Magrini et al., 2021; Mboli et al., 2020), as illustrated in Fig. 8.2. The company can monitor each step during the transportation process of raw materials and final products, from the manufacturing facility to the store where the final customer purchases them. The IoT can control all the processes in real time.

Beyond the multiple benefits that can be identified through the use of IoT for the implementation of the circular economy, data security must be ensured since IoT provides a potential vulnerability in data acquisition and management (De La Torre Parra et al., 2020; Dong et al., 2019; Mishra et al., 2020). Some security issues with IoT are as follows (Intellectsoft, 2020):

1. Lack of compliance on the part of IoT manufacturers.
2. Lack of user knowledge and awareness.
3. IoT security problems in device update management.
4. Lack of physical security.


**Fig. 8.2** Use of the Internet of things in monitoring

5. Botnet attacks.
6. Industrial espionage and eavesdropping.
7. Hijacking the IoT devices.
8. Data integrity risks of IoT security in healthcare.
9. Rogue IoT devices.
10. Cryptomining with IoT bots.

## 8.4 Barriers to the Circular Economy in Supply Chain Management

Regardless of the size or type of activity, companies often face various barriers to implementing the circular economy. In the macro environment, legal/regulatory barriers have been identified, which implies insufficient and inadequate regulation to promote or facilitate the implementation of the circular economy.

Various specific shortfalls have been reported in this area: lack of government support (Araujo Galvão et al., 2018; Badhotiya et al., 2021; Fonseca et al., 2018; Gedam et al., 2021; Grafström & Aasma, 2021; Gue et al., 2020; Kayikci et al., 2021; Kazancoglu et al., 2021; Kumar et al., 2021; Kumar et al., 2019; Rizos et al., 2016; Sharma et al., 2021; Veleva & Bodkin, 2018), lack of indicators (Avdiushchenko & Zając, 2019; de Oliveira et al., 2021; Elia et al., 2017; Foster & Kreinin, 2020; Gravagnuolo et al., 2019; Kristensen & Mosgaard, 2020; Rincón-Moreno et al., 2021; Rossi et al., 2020; Saidani et al., 2019; Santagata et al., 2020), policy barriers (García-Quevedo et al., 2020; Kazancoglu et al., 2021; Kumar et al., 2021; Milios, 2021; Singh et al., 2020; Upadhyay et al., 2021; van Keulen & Kirchherr, 2021), lack of environmental culture (Foster, 2020; Foster & Kreinin, 2020; Gravagnuolo et al., 2019), lack of incentives (Fischer & Pascucci, 2017; Grafström & Aasma, 2021; Hart et al., 2019; Kumar et al., 2021; Mahpour, 2018; Veleva & Bodkin, 2018), perception of expensiveness of the process (Muranko et al., 2019; Rogers et al., 2021), consumer awareness of the circular economy (Kirchherr et al., 2018; Sharma et al., 2021; Sijtsema et al., 2020), complications regarding a uniform approach to the concept of a circular economy (Betancourt Morales & Zartha Sossa, 2020; Geisendorf & Pietrulla, 2018; Hazen et al., 2021; Henry et al., 2021; Kazancoglu et al., 2018; Kirchherr et al., 2017; Korhonen et al., 2018; Morseletto, 2020; Sverko Grdic et al., 2020), and lack of awareness by firms (Bag et al., 2021; Bilal et al., 2020; Bjørnbet et al., 2021; Govindan & Hasanagic, 2018; Hartley et al., 2020; Liakos et al., 2019; Masi et al., 2018).

We now consider one industry as an example. Specifically, various challenges are recognized that organizations have to address for implementing a supply chain in a circular economy in the food sector (Sharma et al., 2019; Demestichas & Daskalakis, 2020; Jinil Persis et al., 2021; Kurkcu & Ozbay, 2017; Nowakowski & Mrówczyńska, 2018; Paiho et al., 2021):

### 8.4.1 Poor Government Policies

A managerial decision can initiate the implementation of the circular economy in companies in the food sector, but the success of this business decision is strongly influenced by the legal and policy context in which the company is situated. In China (Ellen MacArthur Foundation, 2020; Li et al., 2021) and Europe (Calisto Friant et al., 2021; European Commission, 2020; UNEP, 2021), there are already important regulations that support and promote the implementation of the circular economy. However, in many other countries, support from the government is preliminary, and local initiatives have been launched only recently. For this reason, many still desired that governments take the circular economy as a high priority for their companies and citizens, knowing the positive impacts that can be generated at economic, environmental, and social levels. Circular economy initiatives have also been observed in countries, such as those that make up the OECD (OECD, 2020).

### 8.4.2 Transportation and Infrastructure Issues

Traceability, a cornerstone of the circular economy, inevitably requires transportation technology to facilitate traceability.

### 8.4.3 Traceability Issues

Traceability is part of the trustworthiness of the circular economy implementation process (Centobelli et al., 2021; Koh et al., 2020; Schenten et al., 2019). This factor is also related to certain levels of formalization of activities. The formalization and certifications of companies are promoted for the implementation processes. Therefore, general certifications such as ISO 9001 serve as a starting point to ensure that internal processes are consistent and record all activities carried out.

### 8.4.4 Packaging Issues

Product packaging is one of the most commonly recurring themes when examining ways to implement the circular economy (Geueke et al., 2018; Meherishi et al., 2019; Meys et al., 2020; Testa et al., 2020; Van Eygen et al., 2018). While it is true that the vast majority of products can benefit from changing packaging, this may not always be possible for specific products. Nonetheless, much emphasis has been placed on managing plastic waste, anticipating reduced use, and correct management (Alvarez-Risco et al., 2020; Wagner & Schlummer, 2020). More broadly, this can be one of the principles of approaches for the circular economy: ecological management of manufacturing materials.

### *8.4.5 Lack of Cold Chain*

Rural regions or those with less technology availability face problems ensuring the cold chain of the products they receive. In this sense, food can be optimally preserved only if the cold chain is ensured in these scenarios (Jurgilevich et al., 2016; Vilariño et al., 2017). However, the cold chain must be ensured from the starting point of the raw material to its arrival at the manufacturing area and its subsequent delivery to the final consumer. Therefore, there must also be ports with a sustainable approach that ensures the cold chain at all times and that have sustainable operations in all their processes (de Langen & Sornn-Friese, 2019; Gravagnuolo et al., 2019; Karimpour et al., 2019).

## 8.5 A Supply Chain Based on Sustainability and the Circular Economy: A Rotterdam Port Case

One good example of implementing sustainability and circular economy criteria is the Port of Rotterdam. A video describing the Port of Rotterdam is available at https://vimeo.com/342996921.

Some of the main elements of the port are as follows (Port of Rotterdam, 2021):

(a) Municipal waste revaluation.

Circular companies are offered the opportunity to connect with initiatives that extract energy from waste and innovations in the field of water cycles.

(b) Biorefineries of the future.

Biorefineries will provide future generations with the sustainable resources they need to advance based on fertilizers and complex organic matter and biofuels, electricity, and heating.

(c) New generation chemical industry.

The new generation chemical industry houses many specialized and innovative chemical plants that form the new generation of this sector. These forward-thinking factories offer circular economy startups and expansions the option of co-location and collaboration.

(d) Special infrastructure for R&D and innovation.

**Table 8.1** Companies linked to the Port of Rotterdam

| Company | Services | URL |
|---|---|---|
| AEB Amsterdam | Biobased and circular industry | https://www.aebamsterdam.com |
| Avantium holding | Chemical, biobased, and circular industry | https://www.avantium.com |
| Beelen Amsterdam | Circular industry and waste processing | https://www.beelen.nl |
| Biodiesel Amsterdam | Biobased and circular industry | https://www.biodieselamsterdam.nl |
| ChainCraft | Chemical, biobased, and circular industry | https://www.chaincraft.nl |
| Granuband | Circular industry and recycling | https://www.granuband.com |
| HKS metals | Scrap, steel, and metals | https://www.hksmetals.eu |

Prodock is where the Port of Amsterdam offers specialized plug-and-play facilities for circular and biobased innovation. With this approach, they collaborate with the development of startups and scale-ups.

The Port of Rotterdam has various alliances with companies that use the port's waste to generate new resources. Some companies related to the Port of Rotterdam are listed in Table 8.1.

The most valuable achievement by these companies is to take the waste and turn it into products. An infographic describing the Port of Barcelona is available at

https://piernext.portdebarcelona.cat/wp-content/uploads/2021/03/07_marpol-infografia_1.gif.

## 8.6 Changes to Electric Transportation

Some significant changes to supply chains have occurred due to global sustainable commitments and the demands caused by the COVID-19 pandemic. Some of these are now discussed:

(a) The last mile is getting electric.

Since the pandemic, delivery in the last mile with electrified transport has increased within the supply chain. This electrification is a change taking place slowly in the most remote places, but that already exists in the big cities. Likewise, some ports already have electrical transport that contributes to the sustainable traceability of products that benefit from raw materials or circular manufacturing processes and are also transported circularly.

(b) Regulation as pressure.

Increases in local, national, and regional regulations have pressured governments to develop production processes under the circular economy. These changes affect transportation as well as storage, packaging, and waste management processes. In this way, supply chain processes become more circular. Perhaps the progress will be slow and almost imperceptible, but these changes are likely generating efficiencies in organizations that follow these circular practices. Little by little, consumers will also attribute more significant value to these practices by companies and increase purchase intentions for products developed under circular parameters.

(c) Local lessons are crucial.

One of the essential missions of governments, ministries, universities, and citizens is to carry out an inventory of circular economy initiatives that have already been successful and can be replicated on a large scale. Different regions are reporting their findings; these are not necessarily possible in other locations. For example, details on local efforts and lessons were reported for Africa (Charles et al., 2019; Lee, 2019), Asia (Lehmann, 2018; Lobova et al., 2020), Oceania (Halog et al., 2021; Oughton et al., 2021), Europe (Calisto Friant et al., 2021; Domenech & Bahn-Walkowiak, 2019), and Latin America (Alvarez-Risco et al., 2020; Brenes-Peralta et al., 2020).

(d) Efficient transportation software.

The increasing use of electric power in transporting raw materials to finished products requires an efficient technological network that facilitates precise control of the vehicles. A need for cyber-attack prevention measures accompanies this need for software. Therefore, it is required to have technological certifications such as those developed for ISO 35: information technology, which include the following specific certifications:

35.020: Information Technology (IT) in General

Including general aspects of IT equipment.

35.030: IT Security

Including encryption.

35.040: Information Coding

Including coding of audio, picture, multimedia, and hypermedia information, barcoding, etc.

35.060: Languages used in information technology.
35.080: Software.

Including software development, documentation, and use.

35.100: Open systems interconnection (OSI).
35.110: Networking.

Include local area networks (LAN), metropolitan area networks (MAN), wide area networks (WAN), etc.

35.140: Computer graphics.
35.160: Microprocessor systems.

Include PCs, calculators, etc.

35.180 IT: Terminal and Other Peripheral Equipment

Including modems.

35.200: Interface and interconnection equipment.
35.210: Cloud computing.
35.220: Data storage devices.
35.240: Applications of information technology.
35.260: Office machines.

Including typewriters, dictation equipment, addressing machines, letter opening machines, letter folding machines, postal franking machines, ribbons, and other accessories.

## 8.7 Circular Economy in Maritime Transportation

Maritime transport is a fundamental part of international business. However, maritime transport generates around 2.5% of global greenhouse gas emissions, causing the acidification of the oceans, which in turn is causing the death of coral reefs and thus reducing ocean oxygen levels. The decarbonization of shipping is linked to the preservation of the oceans (Poseidon Principles, 2021).

To decarbonize shipping, the Poseidon Principles were developed in June 2019 (Poseidon Principles, 2021). These constitute the first climate alignment agreement for responsible financing of shipping. Engagement is sought to assess and disclose the climate alignment of shipping portfolios and work to align the portfolios with climate goals. Poseidon-linked loans incentivize borrowers (shipowners) to decarbonize their fleets by lowering their interest rate as fleet emissions decline. Currently, 27 banks have already signed a commitment to the Poseidon Principles. Some of them are listed in Table 8.2.

**Table 8.2** Banks signed on to Poseidon Principles

| Bank | Country | URL |
|---|---|---|
| Sumitomo Mitsui banking corporation | Japan | https://www.smbc.co.jp/global |
| Sumitomo Mitsui trust Bank | Japan | https://www.smtb.jp/tools/english |
| Standard chartered | UK | https://www.sc.com/en |
| Sparebanken vest | Norway | https://www.spv.no |
| Société Générale | France | https://particuliers.societegenerale.fr |
| Nordea | Denmark | https://www.nordea.se |
| ING | Netherlands | https://www.ing.es |

## 8.8 Closing Remarks

Supply chain management is an activity that has a direct relationship with the circular economy in organizations. The great importance of the knowledge of each process in the production is described: the purchase of raw material to the final delivery of the product. It is also possible to show that for the supply chain to contribute to the circular economy implementation process, it is necessary to achieve the approval of suppliers to ensure controlled processes. Another aspect that is developed and increasingly crucial in supply chain management is the use of the Internet of things to ensure real-time traceability of the various local and international processes of inputs and products. Additionally, the main barriers to implementing the circular economy in the supply chain are detailed to serve as a reference so that new strategies are generated that help overcome the barriers for organizations. Examples are presented of different ports that have managed to implement the circular economy and can be seen as a referral practice in other cities by both authorities and companies. The examples can also be evaluated in universities to generate new research that helps to identify the factors and opportunities for improvement.

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# Chapter 9
# Public Policy for Circular Economy: The Case of the National Strategy of Circular Economy in Colombia

**Bart van Hoof and Alex Saer**

## 9.1 Antecedents of the National Strategy of Circular Economy

Resource scarcity and impacts of climate change urge governments to motivate and scale the adoption of sustainable practices by all society actors (McArthur Foundation, 2014). Recent estimations of delayed cost for climate change mitigation sum 17% of global GDP in 2070, following the 1.5 degrees' scenario (Sanderson & O'Neill, 2020). Moreover, the global use of materials almost tripled in the last four decades, reaching 92.1 billion tons in 2017 (IRP, 2019), and is forecasted to double between 170 and 184 billion tons by 2050 (PACE, 2019). These global trends are most relevant for the emerging economies of Latin America, mainly based on resource-intensive activities such as agriculture, fossil fuel extraction, mining, and construction (ECLAC, 2020).

For example, Colombia's economy depends mainly on domestic extraction of raw materials (95% of volume), where mining of construction materials, oil, and carbon extraction count for 60% of the economy input and biomass (crops, cattle, and forestry) for 40% (Colombian Government, 2019). Colombian export volumes are 90% of oil and carbon, and domestic consumption is 50% biomass, 30% construction materials, and only 8% industrial materials. In comparison, a

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service-based economy such as the UK depends mainly on imports of resources and less than 10% on domestic extraction (IRP, 2019).

Material extraction is an important cause of environmental problems such as biodiversity loss, water stress, and biomass waste. Likewise, fossil fuel consumption and extensive agriculture are causes of climate change (PACE, 2019). It is clear that the linear consumption systems, take-make-use-dispose, cause waste to end up in landfills. In Colombia, domestic waste production is 0.68 kg per capita, of which 59% is organic waste, and about 98% ends up in a landfill. Recycling materials in Colombia vary from 71% metal, 66% paper, 30% biomass, 20% plastics, and 2% demolition waste (Tecnalia, 2017). Oppositely, in Sweden, 52% of waste is converted into energy, 47% gets recycled, and the remaining 1% is sent to landfills (Kaza et al., 2018).

Circularity, as a strategy for resource efficiency, proposes to design waste out of production and consumption systems by keeping materials and products in use, re-using and recycling the waste as raw materials, preventing waste materials by cleaner production and eco-design, using renewable sources for energy generation, re-using water flows, and regenerating natural systems (McArthur Foundation, 2017). A strategy on circularity invites industry and consumers to mimic natural systems where no material gets lost and the ecological systems regenerate. Implementing a strategy on circularity impacts resource flows by reducing extraction of raw materials, producing less waste, consuming more efficient products, and not disposing of any resource. Moreover, it implies that companies innovate their technology and business models, while consumers have to adjust their behavior, satisfying their needs in a different, more efficient way.

Public policies are essential mechanisms for guiding systematic changes, including paradigm shifts needed to develop a more circular economy (Janicke, 2002). These public policies respond to societal needs in guiding action by identifying priorities, setting goals, and implementing mechanisms that motivate stakeholders to change their behaviors. Moreover, public policies set a course in the mid and long term, triggering a critical mass of multiple actors, contributing to systematic societal changes (Shove, 2010). Guides and toolkits for public policy development in the circular economy (CE) are published by international organizations such as the Ellen MacArthur Foundation and the Organisation for Economic Co-operation and Development (OECD) (McArthur Foundation, 2015; OECD, 2020).

Diverse countries have adopted public policy mechanisms to advance CE (McDowall et al., 2017). One of the first countries was Japan, adopting 2000 laws to promote effective utilization of resources. Following similar ideas, Korea launched in 2005 its national eco-industrial park program, while China issued in 2009 its Circular Economy Promotion Law (Su et al., 2013). The European Commission presented in 2015 its Circular Economy package, including mechanisms to finance research, technological innovation, and regulations (Kirchherr et al., 2018). In 2018, the Netherlands presented its national strategy to advance a circular economy by 2050, followed by a specific policy on circular agriculture (Dutch Ministry of Agriculture, 2018). These international experiences have been studied as references for Colombia's National Strategy of Circular Economy (NSCE).

National antecedents of the NSCE include a tradition of policies integrating environmental protection and economic development. In 1997, and as one of the first countries in the region, Colombia presented its National Policy for Cleaner Production, inviting industry to improve its environmental performance based on voluntary agreements (Blackman et al., 2013). This public policy, led by the Ministry of Environment, was updated in 2010 with the National Policy for Sustainable Production and Consumption, highlighting supply chain approaches, extended producer responsibility, life cycle analysis as mechanisms to advance sustainable consumption, and productive transformation (MADS, 2010). In 2016, the National Policy of Integrated Solid Waste Management was presented, and in June 2018, as part of the process of entering the OECD certification, a National Policy on Green Growth was issued. This policy presented by the National Planning Department (DNP in Spanish) included a chapter on circular economy and assigned to the Ministry of Commerce, Industry, and Tourism (MCIT in Spanish) the responsibility to take up an active role in the matter (DNP, 2018).

Alignment between international trends and national policy development sustained the proposal to develop an NSCE as a commitment of the government of President Duque, who came to power in August 2018. Led by the Minister of Environment and Sustainable Development, Ricardo Lozano, a team of national and international experts developed the first structure of the strategy to be presented to the cabinet within the first 100 days of the new government. In sum, international trends on resource scarcity and climate change are highly relevant as a social need in Colombia's biodiverse and resource-based emerging economy. High-level political commitment and the timing of a new governmental period were fertile ground to advance the NSCE in Colombia.

## 9.2 The Process of Developing the National Strategy of Circular Economy

Developing the NSCE has been planned at the start of president Duque's government period from August 2018–July 2022. The planning concerned six phases; the first phase considered elaborating the proposal of the NSCE to be presented to the cabinet of President Duque's government. A team of national and international experts was appointed the responsibility. Critical decisions in this phase considered the explicit connection of the NSCE to the Green Growth Policy released in June 2018. This connection emphasized the continuity and long-term perspective as fundamental principles of public policy. Another critical decision considered the institutional positioning of the NSCE; even when the initiative was proposed and led by the Minister of Environment and Sustainable Development, he shared political leadership with the Minister of Commerce, Industry and Toursm, to underline the inter-institutional character of the National Strategy, just as was done in the case of the Dutch national circularity strategy (Potting & Hanemaaijer, 2018).

The acceptance of the proposal resulted in the commitment of the presidential office to advance the NSCE. This commitment was confirmed in a high-level public event, where leaders of industry and agriculture, academia, and public institutions signed a voluntary agreement for the transition to the CE in Colombia. Figure 9.1 illustrates the planning of the NSCE in Colombia during President Duque's governance period (August 2018–July 2022).

After developing a first conceptual approach for the National Strategy of Circular Economy, a bottom-up approach was used to disseminate the idea and identify opportunities for circularity initiatives in the regiones. Over 6 months, 12 seminars were organized in cities such as Santa Marta, Bucaramanga, Cartagena, San Andres, Villaviciencio, Buenaventura, Quibdo, Pereira, Mocoa, Cali, Medellin, and Bogota. A typical seminar agenda consisted of a capacity-building session on CE, local circularity initiatives, and a discussion panel that emphasized opportunities for local produce, transformative projects, and programs.

During April–May 2019, the National Planning Office (DNP)organized the first capacity-building program for representatives of public institutions to share the circularity vision among a critical mass of professionals of diverse public institutions. Over 60 participants, representing six different ministries and five national institutes, graduated from a 40-hour course. Besides capacity-building outcomes, the course promoted inter-institutional collaborations and unified criteria on CE perspectives and goals.

The seminars in the regions and the capacity-building programs represented the primary source for identifying circular initiatives, needs, and opportunities and contributing to the NSCE. Additionally, draft versions of the NSCE were discussed with representatives of business associations and Ministries of Agriculture, Mining, Transport, and Housing. After the regional and sectorial legitimation process, President Duque launched the NSCE on the 26th of June in a public event in the Chamber of Commerce of Medellin as the first circular economy public policy in Latin America.

In the first semester of 2019, the CE leadership team was hired as part of the Sectoral and Urban Direction (DAASU) of MADS. The leadership team, led by the director of DAASU, had the main task of promoting and coordinating the strategies proposed in the NSCE to advance its indicators. The leadership team was organized around the primary resource flows of the NSCE. It was made up of five professionals trained in industrial ecology and experienced sectoral experts of DAASU. The leadership team worked closely together with three professionals of the Business Development Direction of the MCIT.

The initial planning of the NSCE followed its course during 2019 and 2020, despite the restrictions imposed by the COVID-19 pandemic (see Fig. 9.1). Adaptation led to campaigns on separating waste at homes, highlighting the importance of the labor of recyclers during the pandemic, and region working groups advanced virtually and training programs and coordination meetings. The NSCE continued as a governmental policy priority. In August 2020, a change of leadership in the Ministery of Environment and Sustainable Development consisted of Minister Ricardo Lozano's resignation and the appointment of the new Minister Carlos Correa.

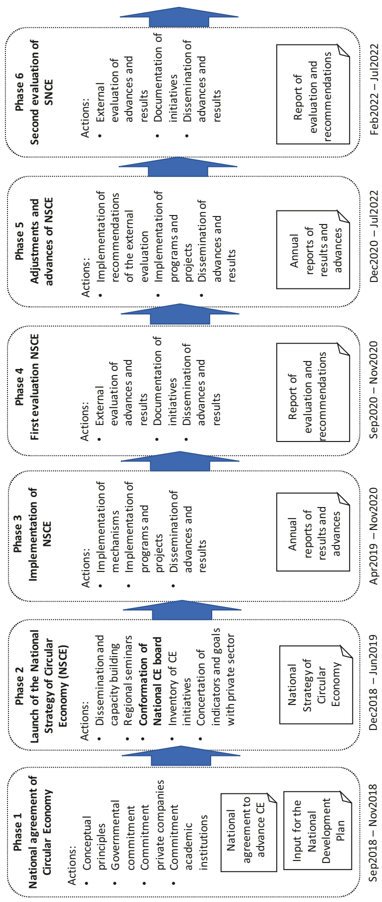


**Fig. 9.1** Planning of the NSCE in Colombia during President Duque's governance period. (August 2018–July 2022)

During the development and implementation phases of the NSCE, international cooperation programs supported several processes. First, the "Switch to Green program" of the European Commission supported international experts who took part in the team responsible for developing the NSCE document and its planning. The Dutch Embassy in Colombia supported the training of members of the leadership team and the organization of workshops on circular water management, circular technology innovation, and circular agriculture. German cooperation provided resources for developing a training program in the circular economy for the National System for Technical Education (SENA in Spanish). Swiss cooperation was provided through the office of the United Nations Industrial Development (UNIDO) technical assistance and resources for a national program on eco-industrial parks. Moreover, the director of DAASU participated in working groups on circular economy organized by the Organisation for Economic Co-operation and Development (OECD) and in workgroups of the Platform for Accelerating the Circular Economy (PACE) of the World Economic Forum (WEF).

In conclusion, the development and implementation process followed a 4-year planning aligned to the administrative period of President Ivan Duque Government. The appointment of a leadership team combining newly hired experts and experienced public employees provided institutional capacity for advancing the NSCE. International cooperation complemented national resources to advance the development and implementation process.

## 9.3 The Content of the National Strategy of Circular Economy

The Colombian approach on CE shares the conceptual bases of the Ellen MacArthur Foundation, highlighting the transformation of business opportunities towards enhanced resource efficiency. It follows the CE scope's European conception, focusing on resources and waste, technological innovation, and business opportunities (McDowall et al., 2017). Production and consumption systems are optimized considering all their elements and dimensions, advancing the capacity of auto-generation, auto-restoring, and regeneration through intelligent design and interconnectivity (Ellen McArthur Foundation, 2014). Transformation to a CE implies a paradigm shift from a linear to a circular logic of production and consumption, resulting from a gradual societal learning process (Kirchherr et al., 2018). The approach differs from the focus of the Chinese conception, which is broader, incorporating pollution alongside waste and resource concerns, and it is framed as a response to the environmental challenges created by rapid growth and industrialization (Ogunmakinde, 2019).

Circularity strategies and circular business models referenced in the Colombian NSCE follow the classification of the OECD (OECD, 2019). This classification identifies five groups of circular business models as (i) valuation of waste materials (e.g., recycling of PET material), (ii) material re-use (e.g., water re-use, demolition waste recovery), (iii) extending the lifetime of products (e.g., refurbish telephones, renewable energy sources), (iv) changing products for services (e.g., renting bikes), and (v) using information technology for dematerialization (e.g., Uber, data-based agriculture). These categories proposed by the OECD are compatible with other classifications of circular strategies that identify the 10Rs (Cramer, 2021).

Besides business models, the NSCE identifies complementary vehicles for the transformation towards the circular economy: First, *value chains* are identified as essential objectives for advances in circularity. In value chains, diverse companies work together to add value to materials and provide products or services. By integrating circular practices in value chains, suppliers, anchor companies, and clients are invited to collaborate in innovations and new business models. Other vehicles include *circular cities* emphasizing public infrastructures such as innovative transport systems, water supply, urban food systems, collective energy and heat circuits, and circular waste management systems. Eco-industrial parks are recognized as industrial systems that share infrastructure and can advance the symbiotic exchange of waste streams among neighbor companies as part of circular cities. *Sustainable consumption* as a vehicle of the NSCE includes changes in consumer behavior and sustainable purchase practices.

As considered by Colombia's NSCE, the science behind the CE model connects to the academic field of industrial ecology (Korhonen & Honkasalo Seppala, 2018). This field studies material flows and the environmental impact resulting from its transformation and consumption. Based on a positivist view, technological innovation and system thinking provide directions for transformation towards more sustainable production and consumption systems (Blomsma & Brennan, 2017). The ecological metaphor introduces industrial ecology to study systems instead of singular organizations and includes nature-based mechanisms such as industrial metabolism, symbiosis, eco-industrial parks, biomimicry, eco-design, and industrial food webs (Boons & Howard-Grenville, 2009). Since the early 1990s, the industrial ecology research community has attracted multidisciplinary scholars among technical scientists, social scientists, economists, and management studies (Ayres & Simonis, 1994).

Following industrial ecology science, the NSCE included selecting primary resource flows as objectives of circularity and the basic structure of the NSCE. Selection criteria were based on the importance of resource flows as inputs for the national economy and their impact on natural resources and political relevance. Available studies on material flow analysis in the country (Vallejo et al., 2011) were complemented with official data of the national statistical office (DANE in Spanish) and national environmental, hydrologic research institute (IDEAM in Spanish). The primary resource flows of the NSCE include:

1. Flows of industrial materials and consumer goods: These flows involve materials used in the industrial process, primarily included in extended producer responsibility regulation (ERP) such as metals, rubber, glass, and electronics. These

materials make up around 7% of the input volume of the Colombian economy and contain toxic waste materials (Vallejo et al., 2011).

2. Flows of packaging materials: Materials characterized by a short lifetime, such as plastics, cardboard, paper, and aluminum used in consumer goods such as food, cosmetics, and pharmaceutics. These materials represent a significant part of non-organic municipal waste.
3. Flows of biomass: These materials involve mainly agri-food chains, wood, and livestock. This flow represents 29% of the input flow of the Colombian economy and high volumes of biomass losses resulting from low productivity in small-scale agriculture (Gonzalez-Salazar et al., 2014).
4. Sources and energy flows: This flow includes energy generation, distribution, and energy use and represents 35% of total greenhouse gas emissions in Colombia (IDEAM, 2018). Potential for sustainable energy sources includes solar panels and wind energy, especially for non-connected regions, reduced energy losses in the grids, and energy efficiency in domestic and industrial use. As a significant resource input of the Colombia economy (29%), fossil energy sources are mainly exported (Vallejo et al., 2011).
5. Water flows: As a country rich in water (5 * global average in availability), water distribution and re-use from the oil industry for agriculture irrigation are included in this prior resource flow. The aggregate value per $m^3$ of water is five times below the OECD average (DNP, 2018).
6. Flow of construction materials: Construction materials make up 25% of the total input of the Colombian economy. Circularity potential is enormous as only 2% of construction materials are re-used or recycled (Tecnalia, 2017).

These primary resource flows shape the basic structure of the NSCE and align with the recommendations of the Ellen MacArthur Foundation (Ellen McArthur Foundation, 2014) and the European Union (Kirchherr et al., 2018). Similar to these antecedents, the *general objective* of Colombia's NSCE is formulated as:

> Advance productive transformation towards maximizing aggregated value in economic, environmental and social terms, of industrial-, Agri- and urban systems using improving circularity of resources flows, technological innovation, collaboration, and new business models.

Specific objectives of the NSCE identify the ways to bring about the productive transformation such as: (i) develop new and innovate existing normative mechanisms and regulations to include circularity concepts, (ii) provide incentives to advance a critical mass of new circular business models and infrastructure including circular principles, (iii) advance research and enhance capacity building in both private and public sectors for motivating circular innovations, (iv) promote the support of international cooperation for the guidance of productive transformations towards circularity, (v) develop information systems based on circularity indicators of resource flows and productivity and added value, and (vi) enhance a circularity culture through massive education and communication programs. These specific objectives of the NSCE represent the diverse public and private stakeholders' mechanisms to advance the transition towards the circular economy.

| Mechanisms for productive transformation / Primary flows of resources | Innovation in regultation | Incentives | Research and capacity | International cooperation | Information system | Culture and communication |
|---|---|---|---|---|---|---|
| Industrial materials | Extended producer responsibility | Finance schemes for circular innovations | Disassembly plant for vehicles | National training program for CE<br>Eco-industrial park program | Waste recycling rates | Lubricant recovery campaign |
| Packeging materials | Prohibition of packing in natural parks | Nation plastic waste management plan | Formalization of recycle companies | Financing pilot projects with street recycles | Waste recycling rates | Domestic waste separation campaign |
| Biomass | Environmental license for compost systems | Small holders access to markets | National system for compost | Small holders access to markets | Water and soil productivity rates | |
| Water | Use of threated sewage | Sectorial guides for water re-use | Biomass energy generation | Knowledge and technology exchange | Measurement of water quality and water productivity | Domestic water losses reduction |
| Energy | Licensing for geothermic and biomass energy | Carbon tax | Biomass energy generation | Knowledge and technology exchange | # electric cars<br>% of renewable energy | |
| Contruction materials | Recycling content rates for construction materials | Certifications for construction materials and buildings | New circular materials | Knowledge and technology exchange | Construction material recycling rates | |

**Fig. 9.2** Structure of the NSCE

This vision of the NSCE includes a period until 2030, a shorter span than the European Community, aiming at 2050 (European Commission, 2015). Indicators of the general objective include energy intensity, water productivity, recycling rates, and reduction of greenhouse gases. These indicators align with Colombia's Green Growth Policy launched in 2018 (DNP, 2018). Complementary indicators relate to the prior resource flows and the mechanisms mentioned in the specific objectives. Figure 9.2 presents the structure of the NSCE, identifying the prior resource flows and the mechanisms for the facilitation of productive transformation towards a circular economy in Colombia.

The National Commission leads the governance of the NSCE for Competitiveness and Innovation. This high-level committee is created by law and presided by the president's office. In its board participate high-level representatives of all Ministries and other national institutions such as; the Ministers of Environment and Sustainable Development, Commerce, Industry, and Tourism, Transport, Mining and Energy, Agriculture, Housing, Urban and Territorial Development, the National Planning Department, and the National Statistics Office, the director of the Scientific Fund, the director of the National Technical Education System, and governmental agencies responsible for public services and representatives of the academia. The commission involves regional roundtables on competitiveness and innovation as coordinators of the regional roundtables for the circular economy. The board meets twice per year to revise advances administrated by technical committees.

In sum, the content of the NSCE follows references to the Ellen MacArthur Foundation and other national policies on the topic. Priorities of the strategy identify resource flows with importance within the Colombian economy. Indicators and goals align and integrate advances of other policies and programs, such as the green growth policy (DNP, 2018).

## 9.4 Early Advances of National Strategy of Circular Economy

Early advances of the NSCE include its launch in November 2018 until the end of December 2021. The period embraces the pandemic restriction in Colombia, including a strict quarantine from 16 of March 2020 onwards. The CE leadership team of MADS reports the advances in this section. Other advances outside the scope of this team might have occurred. The early advances follow the structure of the mechanisms defined in the NSCE to advance the transition towards the circular economy.

Taking the NSCE as a reference, five regulatory initiatives were adopted, and MASD advanced the other three initiatives. The first advances relate to innovation in regulation and public policy that supports the transition to the circular economy. Initiatives concern incentives for recycling of plastics (Regulation 2412 of 2018), prohibition of plastic packaging in natural parks (Resolution 1558 of 2019), regulation of unification for colors of waste bags according to waste streams (Resolution 2184 of 2019), extended producer responsibility for packaging (Resolution 1342 of 2020), advances in the adjustment of construction waste disposal (Resolution 472 of 2017), and regulation of terms of reference for a generation of geothermal energy and another non-renewable energy source such as biomass. The MCIT advanced the modification of regulation related to free-trade zones to include eco-industrial park development principles.

Articulation with public policy initiatives includes integration of circular economy principles in public policy on municipal water management, including water supply and water treatment (CONPES 4004 of 2020), COVID reactivation policy (CONPES 2023 of 2021), the mission of COP 2021 in Glasgow, the National Strategy on Bioeconomy, the green growth law promoted by the Ministry of Finance, and the national program on intelligent municipalities of the Ministry of Technology and Communications.

The second group of advances includes developing *incentives* for private companies to transform towards a circular economy. MADS published several sectoral guides as references for environmental management in the flower industry and pork farms. Additional technical guides include waste management under pandemic restrictions and circular economy initiatives in municipal and territorial development plans. MCIT included circular economy requirements in financial support programs for firms such as “Innpulsa” and “reactivation of the pandemic through circular economy.” Other advances include support to pilots of eco-industrial park developments in Colombia, as part of a global initiative of UNIDO. The pilot included technical assistance to three industrial parks in Barranquilla, Bogota, and Cali, advancing resource efficiency actions through implementation of cleaner production and industrial symbiosis. The mechanism of eco-industrial parks aims to innovate regulating and guidelines for eco-industrial park developments, triggering especially firms in free-trade zones. Complementarily, the National Institute for Industrial Standards (ICONTEC) adopted a standard for implementing circular economy organizations (GTC no. 0314.2020).

Additionally, many public-private platforms have been launched to promote a circular economy among a critical mass of organizations and regions. Complementary to the national agreement for circular economy signed between governmental agencies and representatives of the main economic sectors, 19 regional agreements have been signed by 300 partners among industry, academic institutions, chambers of commerce, and regional authorities. These agreements involve commitments to include circular economy principles in regional development programs and identify and support entrepreneurial initiatives. The regional agreements result from a national program of regional roundtables organized in 22 cities during 2019. Over 8000 assistants participated in these regional meetings, contributing to the dissemination and legitimation of the NSCE. Additionally, sectoral roundtables were organized for primary resource flows such as plastics, biomass, and tires, where firms and national governmental institutions negotiated goals and articulated initiatives to enhance circularity.

The third group of advances comprises the *capacity-building* programs in the circular economy. Significant advances have been achieved: First, in the design stage of the NSCE, a first training program invited 60 representatives of diverse national public institutions such as the ministries and national institutes such as the National Planning Department (DNP), the National Technical Education System (SENA in Spanish), and the National Statistics Office (DANE in Spanish). The program includes a 24-hour workshop aimed at unifying criteria and stimulating inter-institutional relationships as part of the preparation of the NSCE. A second capacity-building achievement developed a train-the-trainer program for instructors of the SENA. The German Cooperation supported the program, which trained over 20 instructors to multiply the Internet-based course.

The Universidad de los Andes launched a virtual Massive Open Online Course (MOOC) on the Coursera platform. Other virtual courses were developed by the Green Growth office of the DNP, supported by the UK Pact program. Other universities participating in regional CE roundtables started to include circular economy in existing programs on environmental management and business education, such as the Universidad de Bolivar in Monteria, in the Caribbean Coast.

The fourth category of advances includes an *information system* on CE indicators developed by the National Statistics Office. In 2020 two reports were published (DANE, 2020a, 2020b), describing the methodology of the CE information systems and the first advances of indicator reports. The four categories of the information system include (i) extraction of resources, (ii) production of products and services, (iii) consumption and use, and (iv) closing material loops. Indicators identify value added ($) per $m^3$ of water, energy consumption per capita, types of transport used, number of jobs generated by the sustainable business, and building implementing energy efficiency.

The fifth category of advances relates to *culture and communication* through sustainable consumption. Advances result from a regional program of UNDP on the promotion of sustainable consumption in Latin America (ICSAL). The program developed pilot cases with companies on information systems and communications strategies, including circular resource use. During 2019–2020, six large Colombian firms took part in the program. Moreover, research outcomes on consumer behavior, part of the same program, proposed guidance for innovation of consumer information, regulation, and standards.

Regarding *international cooperation*, the development of the NSCE collaborated intensively with international cooperation agencies and diplomatic delegations such as the United Nations, the European Commission, OECD, Inter-American Development Bank (IDB), and Embassies of the Netherlands, Germany, United Kingdom, and Denmark. Regional cooperation was advanced, led by the Colombian Ministry of Foreign Affairs by organizing a high-level international workshop on exchanging experiences in circular economy with the Pacific Alliance of Peru, Mexico, and Chile and the invited countries of Ecuador and Paraguay. International leadership of the Colombian government also showed in the organization of a high-level circular economy workshop as part of the Global World Environment Day on 25 of June 2020, and the election of Colombia in the presidency of the region's international alliance for a circular economy organized by the UNEP.

Additional advances in CE include identifying over 130 business cases in circular economy with operations in Colombia. Identified cases cover the diverse primary resource flows of the circular economy, with 19 initiatives related to industrial material flow, 20 to biomass, 25 to packaging waste recycling, 33 to water re-use and efficiency, 25 for renewable energy, and 14 for construction materials. Moreover, programs on extended producer responsibility reported 475.157 tons of waste recovery, including electronics (15.800 tons), batteries (2.730 tons), light bulbs (4.227 tons), tires (248.670 tons), car batteries (180.000 tons), agrochemical packaging (24.551 tons), and medicine packaging (940 tons). Table 9.1 summarizes the early advances of the NSCE as reported by the leadership team of the Ministry of Environment and Sustainable Development (MADS).

Early advances of the NSCE include multiple areas and involve diverse stakeholders and connect to existing programs, projects, policies, and developments in green growth, sustainable development, and reactivation of the economy due to the COVID pandemic. Moreover, the advances show complementary system levels from international cooperation, national policies, and regional initiatives and reaching out to the micro-level of business models.

## 9.5 Lessons Learned

Colombia is the first country in the Latin American region to advance an NSCE. Describing and analyzing the NSCE of Colombia offers the opportunity to learn from its challenges and experiences. The framework on institutional capacity building (Healey, 2003) is combined with network governance's power to implement circular initiatives proposed by Cramer (2021) as references to extract the lessons.

First, institutional capacity building is relevant for CE as it explores (Healey, 2003) "micro-social relations of transformative efforts through partnerships to

**Table 9.1** Early advances of the NSCE 2019–2020

| Categories | Advances | Organizations |
|---|---|---|
| Innovation in regulation | Five regulatory initiatives: (i) waste bags, (ii) packaging waste in natural parks, (iii) industrial parks, (iv) construction waste, (v) extended producer responsibility<br>Integration of CE in four sectoral policies: (i) reactivation policy, (ii) COP 2021 Glasgow, (iii) national strategy on bio-economy, (iv) clean growth policy | MADS, MCIT, DNP, MF |
| Incentives | Financial support: (i) SME – Innpulsa, (ii) reactivation support<br>Eco-industrial park program<br>Technical standards: (i) ICONTEC implementation of CE in organizations<br>Sectoral guides: (i) packaging waste, (ii) flower industry, (iii) pork<br>Roundtables: (i) 22 regional roundtables, (ii) 12 sectorial roundtables | MADS, MCIT, chambers of commerce, Bancoldex, ICONTEC, branch organizations, ANDI, Asocolflores, Acoplasticos, pork-Colombia, GEIPP-UNIDO |
| Capacity building | Technical education<br>MOOC<br>Professional training program<br>Academic programs | MADS, SENA, DNP, UK pact, GIZ, Universidad de los Andes, Universidad de bolivar |
| Information system | Methodology report<br>Indicator report | DANE, MADS |
| Culture and communication | Six pilot programs in large companies<br>Consumer guidelines | ICSAL-UNDP |
| International cooperation | Regional alliance for CE in Latin America<br>Pacific alliance for CE<br>Bilateral agreements | Ministry of External Affairs MADS, Pacific Alliance UNDP, UNIDO, UNEP, OECD, European Commission, embassies of the Netherlands, Germany, UK, Denmark |
| Impacts | 135 CE business<br>475.157 tons' waste recovery: (i) electronics (15.800 tons), (ii) batteries (2.730), (iii) light bulbs (4.227), (iv) tires (248.670 tons), (v) car batteries (180.000 tons), (vi) agrochemical packaging (24.551 tons), (vii) medicine packaging (940 tons) | MADS, chambers of commerce, ANDI, Retorno |

improve place qualities," such as those implied in the dynamics of transformation towards circularity. Being used in the analysis of public policy (Giddens, 1984), the institutional capacity-building framework identifies critical resources required for societal changes, such as:

(i). *Knowledge resources*: the availability and structural sharing of explicit and tacit knowledge, i.e., frames of reference, formal education, guidelines, and learning.

(ii). *Relational resources*: networks or webs of relations in which actors are embedded, i.e., number of organizations involved, inter-organizational collaborations, and level of involvement of actors.
(iii). *Mobilization capacity*: the structure and means by which knowledge resources and relational resources are formed and mobilized, i.e., change agents, core arena, and momentum.

*Knowledge resources* for the NSCE development are built on information gathered over the past two decades by MADS and DNP, advancing various policies on environmental sustainability since 1997, especially national policies on Cleaner Production (1997), Sustainable Production and Consumption (2010), and more recently, the Green Growth Policy (2018). In addition, the arsenal of resources available on circular economy models, experiences, tools, and cases published by international organizations such as the Ellen MacArthur Foundation, the Platform for Accelerating the Circular Economy (PACE) of the World Economic Forum, and the academic literature provided relevant knowledge resources to develop the NSCE. Sectoral studies availed at MADS and MCIT were used as sources to identify priorities. Moreover, existing programs on extended producer responsibility (EPR), recycling associations, and existing sector guides provided up-to-date information to set priorities and goals for national, sectoral, and regional programs. Additionally, universities, research institutes, and the National Statistics Institute (DANE) provide essential knowledge resources resulting from research and network activities.

Second, *relational resources* for institutional capacity building are enhanced through sectoral and regional roundtables where public, private, and academic institutions share experiences and are encouraged to develop collaborative initiatives. Traditionally, building strong inter-institutional ties required for effective relational resources is challenging in the historically divided Colombian society characterized by economic stratification, political centralization, and emerging institutional developments. Capacity building of representatives of diverse ministries and national public institutions such as SENA and DANE contributed to the challenge of inter-institutional collaboration among governmental institutions. The bottom-up approach used in the construction of the NSCE through regional workshops and roundtables contributed to legitimizing the strategy and building networks. Recognition and participation in networks involving international organizations contributed to advancing and maintaining relation resources among the stakeholders of the NSCE.

From its early developments*, the mobilization capacity* of the NSCE was provided by the high-level commitment of Presidents Duque's office; the First Minister of Environment and Sustainable Development, Ricardo Lozano; and the Minister MCIT. Operational leadership was assumed by the Office of Sectoral and Urban Direction (DAASU) of MADS. The CE leadership team represented the national mobilization capacity for events, the follow-up to commitments, problem-solving, alignment of circular economic initiatives, and collecting and disseminating information. On the regional level, competitive regional teams led by chambers of commerce, business associations, universities, and regional development agencies represent the leadership committed to the regional agreement of CE. Strong leadership is shown by the regional roundtables of Quindio, Caldas, Medellin, Pereira, Cali, and Bucaramanga. Capacity-building programs aim to expand and embed CE in institutions and companies. The experience of the Colombian NSCE showed a critical mass of mobilization resources resulting from its early advances, as a change in the direction of MADS maintained the emphasis of the NSCE and the team appointed. Challenges for enhancing mobilization resources include embedding leadership in existing emerging institutional structures and diversifying capacity over time.

**Table 9.2** Analysis of the NSCE following network governance power

| Key feature | Guiding principle | Lessons from NSCE |
|---|---|---|
| Parking the transition | The circular initiative starts with a shared sense of urgency | The NSCE initiated with a high-level agreement led by the president's office, ministers, and directives of business associations |
| | The implementation of circular initiatives occurs in four sequential yet cyclic phases | The NSCE followed a 4-year strategic planning from the beginning; need to maintain focus and political priority to scale and reach a critical mass |
| | Tasks to be performed for each circular initiative are roughly the same, but the focus is case-specific | The NSCE is in the early development stage; it needs to design and implement financial instruments to a scalable technological innovation method |
| | Building a circular economy is a journey with a clear destination but no predetermined path | The NSCE promotes a variety of instruments and initiatives; need for visibility of scalable Colombian showcases |
| Context is key | Focus on the most promising and disrupting innovations | Early advances associated with waste management and EPR; the need for identification of disruptive technology-based innovations |
| | Map the key drivers and preconditions for successful implementation | Early advances centered in institutional capacity building; need to expand and emphasize entrepreneurial initiatives |
| | Identify the relevant actors and assess their willingness to join forces | Collaboration among actors is emerging; need for incentives to enhance collaborative initiatives |
| Successful implementation | New circular business models should benefit all network partners | The NSCE initiated an information system; need to produce indicators for evaluating benefits of all stakeholders |
| | Transition brokers can accelerate circular initiatives | So far, limited transition brokers; need to strengthen capacity for the formulation of scalable, industrial projects |
| | A transparent division of labor among the relevant actors is indispensable | The NSCE counts with a network of roundtables; need for a system for recognition and communication of circular economy initiatives |

Based on Cramer (2020)

The interaction among the knowledge, relational, and mobilization capacity represents the institutional capacity for advancing transformation towards a circular economy, implying a paradigm switch in the way companies produce and users consume products and services, and institutions design programs, projects, and instruments. Professor Jacqueline Cramer identifies guiding principles for the power of governance for implementing a circular economy. The framework is helpful to understand the experience of the NSCE and identify opportunities to strengthen its development. Table 9.2 presents the analysis of the NSCE following the network governance power framework of Cramer (2020).

The lessons learned of the development and early advances of the NSCE show the strategy's systematic design and high-level political support. In the first 2 years, foundations for institutional capacity building are emerging. Moreover, the bottom-up approach has legitimized the strategy within the regions and positioned Colombia's NSCE within international networks. Main challenges appear in integrating circular economy into existing programs, especially in waste management-related tariffs and regulation, attracting programs for scalable, technology-based investments and maintaining political priority to assure the long perspective of the transition towards the circular economy.

## 9.6 Conclusions

This chapter analyzed Colombia's National Strategy of Circular Economic as the first public policy in Latin America. The method of analysis included a description of the background of the strategy, its process of development, content, and early advances. Lessons learned are analyzed using the conceptual frameworks of institutional capacity building and the power of network governance. Both the description and the lessons learned aim to inspire other national and regional governments to advance circular economy strategies to respond to economic, social, and environmental crises caused by resource scarcity, climate change, and the consequences of the pandemic restrictions (Ellen MacArthur Foundation, 2020). The circular economy represents opportunities for structural changes in production and consumption systems by resource efficiency, technological innovations, and collaborations resulting in new business models. Benefits of CE include healthier ecosystems, higher quality of consumption, social consciousness, and new opportunities for employment generation.

Well-designed and well-planned public policies are powerful instruments to guide transitions of societies that improve quality of life and enhance resilience.

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# Chapter 10
# Circular Economy as a Mechanism of Resilience Against COVID-19

**Aldo Alvarez-Risco, Shyla Del-Aguila-Arcentales, Marc A. Rosen, Santiago Diaz-Risco, and Coralia Mesa-Gomez**

## 10.1 Introduction

When the COVID-19 pandemic began in 2020, it was exceedingly difficult to predict the number and extent of changes that would occur in the world (Atalan, 2020; Debata et al., 2020; Song & Zhou, 2020; Thorbecke, 2020).

It has been recognized that the pandemic, due to the lockdown periods, has reduced environmental pollution in various parts of the world. It can be seen in Figs. 10.1 and 10.2, for instance, that reductions of tropospheric $NO_2$ occurred during the period March–April 2019 and March–April 2020 in Europe. Decreases of 48% of $NO_2$ can be observed in Madrid, of 54% in Paris, of 47% in Milan, and of 49% in Rome over the 1-year period.

Likewise, Figs. 10.3 and 10.4 show the reduction of tropospheric $NO_2$ in India over the period March–April 2019 to March–April 2020. Furthermoe, an annual decrease in electricity consumption of 9.2% was reported in March 2020.

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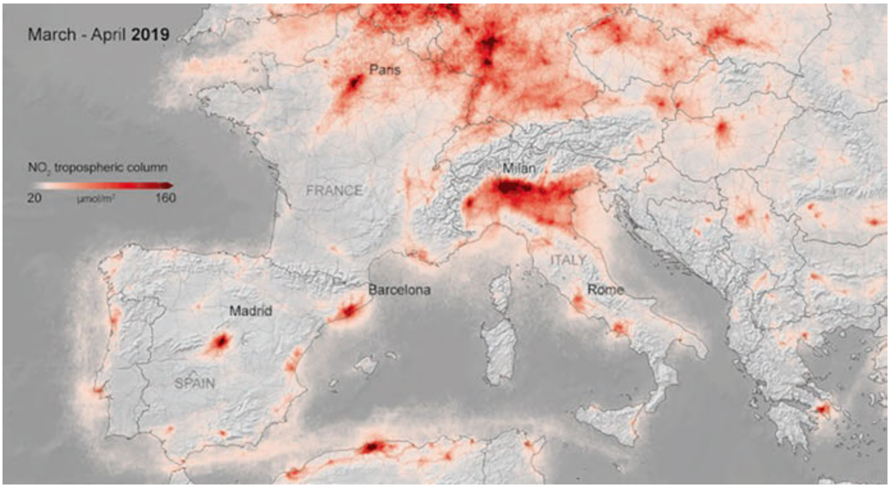


**Fig. 10.1** $NO_2$ tropospheric column in March–April 2019 in Europe. (Source: European Space Agency)

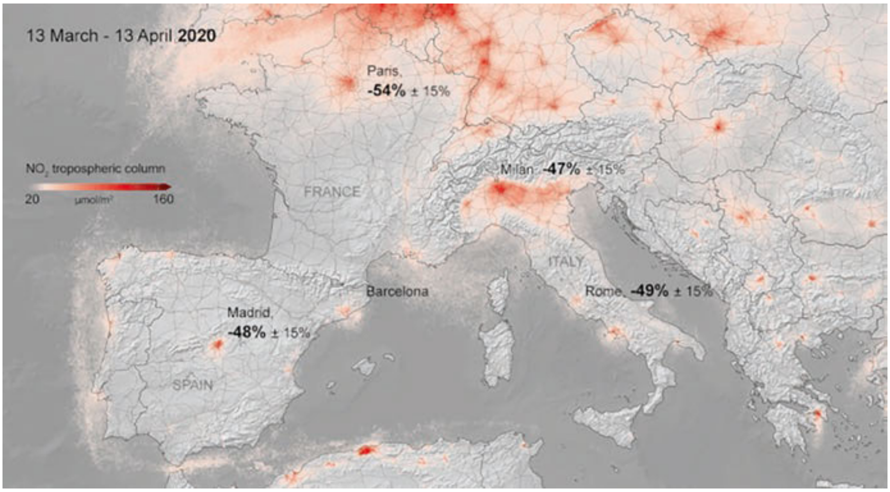


**Fig. 10.2** $NO_2$ tropospheric column in March–April 2020 in Europe. (Source: European Space Agency)

However, this decrease is likely temporary, since once activities were restarted after the lockdown, $NO_2$ levels increased again. Figure 10.5 shows what transpired in China, with data for December 2019, February 2020, and March 2020.

In the European Community, politicians, companies, lawmakers, and citizens have been reported to be calling for green investment to restart growth after the COVID-19 pandemic. Even though many thought the pandemic would be controlled in a year, it is heading into its third year without control. Some suggest that

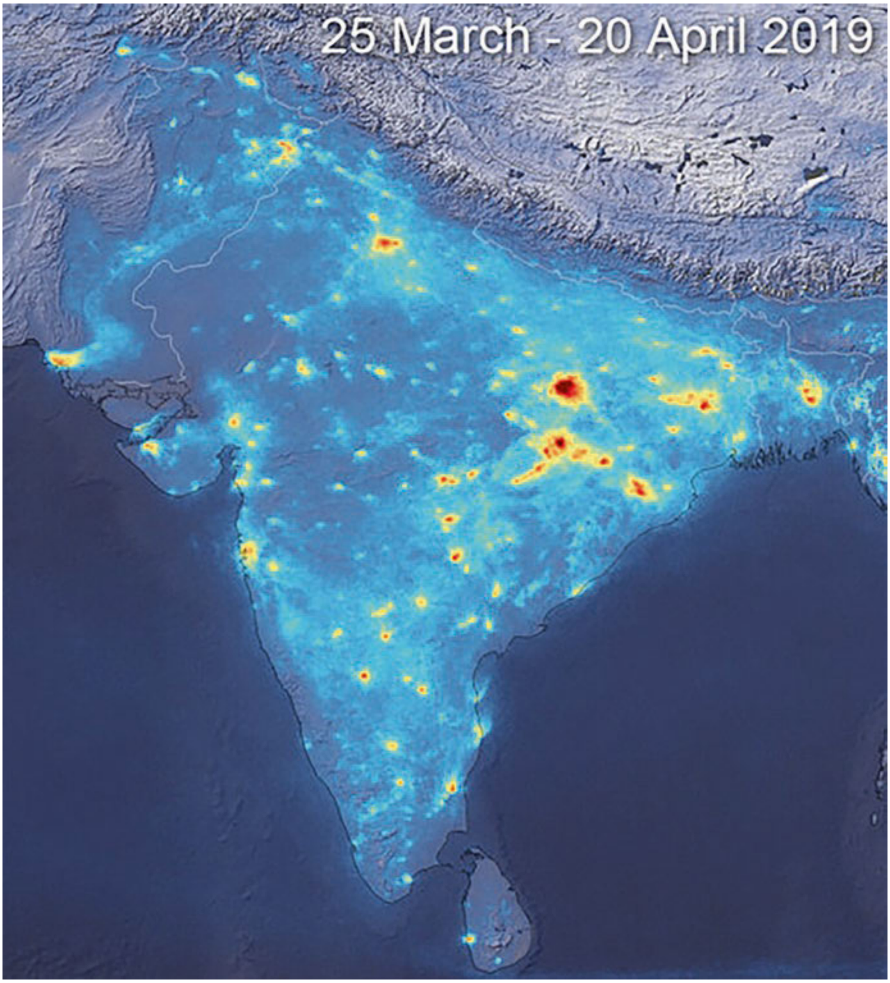


**Fig. 10.3** $NO_2$ tropospheric column in March–April 2019 in India. (Source: European Space Agency)

climate change mitigation and biodiversity promotion will allow rebuilding economies after the pandemic more strongly. Adopting the circular economy (CE), an industrial economic model that fulfills the multiple functions of decoupling economic growth from resource consumption, waste management, and wealth creation has been touted as a viable option.

A few countries have begun to embrace the circular economy. For example, South Korea has initiated its circular economy based on the European Green Deal (European Commision, 2019). Figure 10.6 illustrates the core of the European Green Deal.

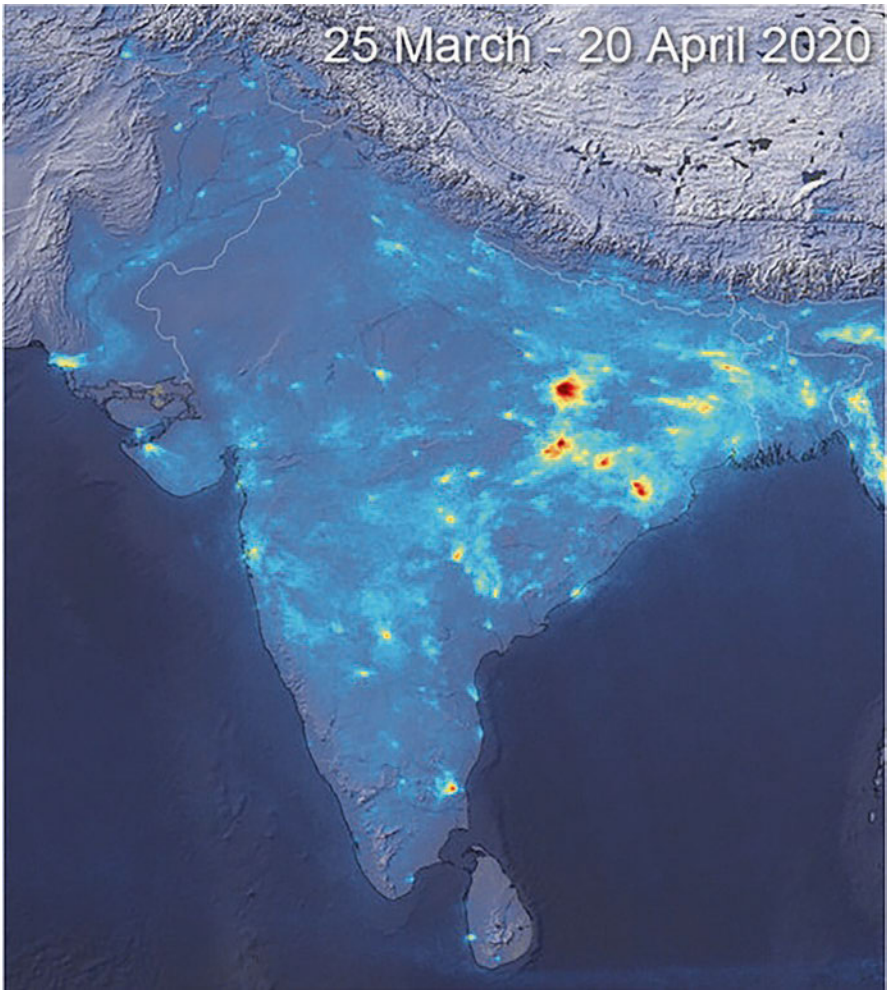


**Fig. 10.4** $NO_2$ tropospheric column in March–April 2020 in India. (Source: European Space Agency)

One may ask: why is it important for South Korea to embrace the circular approach? A main reason is that South Korea is the seventh most polluting nation in terms of $CO_2$ emissions (Forbes, 2019); likewise, South Korea is recognized as one of the largest investors in coal worldwide (Greenpace, 2019).

Nonetheless, few cities have started to plan a circular economy approach. Amsterdam became the first city to use Donut Economics (Raworth, 2017), seen as a revolution in the concept of managing, based on sustainability and social welfare as a starting point for planning productive activities. The circular plan of Amsterdam is called the Amsterdam Circular Strategy 2020–2025 (Amsterdam, 2020).

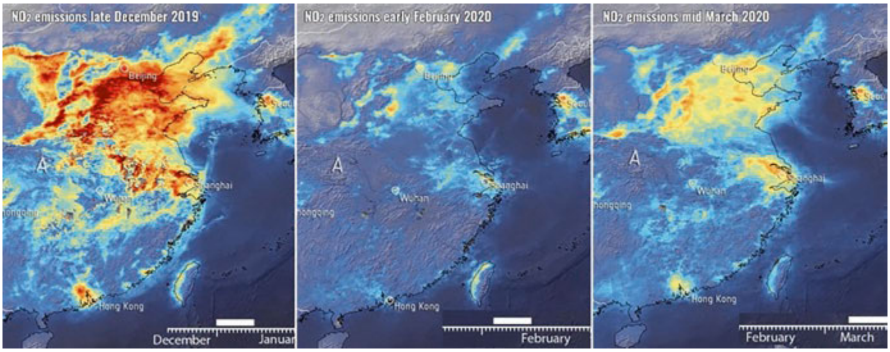


**Fig. 10.5** $NO_2$ tropospheric column in March–April 2020 in India. (Source: European Space Agency)

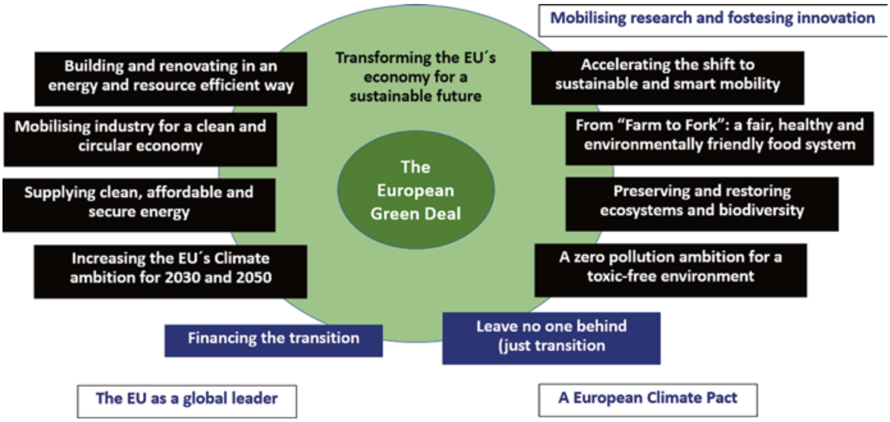


**Fig. 10.6** Components of the European Green Deal. (Source: European Commision (2019))

## 10.2 Circular Economy Initiatives to Rebuild the World Economies

The World Economic Forum is committed to harnessing the potential of technology, innovation, and intelligent politics from the Fourth Industrial Revolution (4IR) through a global partnership called Scale360°, in order to apply technology for the implementation of a circular economy.

Currently, various circular economy initiatives are being reported that should be imitated in other locations. In the Netherlands, Amsterdam is recycling water (Peters et al., 2021), while Rotterdam is filtering drug residues from sewage, turning them into energy in the form of biogas (Boztas, 2017). Another emergent city working in the circular economy is Prague, through the Circle City Scan plan that started in 2019 (CircleEconomy, 2021).

The circular management of water is important for human drinking, personal cleaning, cleaning populated centers, and planting to obtain food. This issue is susceptible because it has been reported that, in the last century, water consumption has more than doubled compared to the world's population (UN, 2012). These initiatives are also relevant because predictions of a water crisis have been made (UNICEF, 2021; Water.org, 2021). The COVID-19 pandemic has shown that significant threats to people's lives can be successfully faced. This same coordination and action plan to reduce infections, obtain vaccines, and carry out isolations, during the pandemic period, is required to face the climate crisis with circular economy strategies decisively. Water scarcity puts the lives of a vast number of people at risk, but it still does not seem to be an urgent task for many governments, institutions, or citizens.

Another initiative that has increased as a resilience mechanism in times of the pandemic is the recycling of plastics (Calabrò & Satira, 2020; Chawla et al., 2021; de Sousa, 2021; Debrah et al., 2021; Fiksel et al., 2021; Kahlert & Bening, 2020; Moreno-Sierra et al., 2020; Tchetchik et al., 2021; You et al., 2020) and the management of plastic in general terms (Gorrasi et al., 2021; Khoo et al., 2021; Mallick et al., 2021; Mehran et al., 2021; Parashar & Hait, 2021; Vanapalli et al., 2021). The importance of the Fourth Industrial Revolution to circularize the management of plastic has also been recognized (Weforum, 2021).

Regarding e-waste, a variety of results have beeen observed through repair rather than recycling (Dutta et al., 2021). Currently, most circular economy initiatives are individual projects focused on materials and physical resources. These efforts are valuable, but in order to achieve a large-scale and transversal impact in various industries, it is necessary to develop solid digital bases, in a coordinated way. These can locally become a digital backbone for productive activities, facilitating the traceability of operations and thus contributing to achieving circularity. In agreements between countries, whether bilateral or multilateral, it is necessary to promote political and regulatory frameworks that encourage commercial activities to transform towards circularity. This transformation towards enhanced digital processes has a prerequisite: the digital literacy of citizens, professionals, and companies. Fortunately, progress has been reported in improving digital literacy (Abdulai et al., 2021; Nash, 2020; Purnama et al., 2021; Reddy et al., 2021; Sánchez-Cruzado et al., 2021; Tejedor et al., 2020). Digital health literacy is the cornerstone of implementation of the circular economy (Türkeli & Schophuizen, 2019).

More generally, it is understood that the industrial economy is largely characterized as being a linear system: resources are input, products are manufactured using these resources, and the product is disposed of at the end of its useful life. This is often described as "extraction-production-use-landfill" process (Geissdoerfer et al., 2017). An extractive approach is often taken without considering that natural resources are limited and that even in the processes of obtaining the raw material, irreparable damage can be done to rivers and lagoons near factories. At the same time, it has become increasingly popular to use approaches involving corporate social responsibility, which has had in many cases a positive impact on the business environment (Asmussen & Fosfuri, 2019; Coffie et al., 2018; Kaymak & Bektas, 2017; Tashman et al., 2019; Uduji et al., 2019). The potential of integration of corporate social responsibility and the circular economy has been recognized (Daú et al., 2019; Fortunati et al., 2020; Frei et al., 2020; Kuo & Chang, 2021; Meseguer-Sánchez et al., 2021). Such an integration provides a comprehensive approach in which the company places sustainability at the center of its activities, rather than treating it only in a complementary way.

Another factor that has been seen as a limitation to sustainable products is the price that consumers have to pay. Although it has been possible to ascertain the willingness to pay higher prices by some consumers, it is difficult to generalize this willingness as it depends greatly on the financial circumstances of people. Nonetheless, consumers can be highly motivated to purchase good such as organic products. It is expected that to some extent society can achieve a more significant offering of ecological products, like organic foods, ultimately at lower prices. In such instances, the consumption of these foods will likely increase, achieving benefits for companies, consumer health, and the environment.

As described by Ibn-Mohammed et al. (2021), the circular economy aims to:

1. Highlight the management of the manufacture and recovery of environmentally conscious products
2. Promote the care of involuntary ecological degradation in everyday actions between companies, consumers, and government.
3. Generate a new approach towards a holistic value chain, where it is understood that each process can be planned, ensuring that it will be managed sustainably, reducing or eliminating waste, and facilitating repair or reuse.

The positive environmental impact previously noted due to the COVID-19 pandemic is expected to fade as companies return to their usual activities, requiring profound new changes for production to be circular. There is a need for more research to demonstrate that developing activities under the principles of the circular economy generates environmental benefits as well as social and economic ones. This absence of evidence continues to be a barrier to organizational change towards circularity. The world is gradually returning to its prepandemic activities. A key question thus arises: Will this motivate organizations to modify their planning and activity to carry out activities with a circular approach? Universities play a fundamental role in the creation of new evidence, which must also consider the opinions of consumers so as to understand the levels of acceptance and preferences of consumers for a circular approach.

Many of the most relevant efforts in Africa, Asia, and Latin America towards the circular economy are summarized in Table 10.1.

**Table 10.1** Efforts towards the circular economy in Africa, Asia, and Latin America

| Region | Country | URL | Efforts |
|---|---|---|---|
| Africa | Cameroon | https://forestsnews.cifor.org/?p=67012 | Wood fuel production |
| | Egypt | https://www.egypttoday.com/Article/3/97230/Cabinet-Egypt-s-Circular-economy-is-promising | Reduced material consumption |
| | Ghana | https://www.pyxeraglobal.org/street-street-circular-economy-ghana/ | Plastic waste to paving blocks |
| | Nigeria | https://www.afdb.org/en/topics-and-sectors/topics/circular-economy/nigeria-circular-economy-working-group-ncewg | Nigeria Circular Economy Working Group |
| | South Africa | https://www.news.uct.ac.za/article/-2021-07-06-exploring-a-circular-economy-in-south-africa | Research in circular economy |
| | Morocco | https://circulareconomy.europa.eu/platform/en/knowledge/circular-economy-africa-eu-cooperation-morocco-report | EU cooperation |
| Asia | China | https://www.china-briefing.com/news/chinas-circular-economy-understanding-the-new-five-year-plan/ | New 6-year plan |
| | India | https://sites.ellenmacarthurfoundation.org/india | Report of implementation |
| | Japan | https://www.eu-japan.eu/tags/circular-economy | Report of implementation |
| | Singapore | https://www.towardszerowaste.gov.sg/circular-economy/ | Benefits of circular economy |
| | Taiwan | https://circular-taiwan.org/en/ | Circular Taiwan Network |
| Latin America | Argentina | https://www.argentina.gob.ar/ambiente/control/mesa-economia-circular | Circular Economy Technical Working Table |
| | Brazil | https://www.efeverde.com/noticias/empresas-brasil-economia-circular/ | Hub of circular economy |
| | Chile | https://mma.gob.cl/economia-circular/ | Circular Economy Office |
| | Colombia | https://www.dane.gov.co/index.php/estadisticas-por-tema/ambientales/economia-circular | Third report on Circular Economy |
| | Mexico | https://www.gob.mx/semarnat/prensa/organiza-semarnat-foro-sobre-economia-circular-para-identificar-retos-y-oportunidades-en-mexico?idiom=es | Ministry of the Environment and Natural Resources |
| | Peru | https://elperuano.pe/noticia/126154-estos-son-los-compromisos-asumidos-por-el-pacto-peruano-por-una-economia-circular | Peruvian Pact for a Circular Economy |

### *10.2.1 Closing Remarks*

Many aspects of society before the pandemic have changed, and there is interest in many parts of the world to develop circularly, so as to ensure the efficient and environmentally sustainable use of limited resources. In Europe, it has been proposed to use the circular economy as a key strategy to reactivate the economy and ensure sustainable use of resources. An important action to support this is the active participation of universities to generate research that helps to understand resilience mechanisms together with their goverments for the creation of private-public initiatives to discuss new implementation strategies of the circular economy. Also, commitment in citizens needs to be promoted to have an active role in circularity. Also, the media have an opportunity to be a part of the massive information communication about the benefits of a circular economy and to spread information about success cases. Finally, it is still expected that information technologies will have an impact on digital management to achieve circular processes.

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# Part III
# Teaching and Research on Circular Economy

# Chapter 11
# Limits to Sustainable Development Goals: Discussing Lessons from Case Studies in (Un)sustainable Production

**Helen Kopnina**

## 11.1 Introduction

The 17 interlinked Sustainable Development Goals or SDGs that were set in 2015 by the United Nations General Assembly and intended to be achieved by 2030 were designed to be a "blueprint for achieving a better and more sustainable future for all" (https://sdgs.un.org/goals). The first SDGs are No Poverty (SDG 1), Zero Hunger (SDG 2), and Good Health and Well-Being (SDG 3), followed by Quality Education (SDG 4). The terms "sustainable and inclusive economic growth," while especially prominent in SDG 8, Decent Work and Economic Growth," are used in most of the SDGs, including Gender Equality (SDG 5) and Climate Action (SDG 13). The SDGs follow the general "sustainable development" strategy that aims to combine social, economic, and environmental aims (known as the triple Ps of People, Profit, Planet).

Progress has been seen in areas ranging from reducing child and maternal mortality globally to advances in health and food production technologies (https://unstats.un.org/sdgs/report/2020/goal-03/) and increasing human resilience to climate change through adaptive measures (https://unstats.un.org/sdgs/report/2020/goal-13/). While the COVID-19 pandemic in 2020 has caused a recession with deprivation and unemployment, the UN noted that the pandemic could serve as the impetus to make the global economy "more resilient to future shock access to essential services and social protection" (https://www.un.org/sustainabledevelopment/economic-growth/), aided by SDG 12, "Responsible consumption and production." The European Union committed to circular economy, the closed-loop system (https://ec.europa.eu/environment/circular-economy/), to meet this goal.

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The closed-loop systems, otherwise known as Cradle to Cradle (C2C) framework (McDonough & Braungart, 2010) or circular systems, share a commitment to measures that address unsustainable consumption as resource loops are narrowed, closed, and slowed to deliver on the increasing demands of a growing world population (Bocken, 2021). In *Cradle to Cradle: Remaking the Way We Make Things*, McDonough and Braungart (2010) criticize the current method of production as a linear, "cradle to grave" (take, make, waste) process. In this process, built-in obsolescence and throw-away culture are encouraged. The Economist (2017a) reports: "Firms say that restricting repairs, either by individual consumers or businesses, helps protect their intellectual property and works on the part of buyers." Thus, "more products, from smartphones to washing machines, are thrown away rather than repaired, adding to waste and pollution" (Ibid).

C2C framework can be understood as both critique of existing sustainability models, such as eco-efficiency and recycling (as they lead to a reduction, not the elimination of damage), and also a proposal for a radical transformation of the production system to "100% good" (McDonough & Braungart, 2010). C2C suggests that "bad" products, such as fossil fuels or plastics derived from petrochemical waste, should not be made "efficient" but eliminated. C2C identifies three fundamental principles: (a) waste equals food, (b) use renewable energy, and (c) celebrate diversity. The "waste equals food" principle can be exemplified by fruit trees' fruits and blossoms, which nourish other species and soil when decomposing. All materials can be designed as nutrients that flow through natural (biodegradable) or technical metabolisms suitable for, ideally, endless cycles of production, use, recovery, and remanufacture (McDonough & Braungart, 2010). The second principle, reliance on renewable energy, does not allow for "partial" renewables such as biofuels derived from burning trees or mixed garbage. Celebrating diversity applies to natural diversity or reliance on local materials (Ibid). C2C has attracted considerable interest and is often regarded as pivotal in the transition to a circular economy.

C2C has inspired the revision of the well-known 3-R framework (Reduce, Refuse, Recycle), stressing that refusing to buy new products or *infinite* reuse is the only sustainable option (Kopnina & Blewitt, 2018). Reducing and recycling serve to minimize but not eliminate the damage and lead only to partial decoupling (eco-efficiency) at best, "making a bad system the last longer" (McDonough & Braungart, 2010). The circular economy can be defined as a system that applies C2C principles in operation at all levels of the economy, based on the nine dimensions in the waste hierarchy arranged by its level of increasing circularity which aims to retain the highest utility and value of products, components, and materials at all times (Potting et al., 2017).

9R hierarchy starts with Refuse, or avoidance of production and buying, followed by Rethink, Reduce, Re-use, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover (Potting et al., 2017). Refuse is the framework's most circular concept. It is categorized into strategies that enable more ingenious product use that can infinitely extend its lifespan. For example, metal cooking pans can be used for many generations. Surprisingly, within the framework (as reduction does not mean the complete elimination of waste), Reduce is positioned higher than Reuse. Reuse, which can be aided by collaborative consumption and using second-hand instead of buying a new product, is prioritized over Recycling with the final option of Recovering embodied energy (Brennan et al., 2015). While Rethink suggests changing ways of consumption, Reduce refers to increasing efficiency (Potting et al., 2017). Repair and Refurbishment aim to put defective products back to their original condition. Remanufacture and Repurpose develop a new product with parts of old products. According to this model, Recycle itself would exhibit a low level of circularity by only processing materials to obtain the former quality as much as possible. The final option is to Recover, which is particularly difficult if not impossible in the food industry and packaging (Aarnio & Hämäläinen, 2008). This hierarchy generally requires a product-service shift from mere manufacturing and ownership to services such as lease and repair. The most service-oriented business models are expected to deliver the most significant environmental impacts in the product-service spectrum of business models (Bocken, 2021).

The circular economy is often seen as a magic wand to achieve ethical objectives and pragmatic sustainability in ecological modernization, which assumes that industrialization, *technology*, economic growth, and capitalism can solve environmental challenges (York & Rosa, 2003). A circular economy blends business and environmental value by adopting a sustainable supply chain management approach (Park et al., 2010). The circular economy, as promoted by the Ellen Macarthur Foundation, is described as a "source of innovation and growth" and the "new engine of economic growth" (EMF, 2013), thus promising absolute decoupling of natural resource consumption from economic growth (Kopnina, 2020; Washington & Maloney, 2020). However, as this chapter shows, some supposedly "circular" or C2C products fall short of the ideal and seem to fit within a more conventional eco-efficiency paradigm. The question is whether the "politically attractive message of a circular economy that promises to enable continued economic growth while radically reducing the level of waste production scientifically, correct?" (de Man & Friege, 2016).

This chapter presents case studies chosen because they claimed to be either circular or C2C. These case studies served as part of a bachelor-level course of sustainable business intended for students to learn to discern the difference between the claims of green advertising, analyzing "ideal" and "realistic" circularity principles as part of their critical thinking in sustainability. Based on these findings, this chapter recommends that a sustainable business curriculum should also focus on degrowth and the steady-state economy as part of a sustainability curriculum.

## 11.2 Sustainable Development Goals in the Context of Circularity

Absolute decoupling can have considerable potential for achieving sustainability. However, there is a growing recognition of the paradoxes of "sustainable and inclusive economic growth," *as it is questionable that the planet can provide infinite* *resources for future generations* (Adelman, 2018; Kopnina, 2020; Washington, 2015). Environmental problems are interlinked with demographic, social, and economic factors, such as consuming natural resources (e.g., Washington, 2015) or climate change and health (Watts et al., 2015). However, issues associated with demographic change, such as growing middle classes and people living longer (also in developing countries), are often downplayed by the "demographic transition theory" and observation that as mortality falls, fertility declines. However, fertility is high and constant in some parts of the world despite lower maternal and child mortality (The Economist, 2015), with the African population predicted to double by 2050 (The Economist, 2020f). When writing this chapter during the COVID-19 pandemic, the UN still projects the global population to rise above 11.2 billion by 2100 (https://population.un.org/). At the same time, people in poorer countries consume less than rich ones, the moral imperative of equal distribution of resources and providing decent lives for all (as SDGs aim to do, eliminating hunger and diseases). Also, international migration from low consumption to high consumption countries suggests that both population and consumption are a problem for sustaining future generations (O'Sullivan, 2020; Washington, 2015; York & Rosa, 2003).

*While decades ago*, *The Limits to Growth* report (Meadows et al., 1972) has been prominent as a warning on the exponential economic and population *growth* with a finite supply of resources. The cognitive dissonance of the SDGs, the wicked problems associated with population growth, and the expansion of material demands are assumed to be addressed simultaneously with environmental problems (Washington & Kopnina, 2018). The SDGs support the "have your cake and eat it" optimism in maintaining the prosperity of a large and healthy human population and keeping the ecosystems intact (Adelman, 2018; Kopnina, 2016; Washington & Kopnina, 2018). Critical scholars have noted that the optimistic rhetoric of the triple Ps downplays the long-term effects of industrial growth, pressure on natural resources, the integrity of ecosystems, and biodiversity loss, failing to recognize that the planet is an essential bottom-line, with people and profit dependent on it (Kopnina & Blewitt, 2018; Victor & Jackson, 2015). In short: without ecological integrity, there is no society, economy, or health. *The secure future of unborn generations is far from certain even with the present level of population and consumption, let alone with increased one* (O'Sullivan, 2020; Washington, 2015).

This cognitive dissonance of the SDGs is similar to the publications of *The Economist* journal, with various authors stressing the science of and the importance of addressing climate change on the one hand and yet praising the liberal economic models and corporate giants that support growth without discussion of finite resources and sustainability. Ironically, while *The Economist*'s leading articles often praise economic growth as a solution for sustainability challenges, science and technology articles in the same journal also point out that environmental conditions are worsening, witnessed by the increase in deforestation (Economist, 2020d), forest fires (The Economist, 2016), or biodiversity loss (The Economist, 2018a, 2018b, 2020a) but also wars and migration fueled by climate change (The Economist, 2019). The Economist (2020b) cheers the global food supply system during the COVID-19 outbreak; international flights carry food in cargo areas between continents. As the lockdowns began, and many feared that food would run short, causing a wave of stocking-up, the COVID-19 pandemic has shown that "today, thanks to fleets of delivery lorries filling supermarket shelves, you can binge-eat as you binge-watch" (Ibid, p. 13). Even in the poorest countries, the supplies remained more or less constant due to international aid's continuous operations of multinational corporate food supplies. The Economist (2020b) praises the fact that "four-fifths of the planet's 8 billion mouths are fed in part by imports," and companies that tie the system together, "giant middlemen like America's ADM, Bunge, and Cargill… all operate on a worldwide basis, sourcing, storing and shipping" (p. 13). It is noteworthy that these companies have embraced the circular economy (e.g., https://thecirculareconomy.com/2020/04/16/adm-announces-sustainability-goals/; https://www.cargill.com/2020/cargill-invests-to-promote-circular-economy-with-its-first), while some, like Cargill, are also responsible for massive deforestation (The Economist, 2020d). Simultaneously, the root causes of zoonotic pandemics, such as mass factory farming and global wildlife trade (Safina, 2020), remain less prominent in policy and media than the technical fixes such as vaccines, resulting from experiments on millions of genetically modified mice (e.g., The Economist, 2020e). As demand slows in some sectors during the pandemic, "supply marches on, and animals born must, at some point, be slaughtered" (Economist, 2020b).

Aside from ignoring animal suffering and robust anthropocentric bias, the precariousness of the momentum of feeding increasing and insatiable global appetites is embodied in these assumptions of progress, both in *The Economist* and the SDGs. In this vision of the planet, "future for all" applies only to one species (Kopnina, 2020), exhibiting little ethical awareness of the intrinsic value of biodiversity (e.g., Piccolo et al., 2018; Washington et al., 2018). The SDGs only focus on the "inclusion" of a single species but also shortsighted "because it erroneously fosters the illusion of combining endless economic growth on a finite planet, social justice, and environmental protection" (Adelman, 2018). Biodiveristy's ecological, life-support systems are comprised of various interrelated organisms and supportive environments, which are often a valuable economic resource and not an intrinsic good (Buchmann-Duck & Beazley, 2020). Protecting biodiversity requires recognizing its intrinsic value and restraining economic activities (e.g., Piccolo et al., 2018; Washington et al., 2018), often overlooked in the circular economy (Buchmann-Duck & Beazley, 2020). Buchmann-Duck and Beazley (2020) called for further research on the interaction between biodiversity and the circular economy and for circular economy advocates to explicitly acknowledge the concept's limitations.

## 11.3 Application of Cradle to Cradle and Circular Economy

The circular economy was first mentioned in policy frameworks in 1976 when Germany enacted their Waste Disposal Act (Ghisellini et al., 2016). Since then, various policies have been enacted in the EU, Japan, the USA, and China to stimulate bottom-up environment and waste management initiatives, including eliminating landfilling and requiring e-waste to be returned to producers (Ghisellini et al., 2016). The European Commission's Action Plan for the Circular Economy states: "better design can make products more durable or easier to repair, upgrade or manufacture" (https://ec.europa.eu/environment/circular-economy/). The European Commission proposed several policies, including *Circular Economy Closing the Loop* (European Commission, 2015), as an alternative to the linear economy, with the promise of creating new jobs in innovative design and business models, research, recycling, remanufacturing, and product development, targeted at long-term measures to optimize waste management and reduce landfill. The most optimistic proposals promise infinite reuse and upcycling, eliminating waste (McDonough & Braungart, 2013). Upcycling promises to increase the value or quality of products, such as designing water cleaning and filtering so that after being used in a factory, it can leave it cleaner than it was (Ibid).

However, it is worth noting that there is no evidence that such is occurring (Victor & Jackson, 2015; Washington & Maloney, 2020). Multiple definitions of the circular economy create openings for subversion (Kirchherr et al., 2017; Kopnina, 2019; Kopnina, 2021). Not all is green or circular what seems so, as realistically, as will be discussed below, there are limitations to absolute decoupling. For example, while the potential recovery rate for fast-food restaurant packaging is 64%, the actual recovery rate lies at only 29% (Aarnio & Hämäläinen, 2008). One of the challenges is that circular products need to be produced locally with a minimum environmental footprint and simultaneously satisfy the demand of global consumers. Circular design interventions are slowed down by rebound effects (Isenhour, 2010) or negation of technological progress by unexpected behaviors of stakeholders in the value chain (Bocken, 2021; Kirchherr et al., 2017). Life cycle assessments can help make informed choices at various stages in the product's life and evaluate the manufacturing and delivery inputs, production outputs, use, and product disposal (Ünal & Shao, 2019).

Critical authors argue that without a radical reduction in population and material demands, natural resources will be constantly consumed (Daly, 1991; Rammelt & Crisp, 2014; Washington, 2015), with circularity used as a ruse to justify even more economic growth while ignoring biodiversity loss (Buchmann-Duck & Beazley, 2020). De Man and Friege (2016) note fundamental problems with the circular economy:

1. The first problem is that, in reality, waste is rarely "food." All production processes lead to downgrading materials, and to create value from downgraded materials, we always need energy.
2. The second problem is the assumption that natural nutrients can be fed into the ecosphere regardless of quantity.
3. A third problem is that our knowledge about the harmful effects of substance flows on the environment is limited (de Man & Friege, 2016).

To address these problems, the concept of degrowth and a steady-state economy, which does not promise absolute decoupling but does require limits to demand, is helpful (Washington & Maloney, 2020).

## 11.4 Degrowth and Steady-State Economy

In order to address social and economic justice, it was suggested that developed countries must contract their economy so that the developing world can expand somewhat to alleviate poverty, with the resulting steady-state economy being within the Earth's limits (Washington, 2015). Steady-state economists have recommended that society and economics need to be transformed from the longstanding model that has created our modern society to one that can thrive in a resource-constrained world (Czech, 2013; Daly, 1991). The Center for the Advancement of the Steady State Economy defines it as an economy with the best possible level of consumption constantly maintained (CASSE https://steadystate.org/) which is espousing the vision that the economy is an open subsystem of a finite environment (Daly, 1991), importing low-entropy raw materials and exporting high-entropy waste (Washington, 2015). Like C2C's critique of downcycling, due to the principle of entropy, recycling cannot continue forever as materials are gradually downgraded and become productively useless as they exit the cycle of use (Ghisellini et al., 2016). It is assumed that any subsystem of a finite nongrowing system must be itself, at some point, also become nongrowing (Daly, 1991; Washington, 2015). Once achieved, the goal is to maintain a stable level of consumption with throughput constant and maintained within ecological limits (Washington & Maloney, 2020). The steady-state economy indicators are derived from social welfare indicators and are not necessarily linked to GDP.

As the economies have expanded, the need for degrowth was identified (O'Neill, 2012). CASSE proposed "Degrowth Toward a Steady State Economy," unifying degrowth and steady-state economy: "Our mission is a democratic and just transition to a smaller, steady-state economy in harmony with nature, family, and community" (https://steadystate.org/). Barely mentioned in the SDGs, degrowth speaks about the need to restrain the economy. Daniel O'Neill (O'Neill, 2012) defines degrowth as the voluntary transition toward a just, participatory, and ecologically sustainable society. Concretely, the objectives of degrowth are to meet basic human needs and ensure a high quality of life while reducing the ecological impact of the global economy to a sustainable level, equitably distributed between nations. The critical challenge of degrowth is reducing natural resource use and waste production while maintaining or even enhancing the well-being of humans (and, significantly, other species!). While several studies have examined the nature and consequences of degrowth or a steady-state economy (Czech, 2013; Daly, 1991), there is no consensus on whether such a state is compatible with capitalism (Washington & Maloney, 2020). Advocates of degrowth disparage the faith that discourses of ecological modernization place in the role of markets, pointing to the deficiencies of carbon markets and the likelihood that decarbonization will be canceled out by unceasing economic growth (Adelman, 2018). However, Drews and Antal (2016) argue that unfortunately, in some interpretations, degrowth is a problematic term as it usually has a negative connotation of decline, a contraction, or decrease, rather than something related to improving welfare while addressing unsustainability, leading to unfavorable subsequent information processing and evaluating. Effective communication of the word degrowth is crucial for social and political impact. The aim of degrowth is better formulated to shield future generations against self-interested corporate interests and scale back the total production and consumption of materials and energy without decreasing human well-being. Even though the term degrowth is increasingly used in economic and social debates, it still needs to be promoted in education and production/consumption practices.

Cradle to Cradle® is a registered trademark of McDonough Braungart Design Chemistry, LLC (MBDC). Cradle to Cradle Certified^CM is licensed exclusively for the Cradle to Cradle Products Innovation Institute. Certification involves specifications for five certification categories (Material Health, Material Reutilization, Renewable Energy, Water Stewardship, and Social Fairness), as analyzed by students as part of their "evaluation of circular products" assignment, described below.

## 11.5 The Case Study: Student Assignments

The two case studies presented below belong to bachelor students of International Business Studies at The Hague University of Applied Sciences who have followed a minor in Sustainable Business in 2018. Within Sustainable Business minor, one of the five modules, Politics, Business, and Environment (PBE), involved (among other didactic strategies) students reading, presenting, and discussing the literature presented in the introduction of this chapter, engaging in debates about economic growth and possibilities of absolute decoupling, and considering alternatives such as degrowth. As part of PBE, the students had to examine the case of a product/process as either greenwashing, circular economy, or the best-case study. The students were asked to compare products to the 9R scale or on the C2C certification procedure by consulting the C2C Products Innovation Institute or corporate case studies on the website of Ellen MacArthur Foundation http://www.ellenmacarthurfoundation.org/case_studies/ and www.c2ccertified.org. It is worth noting that the minor commenced in 2010 and is presently continuing, each year involving different and updated case studies, with most of them being evaluated as "on the way to a circular economy." The randomly selected cases (the first two in order of presentations) are presented below.

### *11.5.1 Infinity Towel*

The students have presented the case of Jules Clarysse, which has achieved C2C Silver certification in 2011 for one of its products, Infinity Towel, "one of the first compostable European bath linens" (http://www.c2c-centre.com/product/interior-design-furniture/infinity-towel). The company claims that it uses 100% pure organic cotton and carefully selects dyes that leave no harmful substances behind after being composted. Students have outlined the factors responsible for the silver certification summing up that the towels are made to be "100% reusable as a nutrient in the biological cycle", using 100% pure organic cotton."

The product website claims that the material uses "non-harmful dyes used for 27 different colors based on six dyestuffs and has the expected use time is >200 washes for private use." Despite evaluating their selected product as "potentially C2C," the students also noted some issues that did not fit C2C's ideal strategy (see Fig. 11.1).

Regarding the use of "100% pure organic cotton," the producer uses virgin material, not recycled or reused material. All organic materials, from cotton to wool, are potentially compostable. The towel is buried in the consumer's backyard (as the producer has given no indication how towels can be taken back and where they can be "returned to biological cycle"), thus downcycled. In this way, the resulting waste product exits consumer use cycle and can be used as fertilizer which applies to the case of "100% reusable as a nutrient" – in the best-case scenario.

The producer does not indicate that the discount, for example, will be given to consumers for towels taken back to be either repaired (that would keep the product longer in use) or "returned to biological cycle" when the threads wear out after the claimed "The expected use time is >200 washes for private use." In this way, material-service shift (as in the service such as collecting used towels and repairing or remanufacturing them) is not apparent or provided. It was unclear what energy was used for making bath linens and how producers could guarantee that the consumers were composting the towels.

Another issue is that at the price of 20 euros, the towel is hardly affordable. In reflecting on assigned literature, the students quoted Isenhour (2010), who reflected that many sustainable products are targeted at a specific small audience of responsible consumers but are less appealing to those who choose for worse quality but cheaper options. One of the students quoted The Economist's (2020c) article, "in the face of climate change, individual willingness to sacrifice the fruits of a high-energy lifestyle is not enough. People and countries that do not share such


**Fig. 11.1** Why is Infinity towel not C2C?

motivations must act, too" (p. 51). Thus, the students have highlighted their presentation; the real question is how to make a product, such as a towel, even more, durable if not fully circular and affordable to push less sustainable options out of the competition. The students wondered whether the transition to the alternative material or service model would require a complete overhaul of the existing model.

### *11.5.2 Toast Ale*

Toast Ale is listed as one of the best-case studies at the website of Ellen MacArthur Foundation (https://www.ellenmacarthurfoundation.org/case-studies/brewing-beer-from-surplus-bread). Quoting the 2015 report *Growth Within A Circular economy vision for a competitive Europe*, the website of Toast Ale states that about 31% of food produced is lost or wasted, both throughout the value chain and as consumer waste. "If food waste were a country, it would be the 3rd largest emitter of greenhouse gases" (after China and the USA). "An incredible 44% of all bread produced in the UK is thrown away." The company started by collecting surplus bread from delis, bakeries, and sandwich makers. In order to produce ale, it is incorporated into the brewing process with malted barley, hops, yeast, and water as this simple switch can replace around a third of the malted barley used for beer (https://www.ellenmacarthurfoundation.org/case-studies/brewing-beer-from-surplus-bread).

The students analyzed why this product is circular and identified the following problems (see Fig. 11.2).

After the presentations by students, broader questions about circularity, sustainability, and the limits to growth were discussed. The students noticed that the supposedly "circular" or C2C products fall short of the ideal for infinite reuse or products that do not diminish quality after use. For example, for food and drink items, while one can be transformed into another (bread into ale), it happens with the loss of quality, and the final waste in the toilet is by no means "upcycled." In the case of towels, after the multiple use and the potential to let the materials biodegrade, they fit within more conventional eco-efficiency or reducing damage rather than the "100% good" paradigm. Also, the root problem of waste bread is not addressed. These cases motivated students to think of the more transformative solutions to sustainability challenges, but they also, regrettably, served to trigger cynicism in some students.

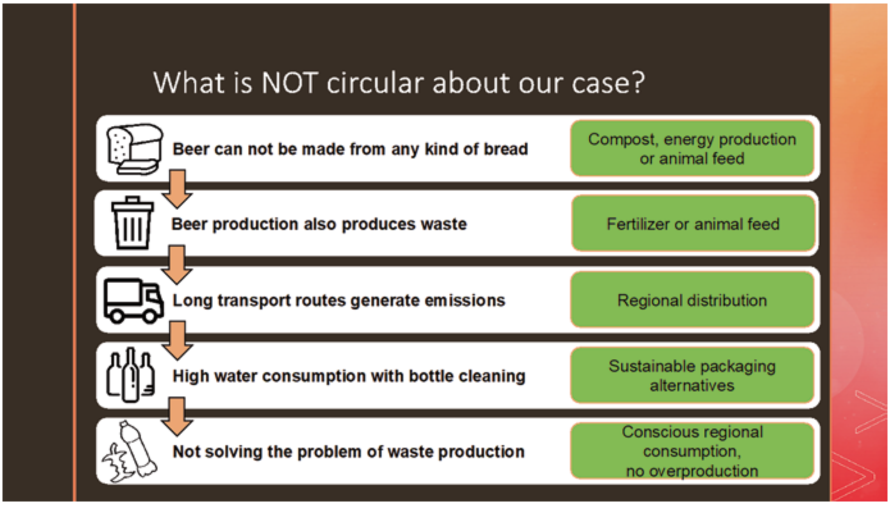


**Fig. 11.2** What is not circular about Bread Ale?

## 11.6 Discussion: Larger Lessons Learned from Towels and Ale

The central issue with the "circular" food and drink is that it rarely discusses the "waste equals food" C2C principle. While bread is transformed into ale as a supposedly circular product, urine produced, with the emission of ammonia, nitrogen, and other toxic or chemically treated materials in the sewage, is not discussed, which is different from waste by a grazing cow, whose excrement fertilizes the ground.

The global sustainability challenges cannot be addressed by simply producing more biodegradable towels or turning food waste into alcohol. Making "good" products more affordable for the global population is one challenge, but the critical question is whether global demand growth can sustain future generations of humans, let alone other species (Buchmann-Duck & Beazley, 2020). Also, while consumption of certain materials might become more sustainable in some segments of the population by choice, for example, by vegetarians, this does not apply to the majority of the population (Isenhour, 2010) and does little to restrain global trade agreements and subsidies, controlled by governments and large corporations. Relevant to the case of ale, large quantities of the restaurant and café/bar supplies, such as beer, are wasted as they spoil in storage (The Economist, 2020b). The formidable quantities of food are increasingly cheap, and, aside from unequal distribution due to skewed trade agreements and subsidies, billions of people are fed, even in the time of pandemic (Ibid). However, this international road, air, and water traffic and dependency on foreign supplies create climate and social vulnerabilities and appropriate the planet's finite resources for the good of one single species (Adelman, 2018). It is not just bread and beer that go to waste.

Without a planetary scale reform of the food production and the downscaling of human enterprise – the subject that the SDGs are silent on – no amount of efficiency can guarantee sustainability. Absolute decoupling of material products such as food or drink is impossible without considering waste products. It seems that some "circular" products fit within the conventional sustainability narrative rather than into a more critical and potentially transformative economic reform. They optimize production systems to completely close material loops that require a rigid coupling of diverse material conversion processes between processes in different companies and countries (de Man & Friege, 2016). Thus, rather than celebrating the global ability to "binge-eat as you binge-watch" (The Economist, 2020b), to move forward, one needs to ask a larger question, as the students did: is all this sustainable in the long term?

Despite these difficulties, it is essential not to "throw the baby out with the bathwater" (Kirchherr et al., 2017; Kopnina & Blewitt, 2018). A single company cannot address food waste, but it can consider system change when the entire supply chain, transport, distribution, and consumer behavior are considered. Rather than churning out new products, future business professionals can consider how existing products, from ceramic cups to appliances, can stay in operation and what type of new business models (services, such as repair) can be offered. There are also positive examples of traditionally single-use products, such as gDiapers, a C2C-certified product, which can be composted by adding them to compost – the urine turns the compost into nitrogen-rich soil. Consumers can opt for open-air, hot, or tumbler composting (Kopnina & Blewitt, 2018).

While it still has a long way to go in practice, the circular economy framework can reach beyond mainstream sustainability strategies. In line with the 9R strategy, the producers can offer repairs and refurbishment. However, while repair enjoys bipartisan support, repair of less durable products, such as clothes, is complicated by the fact that most affordable clothes are made from mixed materials (in C2C terms, "monstrous hybrids"), and mechanical or chemical recycling degrades materials such as mixed polyester (The Economist, 2017b). The Repair Association, a lobby group funded by repair shops, welfare organizations, and charities, supports "right to repair" laws (The Economist, 2017a). Gay Gordon-Byrne, executive director of the Repair Association, reflects that "repair isn't a partisan issue" in America, pointing out that the liberal left and conservative right make a powerful coalition. The political left sees the livelihood of repair shops endangered by big corporations. On the political right, consumers see that "not being able to repair his tractor" amounts to an attack on the "very idea of private property" (The Economist, 2017a).

Understanding these limitations by students and future professionals requires a realistic view of the possibilities within the 9R hierarchy and considerations of the price of and supply chain of the materials – subjects that the business students are well-positioned to approach. While undergraduate students are not yet capable of taking on such considerable global challenges, starting to think critically and honestly about the deceptive promises of the SDGs and overoptimistic promises of circularity is a good starting point. Consequent research evaluating students' progress as future business professionals can show the long-term effects of such lessons, such as conducting and maintaining transparent operations in which ideal and realistic closed-loop production options are considered in earnest.

The broader questions students could ask are whether absolute decoupling promised by the circular economy is possible and under which circumstances? Can SDG 8 be concerned with economic growth be combined with SDG 12, "Responsible consumption and production?" Moreover, what are the actual content and use of "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (SDG 4)? If this "quality education" can face fundamental facts and contradictions of realistic degrowth strategies, it has the most significant future potential.

### *11.6.1 Closing Remarks*

This chapter discussed the potential and limitations of C2C and circular products in the larger context of Sustainable Development Goals (SDGs) and the limits to growth. Akin to the SDGs embrace ecological modernization, circular models rarely mention degrowth or steady-state economy (Czech, 2013; Daly, 1991). The SDG approach and circular economy strategy tend to present an optimistic vision of "sustainable and inclusive economic growth" without addressing the root problems of unsustainability – population growth and expansion of material demands. With recommendations for efficient production, more radical transformative approaches seem underrepresented. However, degrowth strategy is missing from the SDGs, Ellen MacArthur Foundation case studies, or C2C products discussed in this chapter. The case studies discussed here show that circular products may struggle to meet real-world material demands. The case studies of supposedly circular or C2C products, Toast Ale and Infinity Towels, demonstrated the limited potential of decoupling, let alone "upcycling." The virgin materials used for making towels or for the transformation of bread into ale become materially less valuable than the towels after use (in the case of towels producing, at best, biodegradable garbage, and in the case of ale, urine).

Ways forward include a greater understanding of how degrowth can be carried out in business operations and beyond and how noncoercive, volunteer population reduction, and a drastic reduction in material demands beyond basic needs can be implemented at political, legal, social, and economic/corporate levels. Considering degrowth in corporate strategy demands nothing short of complete societal and economic transformation, starting with education. Rather than taking the desirability of "inclusive economic growth," a more critical approach demands nothing short of complete societal transformation toward "degrowth," starting with teaching it as part of (business) education.

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# Chapter 12
# University Contributions to the Circular Economy

**Alfredo Estrada-Merino and Aldo Alvarez-Risco**

## 12.1 Circular Economy

The circular economy represents a new model for transforming the raw materials used towards one that benefits from the reusable or disposable value. Also, it eliminates the disadvantages of the linear economy, which promotes the maximization of the benefit through lower costs (Ferronato et al., 2019; Geerken et al., 2019; Husgafvel et al., 2018; Leal Filho et al., 2019; Moktadir et al., 2018) which has loops in which the products that reach the final years of their terminal life become resources for other purposes in which the waste is minimized. It was first mentioned 40 years ago in a European Commission report, in which there was stagflation (high rates of inflation and unemployment); for that reason, solutions to replace physical and human capital with sustainable sources were sought. Nowadays, the European Union is the region that has taken more long-term measures to seek binding targets for reuse and recycling of municipal waste up to the 65%, recycling of the 75% of the packaging waste, and the limitation of the municipal waste dumping up to 10% in 2030. Additionally, the EU is committed to making all plastic packaging reusable by 2030 and has created a platform to tackle food losses and waste and finance the circular economy. However, a globally accepted definition has not been agreed upon, yet more than 114 definitions for the circular economy exist, according to Kirchherr et al. (2017). Since there are multiple applications based on the type of industry, there is an approach to the correct definition in the field of sustainable

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development and ecological economics to reach a consensus (Korhonen et al., 2018), which is defined as an economy based on the society's systems of production and consumption that maximize the services produced from the linear flow of materials and energy. More articles describe different definitions (Alhawari et al., 2021; Awan et al., 2020; García-Barragán et al., 2019; Lahti et al., 2018; Moraga et al., 2019; Saidani et al., 2019; Teigiserova et al., 2020).

One of the main organizations that also promote the circular economy is the Ellen McArthur Foundation. They define the circular economy as an industrial system that is restorative and regenerative by intention and design (Mac Arthur, 2013). Additionally, they mention that the circular economy gives four opportunities for value creation through minimizing waste production, maximizing materials usage, having diversified options, and the benefits of ensuring an uncontaminated material for its reuse. The last point is based on Cradle to Cradle (C2C), a referential framework that intends to create efficient, sustainable, and waste-free systems. It is a concept of total recycling through design. The product is conceived so that the cost of recycling is lower than the cost of buying new material. In the beginning, a company focuses on increasing competitiveness by reducing costs and transforming a product-oriented approach into a service platform. Although the model application occurs mainly at the microlevel, the concept goes beyond the manufacturing and design processes. It can also be applied to architecture and construction, urban environments, and infrastructure design. In some cases, especially for technological products that are subject to frequent upgrades, durability is not the optimal strategy; in that instance, it is preferable to design the products in a way that allows its disassembly and recovery of components, either to upgrade some elements or to use individual parts for the next generation (Calisto Friant et al., 2020, 2021; Geisendorf & Pietrulla, 2018).

The circular economy's success contributes to the three dimensions of sustainable development: environmental, social, and corporate governance. The critical issue of global sustainable development is the linear flow of materials and energy between nature and human economy and to fight the traditional linear model of extraction-production-utilization materials and energy discharge of the modern system, which is unsustainable, since it causes social efficiency losses that represent a sunk cost in the long term (Calisto Friant et al., 2020; Frosch & Gallopoulos, 1989; Ubando et al., 2020; Wainaina et al., 2020). For that reason, circular economy models have arisen and have already been applied in different fields to quantify the materials flows and the associated emissions of embodied energy, water, and greenhouse gases. Two models correspond to the circular economy: one reuses or extends the product's end of life through its repair or improvement, and the other transforms old raw material into new resources through recycling (Patwa et al., 2021; Stahel, 2016). Among these models, we can see the simulations sought in university campuses that are still in a state of constant experimentation.

## 12.2 Universities' Role

The direct impact of a university may include making the local area more dynamic and diverse, increasing employment, and creating revenue and expenses flows. In addition, it has an indirect impact in the local areas by generally improving the human resources and attracting businesses to educational activities. An economic assessment found out that the university sector represents 2.7% of the total employment in the UK and generates 2.8% of UK GDP based on the expenses both inside and outside the campus, which gives the universities the possibility to play a vital role in the local and regional approaches of the circular economy. Today, universities have included the search for new mechanisms to reduce greenhouse gas emissions, waste, and water management in their curricula. These have an essential role in supporting the transition towards a more circular economy. This function has multiple aspects, including education, research, and leadership. As innovative and progressive centers that employ many people, they have fundamental properties and require significant inflows (and outflows) of materials to operate. The university campuses offer many living labs for a more circular economy, where guidelines and experiments can be applied and proved before being broadened.

Few universities have assessed their materials that comprehensively flow in the campus to identify problems and opportunities for the transition towards a more circular economy (Stephan et al., 2020) which is the first step to implement a circular economy on campus, as highlighted by Mendoza et al. (2019). Likewise, these promote the use of education for future generations, in which the fundamental role of the performance, circular, and linear economy is understood (Stahel, 2016). According to Nunes et al. (Nunes et al., 2018), a university represents a crucial element with the local, regional, or national companies to promote the development and research into solutions that reinforce the value chain of products and services. On the other hand, we can also identify the role of implementing good business practices to companies that decide to adopt a circular economy (Alvarez-Risco, Del-Aguila-Arcentales, et al., 2021; Alvarez-Risco, Mlodzianowska, et al., 2021; Bugallo-Rodríguez & Vega-Marcote, 2020; Díez et al., 2018; Li et al., 2021; Salas et al., 2021; Tasdemir & Gazo, 2020). Within the circular economy, the eco-efficient role seeks to provide goods and services at competitive prices and gradually reduce the environmental impact and the overuse of raw materials. At the same time, the concept of eco-effectiveness is interpreted as the search for the ecological conditions or aspects for products or services and the strategies to achieve it without focusing on the sole reduction of negative externalities (Nunes et al., 2018). Eco-efficiency begins with the assumption of a one-way, linear flow of materials through industrial systems: raw materials are extracted from the environment and transformed into products. In this system, eco-efficient techniques seek only to minimize the material flow system's volume, velocity, and toxicity, but they are incapable of altering its linear progression. Instead of real recycling, this process is descending, a downgrade in material quality, limiting usability and maintaining the linear dynamic. In contrast to this approach of minimization and dematerialization, the concept of eco-effectiveness proposes the transformation of products and their associated material flows to form a supportive relationship with ecological systems and future economic growth (Mac Arthur, 2013).

Universities play a broad role in the circular economy, according to the approaches that are analyzed within it. Since the late 1960s, they have been recognized as drivers of the local economy by promoting employment, economic stability, and purchasing power (Nash, 1973). Later, the emphasis was integrated into the search for social and economic stability, from which three main roles derived: innovation based on knowledge, economic development driven by culture and resource management, and mobilization that allows improving social integration and civic purposes (De Medici et al., 2018). On the other hand, Frondizi et al. (2019), Pedro et al. (2020), and Maresova et al. (2019) summarize different roles and mention that there is a development role played by universities in the regional economy and social development, which focuses on the intersection of the learning economies and regionalization of production and regulation. Universities should not only be perceived as drivers of sustainability through learning, research, and social outreach activities but also as organizations that must apply circular economy (Alnajem et al., 2021; Centobelli et al., 2020; Kapoor et al., 2020; Lopes de Sousa Jabbour et al., 2018; Okorie et al., 2018; Petit-Boix & Leipold, 2018; Ruiz-Real et al., 2018; Zeiss et al., 2021).

## 12.3 Empirical Evidence

The results obtained by Stephan et al. (2020) and Salguero-Puerta et al. (2019) are the evidence of some universities that have decided to assess if they have concretized good circular economy practices. The practices represent specific cases to quantify the materials flows used in university campuses to measure the actual impact of the circular economy strategies, which are successful in calculating an estimate in monetary terms. For the University of Melbourne in Australia, the material inflows, representing less than 2% of the data of purchase expenses obtained, need enough energy to build 8 new mid-size Australian houses and enough water to fill 12 Olympic pools. They are also responsible for the emission of greenhouse gases equivalent to the tailpipe emissions of 9000 cars that travel from Melbourne to Sidney (Stephan et al., 2020). The University of Lome in Togo case highlights that 59.5% of the waste generated on campus in 2018 could be reduced through composting. Besides, 27% of the energy consumed in the campus could be replaced by clean energy obtained from biogas. As far as the plastic fraction, the circular economy, by reusing plastic bottles and selling the rest in the port city, would drive the income obtained, ranging from €15.5/day in 2018 to €34.5/day in 2027. Regarding old tires, 1.5% of the rubber needed to pave the entire campus roadway could be replaced by the waste generated by the tires currently existing on the campus (Salguero-Puerta et al., 2019).

This document and future studies must include improved data about the materials flow to ensure the quality of results. There are some limitations, such as, firstly, the underlying acquisitions should be filtered, cleaned, and adjusted manually to extract the inflow of financial transaction material. Secondly, construction activities have been omitted to maintain a manageable scope. If such activities were included, they would significantly exceed the materials flow unrelated to construction in terms of mass, even when they are annually normalized. Thirdly, the environmentally extended input-output analysis provides a general estimate of the incorporated environmental flows. The model used to measure the resources utilized is divided into five stages: establishing material input; calculating greenhouse gases emissions, water, and incorporated energy associated with inputs; collecting material outputs; combining all data in an integrated material and incorporated environmental flows analysis; and, finally, generating results and identifying opportunities for the circular economy (Stephan et al., 2020). Besides that, the study promoted by Nunes et al. (2018) is also considered. In such a study, they used the database of two world-ranking systems to learn about the environmental practices of the universities leaders in the sector. The UI GreenMetric was the first global ranking of the sustainability performance of universities and was selected for being the most complete and updated list that was publicly available. At the same time, the QS Top Universities show the best universities worldwide in several subjects. Fifty universities were obtained from the latter, from which more than 80% had plans for reducing $CO_2$ and promoting the efficiency in the energy used (Fig. 12.1).

While there are several integration measures at a “top-down” or “bottom-up” level, in which the corresponding authorities contribute to the industry and

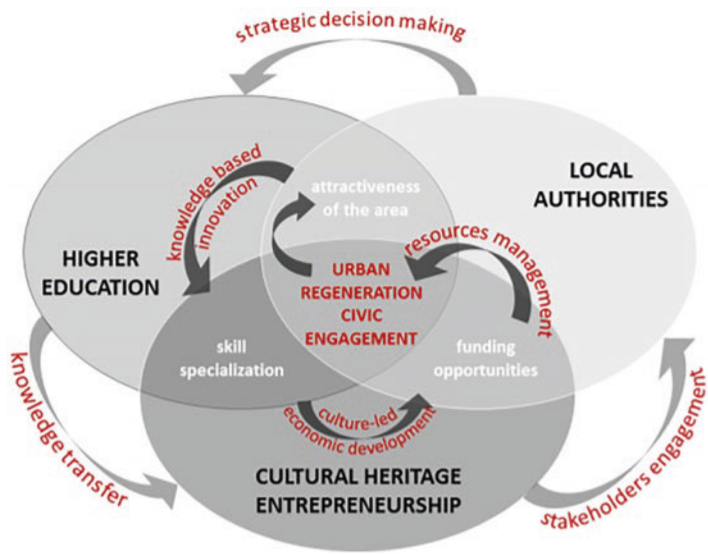


Fig. 12.1 Triple helix model. (Source: De Medici et al. (2018))

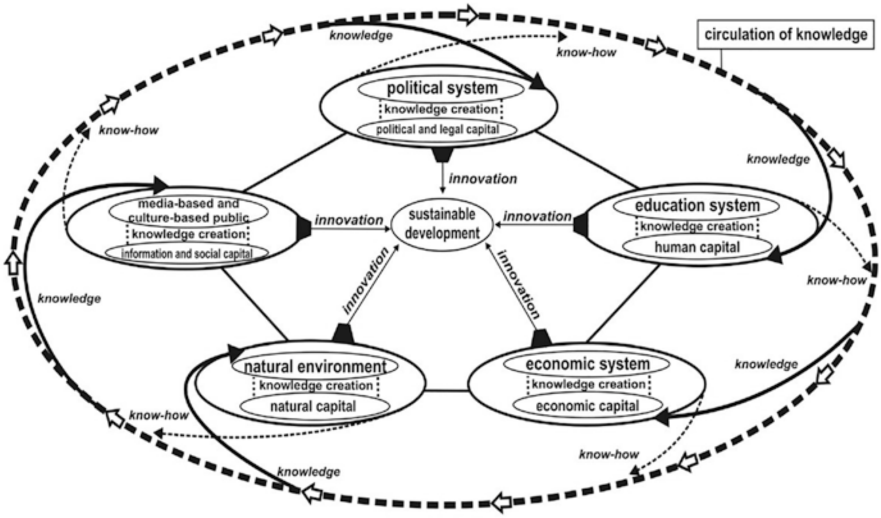


**Fig. 12.2** Quintuple helix model. (Source: Carayannis et al. (2012))

university or small businesses contribute to the community and government, nowadays, the European project "Construye 2020+" (Build Up) is used as an example, and it conducts the quintuple helix. In order to understand the quintuple helix, we will review the triple helix model promoted by Etzkowitz and Leydesdorff (2000) and shown in Fig. 12.1, which denotes the relation among the university, industry, and government and the internal transformations within each block. The initial triple helix emphasizes knowledge production and innovation in the economy, which is compatible with the knowledge economy. The model presents three trajectories that are internal and external to each helix. The first shows the influence of one upon another and representing the interacting processes that trigger the overlay environment, where the knowledge transfer, stakeholders engagement, and strategic decisions are shown. The second is internal, from which overlay characteristics are formed, such as skills specialization, funding opportunities, and attractiveness of the area; lastly, the third is the innermost trajectory, which determines the urban regeneration and establishes the circularity of the processes by reconnecting the overlay environments with the helices (De Medici et al., 2018). Likewise, Fig. 12.2 shows the incorporation of new subsystems that form the quintuple helix initially proposed by Carayannis et al. (2012), representing a model adequate in theory and practice offered to society to understand the link between knowledge and innovation and to promote sustainable development. Within the quintuple helix innovation model framework, the natural environments of society and the economy should also be considered drivers for knowledge production and innovation, thus defining the opportunities for the knowledge economy (Carayannis et al., 2012). The five subsystems that integrate the quintuple helix aim to improve the capital incorporated by any entity to generate sustainable development for society. The first subsystem is education; it reassumes the role of universities to promote education through research and development and its diffusion. The second one is the economy, which integrates the companies and industries. The third one is the natural environment, which provides the natural capital and raises awareness about sustainable development. The fourth subsystem is culture and media, in which the capital based on traditions, values, and customs is formed, according to information networks such as TV, social media, and newspapers, among others. Finally, the fifth subsystem integrates politics by which specific measures will be integrated in the future to define the direction of sustainable development and its proper administration (Carayannis et al., 2012).

Likewise, numerous universities have acknowledged the emergence of the "third mission" that is understood as an evolution in disciplinary organization, creating disciplines and multidisciplinary fields that include nonacademic users. These fields can function in environments that are increasingly multidisciplinary to address polarization and specialization in existing domains. Universities have created institutes and centers to adapt to the emergence of new scientific fields. Although the third mission is still an ambiguous concept, universities present three missions or objectives for education. According to Laredo (2007), these are mass tertiary education, with a bachelor's degree as the main characteristic; higher education and specialized professional research, with a master's degree as the main diploma and "problem-solving research" as the main activity; and academic education and research, with a Ph.D. as primary diploma and articles as the main output.

## 12.4 Limitations and Other Concepts

Finally, in the absence of studies and initiatives that integrate the results and expectations of the circular economy, new methodologies must be promoted in order to collect inputs and outputs of materials and services that maintain a linear economy and that harm the environment, and, at the same time, such methodologies should be standardized for future reviews and research. The data regarding waste was collected regularly with an appropriate level of disaggregation; it was much easier to understand where the campus materials came out and in what way, in comparison with monitoring its origin. It is recommended to collect purchases data where the transactions are assigned to the correct accounts, with the detailed invoice and, whenever possible, a link to the provider.

### *12.4.1 Closing Remarks*

Within the circular economy concept, there can also occur a misunderstanding with several definitions that look for the same sustainable development objectives. In the core of the circular economy concept, resource circularity in the system is obtained by applying a circular design in all activities during the stages of the economy's products and materials life cycles. Despite being the most far-reaching concepts, the definition established for the circular economy and Cradle to Cradle does not include the stages in detail, being the first one of a more significant reach towards macroeconomics. In contrast, the second one is towards mesoeconomics, which sees the economy at a sector, region, or group level, but it does not reach the macroeconomic level as a country. On the other hand, four principles of the circular economy are proposed in its definition: resources and energy recirculation, minimization of resources demand, and recovery of waste value; a multilevel approach; importance as a way to achieve sustainable development; and a close relationship with the way the society innovates. These four components can help the scientific community and political actors to reach a consensus in this field (Geisendorf & Pietrulla, 2018).

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# Part IV
# National and International Experiences in the Circular Economy

# Chapter 13
# Dissemination of Circular Water Practices in Colombia

**Alejandro Medina-Aristizabal and Bart van Hoof**

## 13.1 Water as a Primary Resource for Circular Economy

Water makes all human activities a primary resource for society's well-being and economic growth (UN-Water, 2018). Adequate water management of surface water, groundwater, drinking water distribution, wastewater treatment, and ecosystem protection is required to safeguard social development and economic prosperity. However, current water-related challenges in the world, such as ecosystems degradation, water disasters, population inequalities to access safely managed drinking water and wastewater treatment, have resulted from improper water management and aggravated by climate change effects (Wetlands International, 2017). The importance of water as a resource for well-being is emphasized by the Sustainable Development Goals (SDG) number 6 (UN-Water, 2018). In Latin America, urbanization, industrialization, and agriculture-based activities are significant trends due to population growth and economic developments. Therefore, adequate water management in Latin America is crucial for a resilient region against climate change consequences and economic development (UNESCO; UN Water, 2020). For instance, in 2011, the primary water use in the region was for agricultural purposes, accounting for 68% of the total use of water, while the rest was 11% for industries and 21% for domestic use (Mekonnen et al., 2015). This trend differs from the global average, in the relatively lower use of water in the industry (FAO, 2017), evidencing the region's higher dependence on the agriculture-based economy (highest percentage) compared to the lower water use for industrial purposes (even lower than for domestic).

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**Table 13.1** Top ten countries water use for irrigation in agriculture in LAC (FAO, 2017)

| Country | Total water use for irrigation in agriculture ($10^9$ $m^3$/year) |
|---|---|
| 1. Mexico | 66.8 |
| 2. Brazil | 39.43 |
| 3. Chile | 29.42 |
| 4. Argentina | 27.93 |
| 5. Venezuela | 16.71 |
| 6. Peru | 13.1 |
| 7. Ecuador | 8.08 |
| 8. Dominican Republic | 7.56 |
| 9. Colombia | 6.34 |
| 10. Cuba | 5.52 |

The Latin America and the Caribbean (LAC) region can support its agriculture-based economies due to the higher distribution of freshwater resources compared to other countries in the world. LAC accounts for 34% of all freshwater sources, followed by Southern and Eastern Asia (26.8%) and North America (15.2%). The rest of the regions of the world are below 10% (FAO, 2003) (Mekonnen et al., 2015). Due to relatively high precipitation and limited infrastructure, Colombia uses relatively little water for irrigation compared to other countries in the region. Mexico's agriculture uses a total of $66.8 \times 10^9$ $m^3$/year, and the islands of the Caribbean water use for irrigation average $0.0002 \times 10^9$ $m^3$/year. Table 13.1 presents the top ten countries' volumes of water used for irrigation in agriculture in LAC (FAO, 2017).

The LAC region has low levels of water stress but high pressure in water bodies' quality. Between 2015 and 2017, the average water stress level in the region grew from 4% to 5.3% (FAO, 2020). The increase in water stress caused by larger volumes of water withdrawn for human-related activities that threaten the ecosystem's biological processes required water demand. This condition hinders ecosystems' water-related services that regulate water resources availability. Regarding water quality, it was found that between 1990 and 2010, LAC increasingly polluted water bodies mainly by untreated discharges (UNEP, 2016). Nearly all countries in the region safely treat less than 50% of households' wastewater (WHO and UN-Habitat, 2018).

This context highlights the importance of implementing adequate strategies to promote circular practices of water resources in the region. This chapter aims to present a model for disseminating circular water management, which enabled a group of multi-sectoral firms in Colombia to contribute to water security. Colombia is a characteristic country in LA for its water resources abundance, with the highest water availability, recognized as Kuwait's water resource. It has five times more water sources than the world average and twice the average of LA. For instance, water availability worldwide is 10 L/s/$km^2$, the average in LA is 21 L/s/$km^2$, and Colombia is 56 L/s/$km^2$ (Institute of Hydrology, Meteorology and Environmental Studies, 2015). Despite the vast abundance of water in Colombia, distribution within the country is heterogeneous. Regions as the Amazon, Orinoco, and Pacific regions have high precipitations and are rich in water resources, while the Andean region has moderate precipitation, and the Caribbean region is mainly arid.

The Andean region is located in the Colombian mountain range and has unique ecosystems. One of these ecosystems is Paramos. These are high-altitude mountain ecosystems with high precipitations, low temperatures, and a particular soil and vegetation type that makes them optimal environment water regulators (Cresso et al., 2020). The region is the densest populated and concentrates 50% of Colombia's primary industry. The central department, Cundinamarca, includes the capital Bogota. Near Bogota, there are numerous industries, industrial parks, and free trade zones. Nonetheless, there are also critical agricultural activities not far from the capital city, especially flower farming.

The Bogota River Basin occupies most of Cundinamarca's territory with about 5900 $km^2$. The Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) in Colombia developed an indicator of water vulnerability based on the relation between the water stress and the hydrological regulation of watersheds (Institute of Hydrology, Meteorology and Environmental Studies, 2019). The same study identifies the Bogota River Basin with the highest risk value for this indicator. Furthermore, an analysis of water shortages in different regions concluded that nearly 40% of Cundinamarca municipalities (44 municipalities) are highly likely to be vulnerable to water shortages if extreme weather conditions happen. Under these conditions, Cundinamarca faces serious water security challenges. Moreover, being a department high in the mountains, all discharges and poor water quality of the Bogota River limit industrial and agricultural activities in the neighboring watersheds. In the following sections, the case in Cundinamarca will be analyzed considering circular economy practices in a group of firms located in the Bogota River Basin.

## 13.2 Circular Water Systems and Integrated Water Management

Water in nature behaves cyclically, moving along different ecosystems, transforming into different states of matter (liquid, gas, solid), and finally returning to its initial start point and repeating the cycle (García-García et al., 2020). In its cycle, water carries nutrients and energy throughout the cycle, benefitting different organisms, ecosystems, and users. Water has been primarily used in linear models as "take-make-waste," and much water is discharged without any use despite this circular behavior. This linearity has demonstrated adverse impacts on ecosystem degradation, affecting stress on water availability and quality. Moreover, users compete for water resources affecting water security. In order to shift from the current linearity of water, a systemic perspective is needed.

Circular water practices connect to what is known in literature and practice as Integrated Water Resources Management (IWRM). This approach advocates optimizing water consumption by increasing efficiency, promoting water reuse, reducing water withdrawals, and protecting vital water-related ecosystems (Nika, Vasilaki, et al., 2020). IWRM is rooted in circular economy principles: regenerating natural capital, keeping resources in use, and designing waste (Ellen MacArthur Foundation, 2015) (Nika, Vasilaki, et al., 2020). Circular water management, including IWRM, represents a systemic view of all water-related ecosystems, their human-related activities, and economic outputs. It seeks to coordinate water resources use, land use, ecosystems protection through demand management, stakeholder participation, integration of policies, regulations, and institutional frameworks (GWP, 2018).

Circular water management involves participative and territorial approaches. Rather than having a narrow focus on single industrial sectors, a multi-sectoral participation approach is taken. Circular water management considers the macroscale, in which the water catchment impacts all stakeholders in the territory (Nika, Vasilaki, et al., 2020) and invites collaborative efforts to contribute to the collective water system. Furthermore, it seeks to interrelate different watersheds, as actions happening in one river basin may affect another one, such as the effect of dams, watershed transfer, and water quality degradation from upstream to downstream users.

Circular water management has gained attention worldwide. In Colombia, circular water management began taking part in the national policies in the last decade, 2010–2020. In 2010, the Ministry of Environment and Sustainable Development (MESD) published the National Policy for Integrated Water Resources Management (NPIWRM) (MESD, 2010). The objective of this policy was to guarantee the sustainability of water resources through efficient management in line with land use, ecosystem conservation, and stakeholder participation. In the 2030 agenda, water management has a specific objective under goal 6, namely, target 6.5 (UN-Water, 2018).

Later in 2019, Colombia became the first country in Latin America to develop a National Strategy on Circular Economy Strategy (NSCE) (MESD and MCTI, 2019). The NCES's objective is to help establish guidelines to adopt circular initiatives with six prioritized resource flows: Water Flows. The goals expected from the latter include promoting water reuse initiatives, reducing water losses in water distribution systems nationally, increasing water productivity (gross added value to GDP per $m^3$ of water used), an increase in the level of wastewater treatment, and improving the water quality of water bodies nationwide. This public policy context in Colombia provides an opportunity for promoting a circular water systems paradigm that includes water efficiency, water reuse, and water sources conservation. As a result, goals from the two complementary public policies, the NSCE and the NPIWRM, can be achieved parallelly. For instance, they decrease water stress and water conflict between users in a watershed and increase water efficiency and productivity reflected in more gross added value per water consumed.

Water management faces many challenges, such as the rapid urbanization rates and land use transformation that results in the degradation of ecosystems which impacts water regulation (UNESCO; UN Water, 2018). Moreover, untreated water discharges are severely degrading natural habitats. Additionally, climate change aggravates all mentioned challenges and exacerbates inequalities and vulnerabilities. In its pursuit of safeguarding better water conditions for the future, water management must face increasing water competition, ecosystem degradation, and help natural ecosystems regeneration (UNESCO; UN Water, 2018). Participative and territorial approaches are essential and must be backed up by robust and enabling institutional and regulatory frameworks.

Circular water management was identified by the Universidad de Los Andes and the Environmental Authority of Cundinamarca (CAR) as the Sustainable Enterprise Network (RedES) primary approach, a voluntary mechanism aiming to scale firms' environmental sustainability practices in its jurisdiction.

## 13.3 Sustainable Enterprises Network (RedES) for the Dissemination of Integrated Water Management Among Firms

The Sustainable Enterprise Network (RedES in Spanish) was initiated in 2013 as a public-private initiative between the Regional Environmental Authority of Cundinamarca (CAR) and Universidad de los Andes, School of Management (UASM), both located in Bogota, Colombia. The program aimed to improve the environmental performance of small- and medium-sized enterprises (SMEs) by applying circular economy strategies in supply chains and regional networks of firms. The model is supported by public-private partnerships between firms, academic institutions, and financial agencies, fitting the proposed ideas (Seuring & Müller, 2008) and (Pahl-Wostl et al., 2008).

The program's objectives are achieved by strengthening firms' capacities regarding key factors for productive transformation. Depending on the firm and type of project to be developed, this includes productivity, added value, new technologies, training, participation in value chains, and capacity for collaboration with other firms and external stakeholders (van Hoof & Duque-Hernández, 2020).

RedES started in 2013 with a group of 40 participating firms, 1 university, and the environmental authority, and in 2019 it scaled to a critical mass of 500 firms and 5 universities within the jurisdiction of CAR, conforming to the RedES Community of Practice (CoP) (Lang et al., 2012). RedES encourages firms to develop complementary projects that improve their environmental performance and share their experiences with other organizations. Initially, RedES used a cleaner production (CP) strategy, teaching companies to develop initiatives to improve resource efficiency, mainly by improving internal production processes. As the program and a critical mass of companies advanced, complementary approaches for improving environmental performance were included. From 2018 and onwards, a new industrial symbiosis (IS) program fostered more complex collaborative projects among

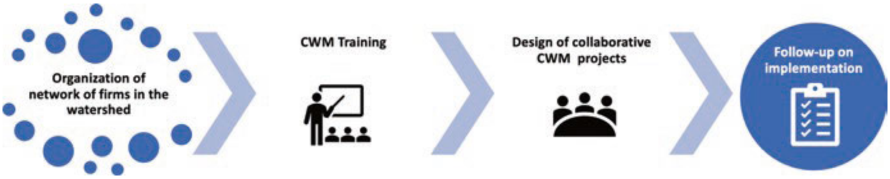


**Fig. 13.1** The four-step process of RedES-CWM

firms for waste recycling and material reuse and initiatives for sharing infrastructures such as water treatment plants and composting facilities.

In 2019, as part of the expansion of the RedES program, circular water management (CWM) was introduced as an approach to advance productive transformation on a watershed level. The dissemination model of RedES-CWM included various steps: (i) organization of a network of firms located around the watershed; (ii) training of firm's representatives in circular water practices; (iii) formulation of collaborative circular water projects; and (iv) follow-up on the implementation of circular water projects. Each of the steps includes guidelines of the RedES-CWM dissemination model. Figure 13.1 presents the four-step approach of the RedES-CWM methodology.

### *13.3.1 Step 1: Organization of Networks of Firms Located in the Watershed*

Circular water management requires collaborative initiatives to advance transformation on a system level in the watershed, such as protecting water resources and ecosystems that play an essential role in water regulation services. Collaboration among firms requires trust, shared vision, communication, and coordination, recognized as collaboration capacity (van Hoof & Thiell, 2014). Through collaborative efforts, the promise of circular water management offers business opportunities to safeguard water resources for their operations.

Together with the support of CAR and the National Water Center (CAN) of the National Business Association of Colombia (ANDI), companies were invited to participate in the RedES-CWM program. Informative meetings were held with representatives of companies to describe the features, scope, and objectives of the program. The pool of firms that participated in these meetings included those that had participated previously in other RedES's programs. Organizations interested in participating in the program sign a letter of commitment where they voluntarily assign at least two employees with an administrative and technical profile to attend the workshops and free of charge. RedES-CWM requires that firms are located in the same watershed, as it aims at developing collaborative projects in the shared water-related ecosystems and sources. Groups are conformed by 10–15 multi-sectoral and different-sized firms (Fig. 13.2).

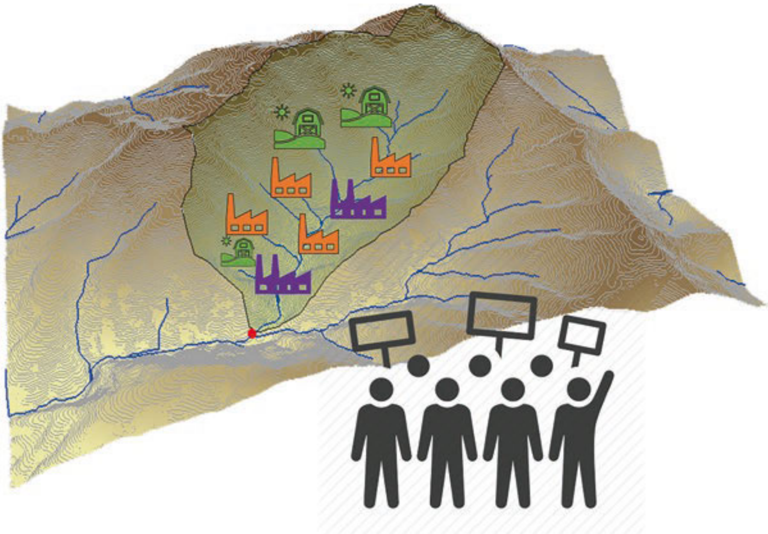

**Fig. 13.2** RedES-CWM multi-sectoral participants in the watershed

### *13.3.2 Step 2: Capacity Building for Circular Water Management*

The capacity building process is used to train company representatives to understand the opportunities of circular water management, generate a shared vision among a group of neighbor companies, and apply tools for the design of collaborative circular water management projects. The learning-by-doing methodology enables participants to identify relevant and adjusted opportunities to the needs of their companies. Learning-by-doing facilitates change in individuals and implements the initiatives designed by themselves (van Hoof & Duque-Hernández, 2020). The methodology empowers companies' employees by learning practical tools instead of offering predesigned solutions.

RedES-CWM capacity building program is based on nine workshops divided into three modules: (I) Introduction to Circular Water Management and Ecosystem services, (II) Water Risk and Water Security, and (III) Economic and Environmental Benefits Calculation. Each workshop introduces circular water management concepts and tools and an intensity of 3 h per session. Participants identify within the context of their firm critical points and quantify inefficiencies that generate economic losses and environmental impacts. As a result, participants participate in the design collaborative projects with a clear objective, description, investment, expected economic benefits, and estimated payback (van Hoof & Duque-Hernández, 2020).

Once the two groups were established, the training cycle began. Workshops were held in one of the companies participating in the program, which helped create trust

**Table 13.2** RedES-CWM training modules and content

| Module | Workshop |
|---|---|
| I. Introduction to circular water management and ecosystem services | 1. Introduction to CWM as a strategy for business productivity and sustainable performance<br>2. Opportunities and challenges of CWM<br>3. Water sources and water uses |
| II. Water risk and water security | 4. Water risk identification and evaluation tools<br>5. Business-critical points and water security<br>6. Collaborative action in the watershed |
| III. Economic and environmental benefits calculation | 7. CWM projects economic, environmental, and social indicators<br>8. Project consolidation<br>9. Projects presentation |

relationships between firms. These workshops are led by experienced consultants that guide participants in the design of a circular water project. Group site visits are held in one of the participating company's facilities to help reinforce the understanding and importance of the shared territory and resources and aid participants in identifying collaborative opportunities to protect ecosystems that provide water services related to water availability, water quality, or water resilience. The structure and topics of the circular water management workshop cycle of the RedES-CWM are presented in Table 13.2.

### 13.3.3 Step 3: Formulation of Collaborative Circular Water Management Initiatives

As a result of the capacity building, participants formulate collaborative projects to improve water security, positively impacting the firm's competitiveness. RedES-CWM approach stresses the relation between water management practices for improving business competitiveness and productivity and builds on previous experiences obtained by the firms in earlier participations in the RedES program.

Project scopes range from an individual firm's focus on their processes and operations promoting the efficient use of water resources to a broader scale involving the value chain and symbiotic relationships with companies from different economic sectors and protecting water-related ecosystems. The project typologies range from business-led initiatives, a collaboration between firms and civil society organizations, and the participation of firms in existent programs from the environmental authority for water-related ecosystems restoration. Once the workshops are completed, participants present their projects. These presentations include clear objectives, phases, a map with ecosystems identified, and impact indicators, including financial and environmental benefits. Yardsticks are used to convert technical, environmental indicators such as water regulated in the watershed in terms of the number of households supplied with water for a year, hectares of ecosystems protected in terms of football fields, $CO_2$ sequestration in terms of car emissions per year, and sediment drag avoided in water bodies in terms of tons of waste produced per household.

### *13.3.4 Step 4: Follow-Up on Implementation of Circular Water Management Initiatives*

Once companies have completed the training cycle and designed their projects, the expert consultants keep tracking the initiatives' implementation progress. These activities include regular meetings to discuss barriers and challenges firms face and present opportunities for sharing the advances of their initiative with other stakeholders in worktables with businesses associations, conferences, and seminars, which helps showcase the projects.

The regional environmental authority further supported the development of the initiatives by providing Geographical Information Systems information regarding vegetation types, delimited areas for restoration, and groundwater recharge areas, which helped in the final information for implementing projects.

## 13.4 Impact Indicators Contributing to Water Circularity

Various indicators measure the impact of dissemination of circularity practices. These include the number of participating companies, their economic sectors, projects designed, typologies, economic indicators, environmental benefits, and contributions to local and national policies.

### *13.4.1 Participants*

Twenty-two multi-sectoral companies, from SMEs to large industries, located along the Bogota River Basin participated in the program. Out of the 22 companies, 14 were SMEs. A total of 44 representatives from these firms participated in the workshops. The economic sectors of the organizations included floriculture, horticulture, alcoholic and nonalcoholic beverages production, dairy products, manufacturing, chemicals, cosmetics, poultry livestock, and entertainment parks. Firms were divided into two groups. Group 1 had companies located in the northern, upper section of the Bogota River watershed, while Group 2 was located in the middle section of the Bogota River watershed. Table 13.3 summarizes the number of companies per group and economic activity.

**Table 13.3** Economic activities and groups of companies that participated in RedES-CWM

| Economic activity | Group 1 | Group 2 | Number of companies |
|---|---|---|---|
| Agriculture: Includes floriculture and horticulture | 5 | 4 | 9 |
| Alcoholic and nonalcoholic beverages, dairy products | 4 | 2 | 6 |
| Manufacturing | 1 | 2 | 3 |
| Entertainment parks | 1 | | 1 |
| Cosmetics | 1 | | 1 |
| Chemicals | | 1 | 1 |
| Livestock | | 1 | 1 |
| **Total** | **12** | **10** | **22** |

The diverse group of participants presented various water characteristics; also, they showed different water usage, various water sources (from wells, municipal water distribution, and reservoirs), and diverse surrounding ecosystems as paramos ecosystems, wetlands, or urban settings.

### *13.4.2 Project Types*

RedES-CWM assisted companies in designing collaborative projects around a watershed by adopting a new understanding of circular water management. It includes applying best practices and technology innovation to optimize water use, recirculation, and reuse. Furthermore, beyond these kinds of initiatives, companies also learn that circular water management considers the role of natural ecosystems in regulating water availability, quality, and resilience.

Generally, the participating companies showed an initial understanding of their water needs in volume, physical, and chemical parameters. Their characterization of intake water is their first step to designing a specific treatment operation that adapts water's characteristics to meet the requirements for an industrial process and optimize the use of chemicals used. However, when water intake changes drastically, operations usually require additional unaccounted resources that increase costs and decrease efficiency. Such is the case of water utilities and flocculants that help remove suspended solids for the distribution of drinking water. This problem is addressed in the RedES-CWM program by expanding their understanding of the water sources. They also understand their ecosystems as part of the process and as an asset for adequate circular water management.

Previous experiences in the RedES helped in sparking collaborative initiatives around the watershed. Some companies pursuing circular water management already advance initiatives of by-products exchange and infrastructure and services sharing.

**Table 13.4** Collaborative CWM initiatives designed by participating companies

| Project type | Projects |
|---|---|
| Businesses initiative | 1. Paramo and groundwater recharge ecosystems 30-ha restoration<br>2. Protection and reforestation of paramo and wetland corridor<br>3. Restoration of 15 ha of paramo ecosystem<br>4. Reforestation of 1 ha of riparian ecosystem |
| Civil society natural reserves | 1. Creation of a 6-ha natural reserve<br>2. Restoration of 0.5 ha of a natural reserve<br>3. Restoration of 2 ha of paramo ecosystem in a natural reserve<br>4. Reforestation of 2000 trees in 2 ha of high-Andean forest |
| Wetlands conservation program CAR | 1. Reforestation of wetland buffer zone<br>2. Restoration of 2 ha of a wetland buffer zone |
| Total | Ten projects |

Through their participation in RedES-CWM, the companies formulated three different typologies of projects. The first type of project was led by a group of companies that agreed to restore critical ecosystems in their surroundings. Firms identified shared ecosystems close to their facility proximities. They agreed to design an initiative that would restore and protect the ecosystem due to its high importance in water availability (groundwater recharge), water quality (natural depuration of impurities), and resilience (adaptation to floods and droughts). The second type of initiative included companies with existing Civil Society Natural Reserves close to their facilities. These initiatives focused on supporting activities in the natural reserve that included restoration, protection, and reforestation of critical areas with essential water services. Finally, the third type of initiative was a collaboration between companies and the regional environmental regulator programs for wetlands conservation. Firms would support wetlands restoration due to their value as a barrier against floods and vital support for groundwater systems recharge.

Companies formulated a total of ten projects and participated in two initiatives. Table 13.4 summarizes the projects formulated under each typology.

### *13.4.3 Impact Indicators*

The twenty-two companies that participated in the program designed ten collaborative projects in the Bogota River Basin. All formulated projects include the calculation of economic and environmental impacts. The economic impacts, investment, and economic benefits from avoided expenses during extreme climatic events were calculated. The indicators include hectares of restored ecosystems, water regulation in the watershed, avoided sediments drag, and $CO_2$ emissions captured for the environmental impacts.

**Table 13.5** Summary of environmental benefits from the projects formulated

| Environmental indicator | | Impact | Equivalent colloquial indicator |
|---|---|---|---|
|  | Hectares restored | 68.5 ha | ~ 92 football fields |
|  | Water regulated in the watershed | 515,000 $m^3$/year | ~ Supply water to 11.300 persons in a year |
|  | Avoided sediments drag | 6850 ton/year | ~ Residues generated by 22.100 persons in a year |
|  | Captured $CO_2$ emissions | 8220 ton | ~ Emissions from 1.250 cars in a year |

The sum of investment for the projects' implementation required USD 275,000. On average, a company would invest USD 12,500. The economic benefits from all the projects were calculated based on the frequency and potential impact of an extreme climatic event. Companies calculated the cost of opportunity associated with water shortages and damages to infrastructure that compromise their production. The sum of the economic benefits was approximately USD 300,000. However, it is worth mentioning that projects would benefit other companies in the watershed. Therefore, the potential economic benefits from other firms in the influence area will undoubtedly significantly increase the current economic benefits value.

The environmental impacts were calculated based on the area of ecosystems identified for restoration. Indicators are related to the volume of water regulated, quality of water improved by avoided sediment drag, and $CO_2$ emissions captured. Calculations were based on the data from the National Water Study (Institute of Hydrology, Meteorology and Environmental Studies, 2019) (Table 13.5).

### *13.4.4 Contribution to National and Local Strategies*

Benefits from the designed projects help more than just the companies involved in the formulation of the initiatives. As mentioned earlier, other stakeholders under the area of influence of the watershed will also benefit from protecting natural resources and ecosystem services that improve water regulation. However, beyond productivity and sustainable performance of companies, local and national strategies are promoted.

The projects designed by the participants promote local plans for land-use planning and watershed management. For instance, early in 2019, the CAR disclosed the updated watershed plan for the Bogota River Basin (POMCA) (CAR, 2019). The projects formulated under the RedES-CWM program are aligned with the watershed plan and serve to boost the implementation of nature-based solutions aiming to improve the basin's water condition by recovering vital ecosystem services related to water regulation. This synergy sheds light on the opportunities to benefit existing programs of regional environmental authorities in watershed planning from models based on the strengthening of capacities in the circular economy.

Furthermore, projects serve as showcases for the NSCE by illustrating the benefits of collaborative territorial projects. First of all, the restoration of ecosystems helps improve water quality in surface water and groundwater, which is one of the goals in the NCES. Additionally, the collaborative initiatives open doors to potential water reuse projects among industries and economic activities, which pushes the government to accelerate the innovation of prohibitive regulations that currently hinder the application of such initiatives. Finally, these initiatives support efficient water use that translates into more added value by less water usage.

## 13.5 Lessons Learned

The experience of companies participating in RedES-CWM illustrates critical factors that help facilitate a territorial perspective of water management for improving businesses and watersheds' water security.

The first lesson learned is related to overcoming the obstacle of the single sector-level approach as identified by Nika, Vasilaki, et al. (2020) and the lack of understanding of the territorial perspective of circular water management. The diverse economic activities of companies participating in the program came as a barrier as these companies usually had not established contact with one another before, which was due to their different economic activities and the lack of understanding and identity of their territory. Moreover, knowledge of their location within a watershed and the ecosystems surrounding their facilities was ignored. Furthermore, knowing the location of other companies was more often not known. Once companies understand the importance of a multi-sectoral, participative, and territorial approach and become ingrained in their corporate business strategy (UNESCO; UN Water, 2020) and circular water management, it allows them to comprehend that through the collaboration with different organizations in protecting the shared water sources and ecosystems in the watershed, they move forward and improve their water security.

Another important finding of the program was the synergies and complementarity between land planning instruments and circular economy practices. As mentioned in Sect. 3, the RedES model is based on change strategies and capacity building in line with CE. However, land planning instruments as the watershed plan for the Bogota River Basin have not included circular water management from companies as part of their strategies (CAR, 2019). In this case, RedES-CWM showcased that circular water management is an efficient vehicle to promote plans and goals of territorial planning. Companies designed circular water initiatives to improve their water security, productivity, and sustainable performance, which took place in the territory, elucidating the complementarity of these programs.

Additionally, RedES-CWM promoted existing environmental programs from the regional environment authority and civil society organizations. For instance, projects from CAR with wetlands were boosted by raising the awareness of their existence and their benefits to companies' water management. Furthermore, natural reserves from civil society organizations provided a platform to explore alliances with the private sector that helps protect essential natural ecosystems for the water regulation in the territory. The triple helix structure of RedES (van Hoof & Duque-Hernández, 2020), which includes the public sector, private sector, and academia, creates an enabling environment for the alliances encountered with the CWM program the inclusion of civil society organizations in an expanded helix.

CWM is a gradual learning process that requires companies to "move beyond the factory fence." Previous experience in the RedES program facilitated companies in this transition as symbiotic exchanges had established trust relationships. CWM promotes a shared vision for the watershed and empowers firms to better understand their surrounding water systems, enabling collaborative initiatives among multi-sectoral and different sized organizations in pro of water security.

Finally, the results of the program suggest the potential for scaling. The project's first year with 22 companies and 10 initiatives can serve as a first step to promote more companies in participating in the program. The exact process can be repeated in more watersheds with different contexts and water needs, encouraging more companies to advocate for circular water management strategies and frame circular water systems with the support of the public sector, the private sector, and academia.

## 13.6 Conclusions

This chapter presents RedES-CWM as a model for disseminating circular water management contributing to participating companies' water security, productivity, and sustainable performance. It illustrates how a participative and territorial approach can help companies in adopting circular water management strategies. RedES-CWM benefits are especially relevant in emerging market contexts, characterized by environmental degradation and deteriorating water resources conditions. Therefore, it highlights the importance of water resources for the circular economy, economic development, environmental restoration, and social well-being. Moreover, through capacity building, a transition toward collaboration and trust relationships among firms is facilitated, eliminating segregating behaviors and lack of confidence.

The RedES-CWM program was able to promote different goals related to water resources. First, it boosts water programs as one of the Wetland Adoption Programs of CAR, the Civil Society Natural Reserves, and the National Strategy for Circular Economy. Second, local governments' land-use and watershed planning policies were used and made available to businesses, which enhances the implementation of such plans. Third, a multi-sectoral network of companies was built, with new trust relationships that facilitate circular water management initiatives and opens the door to new business opportunities among the participants. Finally, water security for companies and the territory will be improved when projects are implemented.

This program is designed to multiply and scale to a critical mass of companies and watersheds. It empowers businesses to approach water management more efficiently by collaborating with multiple stakeholders and brings an opportunity for the public sector, the private sector, academia, and the civil society to promote circularity in water systems.

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# Chapter 14
# The Circular Economy: The United Kingdom

**Patricia Tapia-Meza, Aldo Alvarez-Risco, and Shyla Del-Aguila-Arcentales**

## 14.1 Introduction

Based on the recent literature reviewed, this chapter presents an overview of the rolling out of the circular economy model applied by the UK. First, a review of the comprehensive report on the implementation of the Circular Economy Action Plan will give a clear understanding of the framework adopted. Second, the implementation and development of the different strategic projects will show the real impact of the model. A specific case study will provide a better understanding for applying and developing a circular economy model in detail.

Also, the progress of these projects will be examined from three practical perspectives: economy, social, and environment. Finally, the initial explorative assessment will give essential outcomes of the measures adopted.

## 14.2 UK Circular Economy Model

The European Commission launched the first Circular Economy Action Plan in 2015. The UK has a 25-year environmental plan that sets goals and targets to improve the environment for future generations. This plan is divided into key areas

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that seek clean air and water from impurities; preserve plants and wildlife; improve natural heritage, biosecurity, and sustainability in using resources; and minimize environmental hazards, waste management, and exposure to chemicals. Britain has a policy statement to promote achieving a circular economy. Within these guidelines, the strategic plans with the most significant coverage have been identified, which are the pillars to develop the desired circular economy model established by the government.

### *14.2.1 The Clean Growth Strategy*

The clean growth strategy is one of the first pillars of establishing a circular economy in the UK. This strategy establishes a comprehensive set of policies and proposals to achieve economic growth while reducing greenhouse gas emissions. While ensuring an affordable energy supply for businesses and consumers, achieving clean growth is the core of the UK's industrial strategy. It will also increase productivity, people's purchasing power, create good jobs, and help protect the environment.

The UK has been one of the first countries to join the Climate Change Act, passed in 2008 to reduce greenhouse gas emissions by at least 80% by 2050. According to the UN Paris Agreement, the carbon budget must be embodied through a 5-year process (Ha Rhodes, 2016). Since 1990, emissions have been reduced by 42% while maintaining the growth of the economy. In the first period from 2008 to 2012, it was possible to reduce emissions by 1%, with a projection of exceeding them by 5% and 4% in the periods from 2013 to 2022, respectively (Raybould et al., 2020).

One of the country's essential characteristics is that it has the world's largest installed offshore wind capacity. The increased use of renewable energy had a significant impact on all industries. From small homes to large buildings, they have efficient lighting, which reduces emissions and consumption rates. For example, in 2016, 47% of electricity came from low-carbon sources, roughly double the level in 2010 (Heubaum & Biermann, 2015). At the same time, the average energy consumption of homes has decreased by 17% since 1990 (Economy, 2014). Likewise, in the automotive industry, technology and the use of renewable energy helped reduce emissions per kilometer driven by up to 16% and save on fuel costs.

This change has generated new industries focused on developing low-carbon technologies and a reduction in their cost. On the other hand, more jobs and new companies specializing in Cleantech have been created to boost the economy. Renewable energy sources like solar and wind are comparable to coal and gas in many countries. For example, energy-saving light bulbs today are 80% cheaper than in 2010, and the cost of battery packs for electric vehicles has been reduced by more than 70% in this time (Dayan, 2017). Furthermore, one in five EVs has driven in Europe is manufactured in the UK (Berckmans et al., 2017). For this reason, the UK has positioned itself as one of the leading countries in technologies such as offshore wind energy, power electronics for low-carbon vehicles, and electric motors, leading in green finance.

### 14.2.2 The Opportunities and Challenges

The privileged geographical position and the experience and leadership in different industries such as scientific research and financial service represent a tremendous economic opportunity (Middlehurst, 2014). In addition, the country's regulatory framework provides direction and long-term support for innovation and excellence in the design and manufacture of cutting-edge technology. According to Energy and Environment for the Committee on Climate Change (2017), the low-carbon economy could grow approximately 11% annually between 2015 and 2030, four times faster than the rest of the economy (McCullough et al., 2017). Moreover, it could generate between £ 60bn and £ 170bn in export sales of goods and services by 2030, which means that maintaining clean growth is key to achieving more excellent economic, social, and environmental benefits. However, the UK still has many challenges in meeting carbon budgets and expanding the low-carbon economy, mainly emissions generated by heating in homes and commerce, the transport, and industrial sectors.

According to BEIS (2018), emissions caused by heating are equivalent to 32% of total emissions in the UK, with the industrial and transport sectors generating the highest percentage of 25% and 24%, respectively. According to the Department for Business, Energy, and Barker et al. (2017), meeting the fourth and fifth carbon budgets (covering the periods 2023–2027 and 2028–2032), the UK sets flexible internal policies subject to requirements established in the Climate Change Law to promote an acceleration in the rate of decarbonization. For example, the Green Paper on the Industrial Strategy ensures that energy is affordable for the consumer and is updated as changes are revised to meet the government's carbon targets while ensuring that the economy remains competitive. On the other hand, leaving the European Union represents a challenge in the future management of participation in the EU Emissions Trading System, coordination.

### 14.2.3 Key Policies and Proposals

The key policies and proposals in the UK adopted to achieve the fifth carbon budget focus on fostering innovation in low-carbon technologies, processes, and systems as cheap as possible while maximizing social and economic benefits. The reduction of energy costs and low-cost clean technologies will protect businesses and homes from high energy costs. Second, the country encourages investment in the private sector as an industrial strategy, fostering innovation and smart regulation to support entrepreneurs and investors who develop new technologies at scale. Innovation in better products, processes, and systems will contribute to reducing the cost of clean technologies. Likewise, the policies provide benefits such as a better quality of life for citizens and a cleaner environment, creating more jobs.

According to HM Treasury (2011), the government will invest more than 2500 million pounds sterling to support innovation with low carbon emissions from 2015 to 2021. The national productivity investment fund will provide 4700. An additional £ 2bn, with an additional £ 2bn a year from 2020 to 2021, represents the most significant increase in UK government spending on science, research, and innovation since 1979 (HM Treasury, 2011).

1. *Accelerate Clean Growth*

   Develop world-leading green finance capabilities with public and private investment. For example, it is working with mortgage lenders to develop green mortgage products that consider the lower credit risk and improved repayment associated with more energy-efficient properties.
2. *Improve Industries and Achieve Efficient Trade*

   Develop a package of measures to help companies improve their energy productivity by at least 20% by 2030, including consulting to raise minimum energy efficiency standards for commercial buildings, building standards to improve performance, and providing information such as advice on energy efficiency in general. It establishes an industrial energy efficiency scheme to help large companies implement measures to reduce their energy consumption and bills and joint action plans for industrial decarbonization and energy efficiency of the most energy-intensive industrial sectors. In addition, it supports the recycling of heat produced in industrial processes to reduce energy bills for companies and benefit local communities. The Energy Entrepreneurs Foundation invests around £ 162 million of public funds in research and innovation in energy, resources, and process efficiencies, including up to £ 20 million to encourage the shift to lower-carbon fuels supporting innovative energy technologies and processes.
3. *Improve the Energy Efficiency of Our Homes*

   The UK invests heavily in innovation around £ 184 million of public funds, including two new £ 10 million innovation programs to develop new heating and energy efficiency technologies to enable lower-cost low-carbon housing. Through Energy Company Obligation (ECO), around £ 3.6 billion of investment is supported to upgrade around one million homes in energy efficiency home improvements by 2028. The upgrade is promoted for as much as possible to Band C energy per consumer by 2030, developing a long-term process to improve the energy performance standards of private rental housing. Building regulations should be strengthened and monitored, including the protection of new homes for low-carbon heating systems. The increasing deployment of smart meters is offered for energy savings in homes and the implementation of low-carbon heating.
4. *Accelerate the Shift to Low-Carbon Transport*

   Emissions generated by transport represent 24%, one of the sectors that cause environmental pollution. The UK works with industry to develop an automotive sector agreement to accelerate the transition to zero-emission vehicles, definitively banning the sale of conventional gasoline and diesel cars and vans by 2040. In addition, cycling and walks are for short trips. For example, developing one of the best electric vehicle charging networks worldwide is promoted through an investment of £ 80 million and £ 15 million from Highways England to support the deployment of the charging infrastructure across the UK (Wang et al., 2020). Adopting ultralow-emission vehicles is supported, including helping consumers overcome the initial cost of an electric car, and then low-emission taxis and buses, providing charging points dedicated exclusively to this type of transport. The UK invests in cutting-edge research, development, and demonstration of connected and autonomous vehicle technologies.

5. *Clean, Smart, and Flexible Energy Supply*

   The UK follows a smart system plan to help flexibly reduce energy use and generate savings. Ofgem and National Grid are responsible for creating a more independent system operator to keep bills low through increased competition, coordination, and innovation across the system. Additionally, new nuclear power is supplied through Hinkley Point C and developers to ensure competitive pricing for future pipeline projects. The market for renewable technologies plays a predominant role as offshore wind energy, and future projects are underway. It is also planned to endlessly eradicate the use of coal to produce electricity by 2025.

6. *Improved Benefits and Value of Natural Resources*

   The departure of the UK from the European Union offers to address the fight against climate change using a more direct system for the future of its natural resources. One of the purposes to be fulfilled is to establish a new forest network in England that includes new forests on agricultural land and to finance the creation of forests and woodlands on a larger scale, in support of the commitment to plant 11 million trees and increase the amount of wood used in construction. On the other hand, it is expected to achieve zero avoidable waste by 2050, maximizing the value extracted from resources and minimizing the negative environmental and carbon impacts of their extraction, use, and disposal, enhance the resource and waste strategy to make the UK a world leader in competitiveness, resource productivity, and resource efficiency, and promote innovation in technology and research for agriculture, land use, gas removal technologies, greenhouse effect, waste, and resource efficiency.

7. *Government Leadership to Drive Clean Growth*

   The UK has celebrated "Green Britain" week since 2018 in order to promote clean growth where business and civil society are sponsors of this event. An inter-ministerial clean growth group is responsible for responsibly regulating and monitoring the implementation of this strategy and promoting more beneficial policies. Likewise, annual information on generating GDP growth and emission reduction is published through an emission intensity index.

#### 14.2.3.1 First Conclusion

The UK recognizes climate change as an economic and political problem rather than an exclusively environmental problem. For this reason, the government recognizes that it cannot achieve the necessary changes for the economy on its own, establishing a framework for action throughout the economy. In addition, clean growth has to be a shared effort between the government, companies, and citizens. Creating this supportive environment will help attract national and international investment. However, to achieve decarbonization of the country as the economy grows, the focus of the growth strategy is to adapt to changing circumstances, using its world-leading economic, scientific, and technical skills to meet future carbon budgets. An Emission Intensity Index (EIR) has been developed to measure clean growth performance and is published each year to track progress. To meet the 2032 targets, the UK will need to reduce the economy's emissions intensity by an average of 5% per year until 2032, accelerating from the 4% annual decline since 1990 (Stenning et al., 2021).

## 14.3 The Industrial Strategy

The industrial strategy aims to achieve an economy that boosts productivity and purchasing power. This strategy has five bases aligned with the vision of a transformed economy that will boost productivity.

1. *Ideas*

They seek to elevate research and development through innovation. The country intends to increase the tax credit rate for research and development and invest in a new industrial strategy. The UK is ranked as one of the world's most innovative countries and a leader in innovation. Innovation is about new ideas, new ways of doing things, new products and services, new technologies, and business models that can come from a radical transformation or incremental improvements from within a company, a significant scientific advance, or a well-known technology application. Ideas are crucial to improving productivity which in turn increases purchasing power. Therefore, innovating and developing new ideas and deploying them is key to achieving the industrial strategy. The UK's innovation indicators are 23% above the European Union average (Csur & Salvador, 2020).

The country is recognized as a world leader in science and research, a leader in measures of research excellence and universities in the world delivering quality work of the high quality of cutting-edge research and development and many sectors and industries, including life sciences, aerospace, automotive, technology, energy, and creative industries. Because it is a predominant sector in high-quality education, the country attracts many talented people worldwide. In recent years good results have been obtained in research and innovation, but there are still challenges to be achieved according to the survey on innovation in the UK. Just over half of the companies are classified as innovative; this means that it is a significant potential to improve (Olive, 2017).

There are four key challenges that this industrial strategy will address:

The first challenge will be for the government and the private sector to invest more in research and development. According to the OECD, the UK invests less in research and development than most of its competitors: 1.7% compared to 2.8% in the USA and 2.9% in Germany (OECD, 2018), which means that the UK could lose the opportunity to develop the technologies and innovations that will shape the businesses and markets of the future. The second challenge will be to improve exciting commercial products and services that give more incredible value. Not all pioneering ideas in the UK have benefited and opened markets in the country. Great ideas generated have been bought by foreign companies (Keohane, 2018), which is why an additional push is needed in development. The results of innovative products should open up new market opportunities.

The third challenge will be building research and innovation excellence, but it must be based on excellent research in university departments and leading public organizations and investment companies. It is necessary to capitalize on strengths and foster local ecosystems that can support innovation and sustained growth. Likewise, the science and innovation audit led by consortia of companies, universities, and local business associations in England and relevant sciences in decentralized nations create opportunities at local and regional levels (Azmat et al., 2020). A fourth challenge is to maintain global positioning and leadership in global science and innovation collaboration. Emerging economies are growing along with more investment in talent. For example, a total of 17% of research and development is funded from abroad (Karczewska, 2013). Finally, 50% of investment companies are established abroad (Keohane, 2018).

2. *Citizenship*

People are the key actors in achieving change, establishing a technical education system in science, technology, engineering, and mathematics to create a national training that is aligned with a short duration that follows an efficient system. While the UK is the birthplace of education, not enough attention has been paid to technical education. It needs to have enough science, technology, engineering, and math experts to reduce disparities between communities in skills and education. In this way, it will be possible to eliminate the barriers workers face from different groups to reach their maximum potential. Therefore, emphasis is placed on equipping the skills of citizens for jobs shaped by the technology of future generations. The technical education to achieve equality in the educational system how learning and qualifications support flexible schools of professional learning and other measures to transform people's life opportunities. For example, England has 1.8 million children with an excellent level compared to 2010 (Wilshaw, 2015).

Similarly, it is estimated that half of all 17-year-olds in the UK participate in further education by 30 (Morrice et al., 2020). It has a world-class higher education system, one of the most popular destinations for international students after the USA. Likewise, there is also a flexible and growing labor market. Labor market participation rates are being gradually increased to close the wage gap. For example, one of the significant reform programs is led by Lord Sainsbury. The New T level program is committed to creating 15 new technical educational routes designed through rigorous analysis of the labor market and partnership with employers (Esmond, 2018). Learning and new levels T will be based on the same standard values of occupational competence, designed by employers, and students will have opportunities to move between the academic and technical path.

3. *Infrastructure*

The supporting investment in transport is focused mainly on electric vehicles and repowering the digital infrastructure. The availability of high-quality infrastructure is critical for development. Efficient transportation systems provide jobs, goods markets, and suppliers. Digital infrastructure brings modernity and doing business in the technologies and industries of the future.

The pipeline infrastructure and construction is worth around £ 600bn, and investment in public infrastructure has doubled in a decade from 2022 to 2023 (Oxburgh, 2016). Through industrial strategy, the economic geography of the UK aims to be transformed by a wave of investment in infrastructure heralding a new technological era, with full fiber broadband, new 5G networks, and smart technologies. We will create a new high-speed rail network that connects people with jobs and opportunities, regenerates stations and airports, and progressively improves the road network. Moreover, we will improve the people's lives where they live and work, with high-quality housing and clean, affordable energy. Providing the proper infrastructure in the right places increases the purchasing power of individuals, communities, and our businesses.

The government has improved coverage for digital infrastructure; it is estimated that 95% of the premises have had access to ultrafast broadband since 2017 and 96% have 4G data coverage (Oughton et al., 2018). UK cities embrace new technology, instructed by Swansea, exploring the potential for 5G technology as part of its City Deal. While investments in clean energy infrastructure have helped reduce carbon emissions by 42% since the economy grew by 2.3% (Albanito et al., 2019; Smith, 2015), all nations' partners collaborate in sync. Decentralized administrations in Scotland, Wales, and Northern Ireland have responsibility for their regional infrastructure development aspects. Each has responsibility for water, waste, flood defenses, and road transportation. With minor exceptions, Northern Ireland also has responsibility for energy and other transport infrastructure forms and Scotland for its internal rail infrastructure. The UK government is responsible for digital infrastructure and telecommunications across the country in general.

4. *Eco-Friendly Businesses*

Promote the deployment of sectoral agreements with the predominant sectors: artificial intelligence, life sciences, construction sector, and the automotive sector. The UK has large globally recognized firms. It is recognized as one of the best places to start friendly businesses with the environment, innovation, and technology. A new business starts in Great Britain every 75 s (Hassan & Basit, 2018).

Over the past decade, governments have developed a partnership approach to working with emerging sectors, helping to identify where specific interventions can help increase productivity. According to HM Treasure research, 2015, the UK ranks third among OECD countries for startups (Treasury, 2015); however, the emergence of new companies can be further enhanced, exemplified by the Office of Life

Sciences co-funded by the Aerospace Technological Institute and the Center for Propulsion. The ScaleUp Taskforce program was established, cochaired by businessman Sahar Hashemi. The task force was created to explore what the government and the private sector can do to help businesses grow.

For example, the government and artificial intelligence have agreed to a sectoral agreement to boost the UK's global position as a leader in developing AI technologies. Digital Genius is an ambitious project in this sector that works with artificial intelligence applications to bring practicality to customer service. The platform automates and increases the quality and efficiency of customer support through communication channels such as email, chat, social media, and mobile messaging. One of the main customers is a major airline, which has used the platform to help customers and service agents cope with the significant increase in messages from social media channels. Likewise, this project also helped the export sector in the logistics process, building software currently feeding more than 30 contact centers worldwide. In 2015, a group of business leaders created the Productivity Leadership Group to identify practical steps to increase productivity among British companies. Through this, large companies reach SMEs in their supply chains, inviting them to a 12-month co-funded development program where they are offered best management practices, driven by business schools in the region, and aim to improve their production skills.

### *14.3.1 Second Conclusion*

The industry strategy sets out a vision for the open and agile economy built on innovation and enterprise that aims to boost productivity, purchasing power, and the quality of life of UK citizens. In order to become and maintain its position, it proposes different actions in different sectors and the collaboration of actors committed to the same objective: companies, universities, researchers, and citizens. The government and its actors will take advantage of the country's opportunities, enhancing its strengths and strengthening the foundations of productivity: ideas, people, infrastructure, businesses, and the environment in general.

## 14.4 Waste Policy

EU legislation on waste can be directly transposed through regulations in individual countries. The waste policy is essentially a delegated matter in the UK; therefore, in Scotland, Wales, and Northern Ireland, delegated administrations are responsible for strategy and policy related to waste management. However, despite differences between delegated administrations on the specifics of policy measures, national priorities and strategies for waste have been consistent in their goal of pushing action higher up the waste hierarchy and working to advance toward a more circular economy.

The circular material use rate indicator measures the contribution of recycled materials to public demand. The indicator is lower than recycling rates, which measure the proportion of recycled waste because some materials cannot be recycled. For example, fossil fuels are burned to produce energy or biomass consumed as food or fodder. A circular economy aims to maintain the value of products, materials, and resources for as long as possible by returning them to the product cycle at the end of their use, minimizing waste generation (Malinauskaite et al., 2017).

The EU recycled around 55% of all waste, excluding the main mineral waste in 2016 (compared to 53% in 2010). The construction and demolition waste recovery rate reached 89% (2016), the packaging waste recycling rate exceeded 67% (2016, compared to 64% in 2010), while the packaging waste rate plastic was more than 42% (2016, compared to 24% in 2005). The municipal waste recycling rate stood at 46% (2017, compared to 35% in 2007) and due to the waste of electrical and electronic equipment such as computers, televisions, refrigerators, and mobile phones, which include valuable materials that are can recover (e-waste) in the EU reached 41% (2016, compared to 28% in 2010) (BEIS, 2018).

1. *Waste and Resource Management in England*

In the period from 2015 to 2016, cleaning the streets cost the local government £ 778 million. The cleaning expense may be avoidable, and the money could have been better spent on vital utilities. The UK employs the strategy of applying best practices in education, compliance, and infrastructure to substantially reduce litter and littering behavior so that littering behavior improves over time. Likewise, they consider that natural capital is one of the most valuable assets: air, water, the land on which we live, and material reserve. The resources used daily are the backbone of the economy, society, and way of life. The strategy aims to establish guidelines for conserved resources, minimize waste, and promote efficiency, moving toward a circular economy. The waste and resource management strategy in England will follow the following actions.

### *14.4.1 Sustainable Production*

During the first stage of the life cycle of resources, natural and material resources are converted into the goods and services on which modern life depends. However, waste can be avoided if more careful decisions are made at the production stage (Gong et al., 2020).

- England invokes the “polluter pays” principle to expand producer responsibility for the packaging, ensuring that producers pay the total cost of disposing of the packaging they sell.

For example, the landfill tax and the five pence plastic bag charge have led to changes in behavior and attitudes. More than 15.6 billion fewer plastic bags have been used since the strategy was introduced. The landfill tax was introduced in 1996 and has been a critical factor in waste management (Wüstemann et al., 2017).

- The demand for recycled plastic is stimulated through the introduction of a tax on plastic packaging.

For example, the UK Plastics Pact is a collaborative initiative to create a circular system that keeps plastic in the economy and out of the natural environment, led by the charity WRAP and established in partnership with the Ellen MacArthur Foundation, a coalition whose members cover the entire plastics value chain. Its ambitious targets until 2025 for plastic packaging are 100% reusable, recyclable, or compostable, 70% to be recycled effectively, and 30% average recycled content in all plastic packaging (Van Beukering et al., 2007).

In addition, steps have been taken to eliminate problematic or unnecessary single-use plastic packaging and harness the potential of extended producer responsibility for other products. In general, establish minimum requirements through ecodesign to encourage resource-efficient product design.

2. *Choosing and Promoting Sustainability*

The strategy comprises helping consumers to take action to choose and use more sustainable products that are beneficial for them and the environment. Despite the technological advances of the last decades, the average lifespan of many products that we buy and use daily is lower than 20 years ago (Hanson & Mitchell, 2017), which requires providing consumers with better information on the sustainability of their purchases, extending the useful life of products through repair, reuse, and remanufacture. The government aims to be the example through acquisitions and green government commitments and act against barriers to reuse and support the remanufactured product's market.

A strategy to address barriers to reuse and recycling sustainability is to manage chemicals through a chemical strategy. As with construction, there are significant resource-saving opportunities in the chemical sector, and it is intended to establish a framework to make this happen. Currently, these chemicals cannot be traced through the supply chain, which means that recyclers often do not know what chemicals are present in the materials they receive. For example, measures like EPR and ecodesign can help address this problem.

3. *Resource Recovery and Waste Management*

The strategy promotes better quantity and quality in recycling and more investment in national markets for recycled materials. The government supports systematic waste collection and helps local authorities and businesses with waste management activities in the most sustainable and resource-efficient way. In addition, one of the goals is to drive UK-based recycling and export less waste for overseas processing.

For example, Renescience from Orsted Renescience is a unique technology created by Orsted that significantly increases recycling rates for sorted and unsorted waste. The technology mixes water and enzymes with municipal waste, breaking down all organic material such as food waste, labels, and food that stick to packaging and cans. The resulting bioliquid is drained and sent to an anaerobic digester to create green gas (biomethane). The technology also breaks down complex materials such as cardboard and plastic composites. Trash that comes out the other side can undergo a mechanical process to allow materials, such as cans and plastic containers, to be sorted. Another initiative is the VinylPlus Initiative, with a voluntary commitment that represents the entire value chain of the PVC industry, from producers to recycling companies that handle PVC at the end of its useful life. The primarily recycled materials are windows, cables, floors, pipes and accessories, and rigid PVC (Schiller & Everard, 2013).

Waste-related crimes significantly reduce resource efficiency, indiscriminately using natural capital. The government tries to strengthen the exchange of intelligence and the commitment to tackle illegal activity. Reform will be carried out in the regime to prevent illegal activity from being hidden through waste exemptions, and the digital register of waste movements will be required. Likewise, improving the transportation, management, and description of waste through regulatory reform includes creating a joint unit for waste-related offenses and strengthening penalties for waste offenders, which will raise awareness of waste regulations and publicize the positive work of law enforcement agencies while tackling waste crime.

One of the initiatives is the challenge of intelligent waste monitoring. The challenge is to track individual waste movements through the economy to learn more about the types and amounts of waste generated, what is done, where it ends up, and what form. They do it by offering incentives to award up to a maximum of £ 80,000 to five companies to develop their ideas further. Another initiative is the Thames Tideway Tunnel for waste minimization. This £ 4.2bn Tunnel will prevent millions of tons of raw sewage from flowing into the River Thames each year to help avoid inefficiencies such as lack of coordination in the design of large construction projects. 3D digital models to solve design problems by working together in a virtual environment achieve projects such as the Thames Tunnel, helping processes be as efficient as possible, saving time and resources in design.

4. *Reducing Food Waste*

The UK has long recognized the need to tackle food waste and is an international leader on the issue. Since 2007, they have tackled the problem from numerous angles, including through a series of voluntary agreements that have reduced per capita food waste by 14%. The latest agreement, the Courtauld Commitment 2025, aims to reduce per capita food waste in the UK by over 20% between 2015 and 2025 (Sheppard & Rahimifard, 2019). One of its main strategies is WRAP to prevent food waste by citizens. The successful initiative achieved reducing food waste at the domestic level (Moult et al., 2018). WRAP will continue to participate and help businesses and the public through its “Love Food Hate Waste” platform. Part of the new strategy aims to start a conversation about food waste. To support the public, WRAP is working with companies to improve product design to address food waste, including through resealable packaging and through package size and labeling that helps people plan and sensibly use food.

## 14.5 Ensuring a Green Brexit

The departure of the UK from the European Union has represented much uncertainty for many. However, the government remains firm in ongoing initiatives and future activations of strategies to achieve a circular economy that benefits the country. Leaving the EU means that the country regains control of environmental legislation, which presents a unique opportunity to design a set of policies to promote environmental improvement and growth tailored to the country's needs. The vision adopted is a green Brexit in which environmental standards are not only maintained but are improved. The EU Withdrawal Act 2018 EU will ensure that current European Union environmental legislation continues to affect UK law after leaving the EU, providing businesses and stakeholders with the utmost certainty, which includes any Circular Economy Package (CEP) commitments about waste and recycling which are part of UK law at the time of recall.

The UK will put a new independent statutory body to hold the government accountable for its compliance with environmental law after it leaves the European Union and develops a new policy statement on environmental principles. There is transparency and accountability in achieving their wasteful resources and ambitions with circular economy package related to waste, part of measures to promote a more circular economy. The package includes targets to reduce waste going to landfills (no more than 10% by 2035) and sets higher targets for recycling various everyday materials, including plastic, paper, cardboard, and glass packaging. The municipal waste recycling targets are 55% by 2025, 60% by 2030, and 65% by 2035, with a review clause in 2028. The general recycling targets for packaging waste are set at 65% for 2025 and 70% by 2030. In addition, the package appears to extend separate collection requirements for biological waste (by 2023) and textiles and household hazardous waste (by 2025).

As the objectives are achieved, greater measures will be implemented, and new strategies proposed by the European Union will be applied. As we implement and apply this strategy, we will explore our stricter goals.

### *14.5.1 Closing Remarks*

It can be seen that the implementation process of the green economy in the UK has been going through different steps and that the recent Brexit presents an excellent challenge for the authorities, companies, and citizens so that activities can be developed increasingly closer to the concepts of the circular economy.

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# Chapter 15
# Implementation and Scalability of Circular Practices in the Leather Tanning Industry: Evaluation of a Colombian Tannery

**Paula Barco and Bart van Hoof**

## 15.1 Introduction

Leather has been manufactured for centuries (Bouzayani et al., 2019). The industry currently plays a vital role in the global economy, with an estimated annual value of US$100 billion (United Nations Industrial Development Organization, 2010). Leather is manufactured from a by-product of the meat industry, recovered and processed by the leather tanning industry to produce hides used to manufacture shoes, leather goods, and clothing. According to the FAO, Latin America is responsible for 19% of the world's leather production (FAO, 2016).

Although the leather industry is considered to play an essential role in advancing environmental sustainability because it reuses the by-products of the meat industry, the processes involved in its production impact the environment (INESCOP, 2016). The common practice of tanneries transforming hides into leather involves the employment of chrome alongside the intensive use of other substances, including chemical products, dyes, and water. The production process is linear and produces waste products at every stage of manufacture, principally in wastewater and solid products such as tannery sludge and leather trimmings (Moktadir et al., 2017). These waste materials and chemical by-products are not generally recycled nor treated adequately, a factor that negatively affects soil and water quality. Most of the stages involved in the tanning process take place in water. Consequently, sewage is one of the principal concerns associated with the industry, as, untreated, it incurs

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considerable chemical and biochemical oxygen demand (COD and BOD) and high salt and chemical content. Furthermore, the traditional leather industry is known for its high consumption of resources, increasing efficiency, both economically and in terms of the process itself, but producing high levels of environmental pollution, destroying biological chains, and producing high levels of waste (Hu et al., 2011).

The literature identifies a range of perspectives to improve environmental performance: Moktadir et al. (2017) analyzed the factors facilitating sustainable manufacturing practices in Bangladesh; Pringle et al. (2016) identified the factors complicating the creation of a CE in tanneries based on the recycling of leather; Pringle (2017) evaluated the possibility of implementing a CE based on solid waste; Tasca and Puccini (2019), Chen et al. (2014), Notarnicola et al. (2011), and Chowdhury et al. (2018) carried out life cycle analyses (LCAs) determining critical points in the productive and operational processes of tanneries; Hu et al. (2011) and de Aquim et al. (2019) presented successful cases of the application of systems of water recirculation in the tanning process, while other investigations with industrial applications focused on the efficient use of resources. In a complementary manner, there has been a significant increase in the number of reports and publications produced by government institutions and world-renowned entities on good manufacturing practices in the sector.

Despite these advances, literature recognizes gaps for implementation and scalability of circularity practices in the tannery industry associated with the identification of opportunities to improve the circularity of potentially scalable industrial materials (Pringle et al., 2016), translating circular perspectives into the management and operational model of tanneries (Moktadir et al., 2017), applying circularity to particular contexts and the role of human resources in the context of the implementation of circular practices and technologies (Chappetta Jabbour et al., 2019).

Accordingly, this chapter seeks to understand the criteria influencing the selection, implementation, and scalability of circular practices in the tannery industry. In this way, a case study was conducted of a tannery in Colombia. Based on an evaluation of material flows and critical processes, circular strategies were selected for evaluation. Feasibility criteria for implementation and scalability considered cost-benefit analysis and organizational viability study using the viable system model (VSM) as a design tool to create organizational standards in the tannery.

## 15.2 The Circular Economy in Tanneries

The circular economy (CE) has captured the attention of the academic community, companies, and governments as one of the alternatives to the linear model of production and consumption that has the most potential to contribute to sustainability (Moktadir et al., 2017; Lewandowski, 2016; Kirchherr et al., 2017). The CE involves creating reparative, regenerative production and consumption systems aiming at resource efficiency of products, components, and materials, assuring their utility and value for as long as possible. It also seeks to maximize the value embedded in the waste- and by-products produced by the process (Korhonen et al., 2017). Circular practices that optimize both resources and processes include renewable energy sources, efficient consumption of harmful chemical substances, technological innovation in production processes, and business and design models that can be easily reused, repaired, remanufactured, recycled, and that is biodegradable. In most cases, the implementation of circular practices of this kind implies systemic and synergic action by interest groups intended to optimize the relevant industrial systems (Moktadir et al., 2017; Korhonen et al., 2017).

According to SCOPUS data, there has been an exponential growth in the number of academic articles written about circular practices in the leather tanning industry. Since 2008, the number of published articles has been more than sixfold. The geographical location of most of the authors of these articles is Asia (in India and China, accounting for 60% of the total), followed by Europe (Spain and Italy, 20%) and the Americas, with 7% produced in Brazil (see Fig. 15.1).

The reviewed literature identifies different circular models used to improve resource efficiency in the diverse stages of the leather tanning sector. Circular practices can be grouped into four principal categories according to their role in each stage: the modification and addition of new technology to the process, the replacement of chemicals, the treatment of waste, wastewater, and sludge, and the exploitation of waste (see Table 15.1).

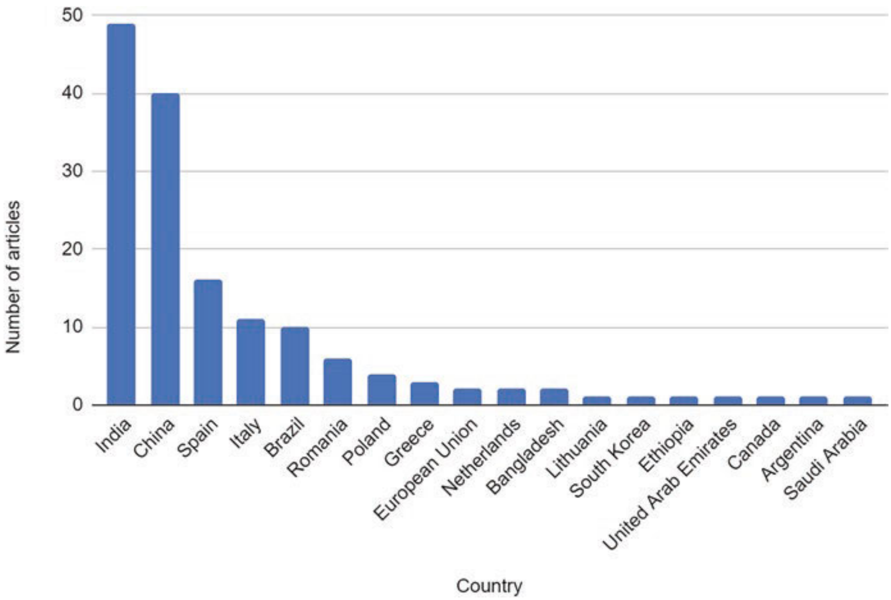


**Fig. 15.1** The geographical location of authors of publications (2008–2020) on circular practices in the leather tanning sector

**Table 15.1** Circular practices

| Category of circular practice | Example of circular practice | Examples of technology | Benefits | Authors |
|---|---|---|---|---|
| Modification and addition of technology used in the process, without altering the consumption of traditional resources | The new method permits more efficient use of the inputs and reduced consumption and operation time | New continuous system in which hides are dehydrated and then passed through a roller with a 10% chrome salt solution at base 45°Sch in the immersion chamber | Pickling is not required during tanning and post-tanning, 30.6% reduction in water consumption during other operations, 50.2% in chemical consumption, 47.5% in thermal energy, and 16.4% in processing time. Electricity consumption increases by 63.03% | Bacardit et al. (2015) |
| Replacement of chemicals that damage the environment | Salt-free tanning and pickling, replacement of chrome as a tanning agent, replace hair removal agents, traditional dyes | New chrome tanning technology – salt-free pickling using epoxy compounds and optimization and pretreatment involving a pickling mixture using collective polyoxyethylene diepoxy ether (as a pretreatment agent deployed during the pickling process), catalyzed by methenamine (urotropine) | Zero consumption of NaCl in the pickling process. 23.3% reduction in consumption. Cr capture increases to 91.3% compared to 74.2% in the conventional process. 15% reduction in COD and 42% in total dissolved solids | Jia et al. (2020) |
| Treatment of waste, wastewater, and sludge | Wastewater treated before discharge, stabilization of sludges, and adequate disposal of waste | Stabilization of tanning sludge by co-treatment using aluminum anodization sludge and phytotoxicity of end products | The aluminum anodization sludge is capable of stabilizing the chrome and the organic contents of tanning waste effectively. Tanning waste products that have been stabilized at a 50:50 ratio may be classified as nonhazardous waste discharges | Pantazopoulou et al. (2017) |

(continued)

**Table 15.1** (continued)

| Category of circular practice | Example of circular practice | Examples of technology | Benefits | Authors |
|---|---|---|---|---|
| The exploitation of waste (divided into two subcategories) | Reincorporation of waste for processing leather | System for recirculating effluents to a collection and flotation zone, subjecting them subsequently to multiple filtrations using solid-liquid and screen separators | Recuperation of 30.8% of utilized chrome (471 tons annually), which is recirculated toward the pickling and tanning process; a 25% reduction in the consumption of salt (176 tons annually), and in the use of clean water per kg of processed leather from 1.9 to 1.1 L/kg | Hu et al. (2011), de Aquim et al. (2019) |
| | Use in other industries (including construction, energy generation, minerals for cultivation, gelatin, and keratin) | Production of three-dimensional molecular networks known as hydrogels by reticulating the hydrolyzed proteins (obtained from hides and leather) using copolymers. Liberation of organic compounds to produce three kinds of hydrogels known as AMIGEL, POLYGEL, and SMARTGEL, which are used as fertilizers for agricultural activities on degraded soils | Collagen hydrogel functionalized using biopolymers (e.g., starch) exhibits a greater fertilization capacity with synthetic polymers | Stefan et al. (2019) |

The studies of circularity practices in the literature evaluate diverse dimensions related to the feasibility of implementation and scalability. The evaluation in this research integrates diverse dimensions of feasibility in order the propose a comprehensive method for evaluating implementation and scalability of circularity practices in the tannery industry:

1. *Physical*: the flow of materials was analyzed to gauge the efficiency of the process, quantify the inputs and outputs, identify critical resources and possibilities for improvement, and provide tools for monitoring their effectiveness (Ayres & Ayres, 2002).

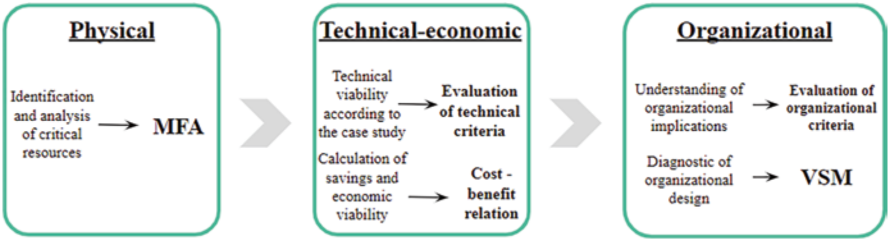


**Fig. 15.2** Methodology for analyzing the feasibility of circular practices in the tannery industry

2. *Technical-economic*: this perspective is related to criteria covering the physical implementation and infrastructure of this kind of strategy, such as investment, the adaptation of industrial plants, and other resources required for their maintenance. Additionally, it includes calculating the potential savings for the organization and cost-benefit relations (Van Hoof & Lyon, 2013).
3. *Organizational*: consisting of organizational aspects that are indispensable to effective implementation, such as levels of commitment, adaptation, training, and communication, which help ensure the strategy is congruent with the internal development. In addition, the application of the VSM makes it possible to improve connectivity, establish systems to facilitate the healthy development of relations, and ensure global cohesion (synergy) and local autonomy of the units making up the system (Espejo & Reyes, 2011). The degree of complexity of change is directly related to the organizational implications that must be resolved to ensure successful implementation and coordination of the system (Espinosa & Walker, 2011).

Figure 15.2 presents the methodology for analyzing the feasibility of circular practices implementation in the tannery industry.

## 15.3 Case Study of Tanneries in Colombia

In order to analyze the feasibility of implementation and scalability of circular concepts in the tannery industry, this research studied the case of a Colombian tannery firm. This firm represents a small family-run business with 16 employees, located in Villa Pinzon, a traditional tannery village 80 km north of Bogota. The company was founded in 2014 using traditional tannery processes to supply hides to small-scale furniture and car seat producers. The company uses traditional chrome tanning techniques to produce an average of 600 hides monthly. During the second year of its operation, the firm installed a sewage treatment plant financed by the environmental authority.

### *15.3.1 Materials Flow Analysis*

Material flow analysis (MFA) of the tannery operation identifies the environmental impact of the pickling and tanning processes. Data for the case study was obtained through side visits by observation and interviews with employees operating the processes. Proportions of material uses were validated with information from the literature (Notarnicola et al., 2011; Chowdhury et al., 2018).

The production process of the firm includes processes such as pickling, tanning, and finishing. Pickling prepares the hides for the tanning process, making the fibers more receptive to tanning. Pickling increases the acidity of the hide to a pH of 3, enabling chromium tannins to enter the hide. Salts are added to prevent the fibers from swelling. For preservation purposes, fungicides and bactericides are used. A second process consists of the tanning process, where the hides are converted into leather. The tannery process involves a process that permanently alters the protein structure of the skin, making it more durable and less susceptible to decomposition and possibly coloring it. The hides are sold as wet blue and are finished by the clients by liming and painting processes. Monthly use of resources includes chrome (480 kg), formic acid (172.8 kg), and salt (576 kg), generation of 7 $m^3$ of wastewater, and 180 kW energy consumption. Especially the chrome and salt used in the traditional tanning process are critical for their impact on water contamination. Figure 15.3 presents the material flow analysis of the pickling and tannery process, including data of the Colombian case, the object of analysis.

In the preparatory stage, rawhide trimmings account for between 5% and 7% of total solid tanning waste (Yoseph et al., 2020). Disposed of hair along with the sewage produces high levels of BOD (40%) and COD (50%) and ensures that 100% of effluents are highly alkaline (Tian et al., 2019). It is believed that operations occurring during this phase account for approximately 80% of the solid waste produced during the entire leather-making process (Yoseph et al., 2020). Finally, in the finishing phase, up to 5% of the overall amount of dyes used may be present in the sewage produced by the industry. Without appropriate treatment, these substances harm the environment (Bouzayani et al., 2019). Conventional dyeing processes use numerous chemicals and auxiliaries that are generally minimally biodegradable because of their high levels of COD and BOD (Sudha et al., 2016). Approximately 35–40% of solid tanning waste consists of buffing powders – some 2.6 kg per ton of processed leather. These materials are incinerated or disposed of in landfills (Hu et al., 2011).

Both the pickling and tannery processes require high volumes of water as the carrier of all the other resources used in the pickling and tannery processes. The water is used as a medium to prepare, transport, and impregnate the hides with salt, chrome, formic acid, basifier, and bactericide. The hide does not entirely absorb these materials due to the operational limitations of the process. A significant volume of the materials remains in the water solution and is discharged sewage. Reuse of the sewage, containing and valuable materials and water, prevents the discharge of sewage and environmental impacts and improves resource efficiency in the use of salts, chrome, and other ingredients (Hu et al., 2011; de Aquim et al., 2019).

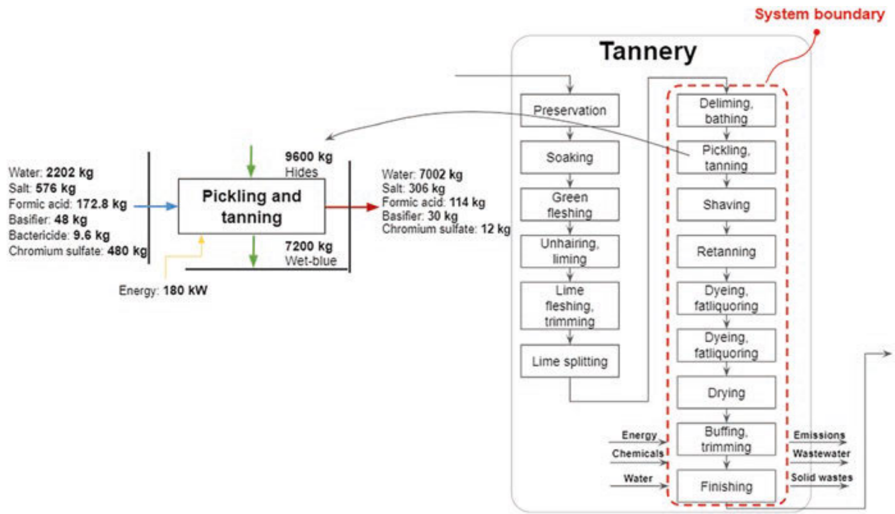


**Fig. 15.3** MFA of the pickling and tannery process of the Colombian case

### *15.3.2 Technological Innovation*

Based on a systematic review of the literature on alternatives presented in Table 15.1 (see Sect. 15.2), and according to the critical resources identified by the MFA, three circular practices were selected for evaluation in the case study: (i) system for recirculating effluents (de Aquim et al., 2019), (ii) dehydrated-based tannery system (Bacardit et al., 2015), and (iii) salt-free tanning and pickling (Zhang et al., 2016; Jia et al., 2020).

The technical-economic criteria for evaluation (see Sect. 15.2) included (i) amount of investment required, (ii) adaptation of industrial plant, and (iii) resources required for their maintenance. The evaluation was discussed with directives of the tannery, using a Likert scale. Implementation of the circular practice using salt-free tanning and pickling is less complex than the others. However, from the perspective of the directives of the tannery, considering its competitive priorities, it was clear that the reuse of water adjusts better to its needs, context, and operating realities. Furthermore, it produces greater environmental benefits. Table 15.2 presents the evaluation of the technical-economic feasibility of the circular innovations for the case.

Based on these results, the circularity innovation for water reuse was proposed as the first alternative to improve resource efficiency in the tannery firm. The strategy selected for reusing water consists of recovering water from the first soaking process, whose main waste product is sewage and which, following a process of filtration to remove excess proteins, salt, and sodium sulfide, is recirculated to be used in the second soaking. The same process is followed for the third and fourth soakings. In addition, a system for the recovery of chrome from the wastewater produced by the tanning process is proposed, using filters with solid-liquid separation and separation screens and adjustment tanks (Hu et al., 2011). These steps concentrate the residual chrome to be recirculated yet again for use in the tanning process. This approach can reduce virgin chromium sulfate, resulting in benefits for the organization and reductions in its environmental impacts. A schematic diagram of these proposed changes is presented in Fig. 15.4.

The circularity practice proposes that the second soaking can be partially carried out using water recovered from the first soaking and that the fourth soaking can use water taken exclusively from soaking three, which would reduce water consumption

**Table 15.2** Scores for technical aspects of the three circular innovations selected

| | Techniques | | |
|---|---|---|---|
| Circular innovation | Investment | Improvements to industrial plant | Maintenance requirements |
| System for recirculating effluents | 5 | 4 | 3 |
| Dehydrated tannery system | 5 | 4 | 5 |
| Salt-free tanning and pickling | 3 | 1 | 2 |

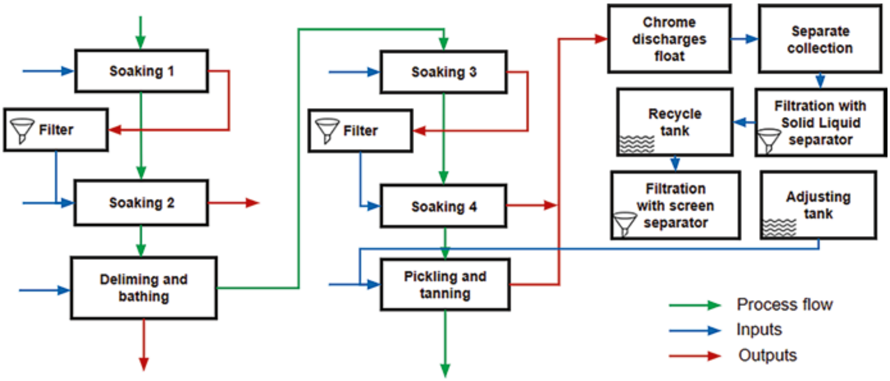


**Fig. 15.4** Innovation for reuse of wastewater in the tanning process

by 30,720 L a month, a reduction of 39%. On the one hand, recirculating chrome results in a monthly recovery of 12 kg of the chemical, reducing consumption by 7% compared to the current process.

Implementation of this process would produce significant financial savings. First, it is estimated that it would reduce the annual costs of treated water consumption by about US$220. The estimated annual reduction in the consumption of virgin chrome would be around US$2500, and, finally, the cost of wastewater treatment would fall by more than US$3250, resulting in an overall calculation of annual savings for the company of about US$6000 (see Fig. 15.5).

Implementation of this circularity practice would require an initial investment in filters and pools, adaptation to treatment processes and industrial plants, and the workforce's training in the new methods.

The cost-benefit analysis carried out by the company puts the estimated cost-benefit of the project at 0.81. Values of B/C below one mean the value of the benefits is lower than the costs, resulting in the investment not being recommended. Initially, it was believed that the result matched the company's monthly production volume, which does not operate at total capacity. However, when growth projections and the company's environmental commitment are joined with the reduction in the use of chrome, the project was revised with a view to its potential long-term implementation. The project was possible because, for the cost-benefit equation to deliver a result even marginally above one – indicating that the income and savings of the project would exceed costs – monthly production would have to rise to a minimum of 840 hides, 240 more than the monthly average, because of the additional costs the rise in production would imply. For this to be possible, adjustments would have to be made to the installed capacity of the production plant, such as production planning, the number of batches to be produced in a given period of production, staff requirements, and inputs, which would involve a continuation of the overall methodology for carrying out the analysis of viability, in this case, focused on the last dimension, namely, organizational level.

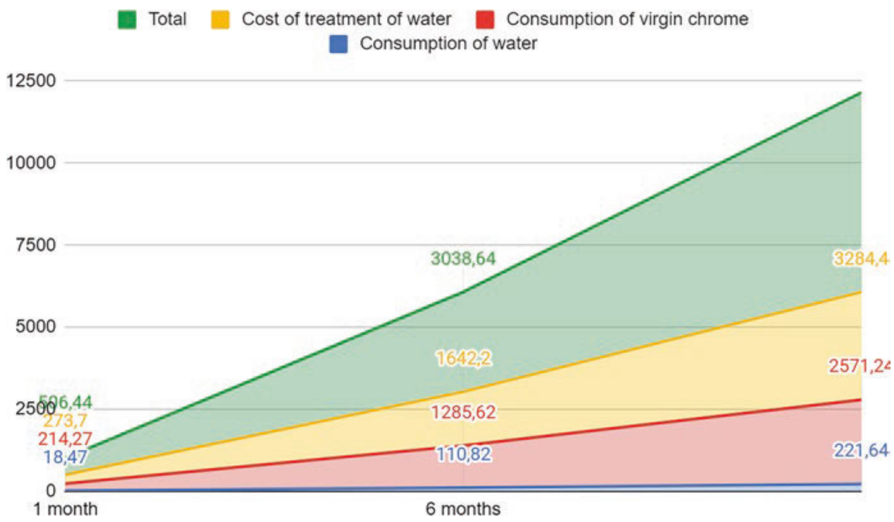


**Fig. 15.5** Projection of savings in consumption and treatment of water and consumption of chrome

The modification of the process requires commitment, communication, and monitoring of the employees because the leather quality is ensured by finding traces of the chemical compounds used in the wastewater.

### *15.3.3 Organizational Viability of Circular Practices*

After analyzing the technological adaptations required to recirculate water as part of the process and the technical implications of incorporating them into the business model, evaluating organizational viability helps to understand the influence of the specific circular practice on the components that define its effective functioning operation. Evaluation of organizational viability considers the level of commitment, adaptation, training of personnel, and communication required to implement, operate, and maintain the practice. The circular practice for water reuse requires greater attention to changing the chemical formula used in the pickling and tanning processes in response to the chemical traces found in the sewage. Given this, effective communication among employees plays a vital role in the transmission of information.

Organizational viability theory studies organizations from a systemic point of view: it understands organizations as evolving structures that result from recurrent interactions between stakeholders and actors, who develop norms, routines, and behaviors while learning by doing to achieve their purpose (Espinosa & Walker, 2011). In the original viability theory, encapsulated in the "viable system model" (VSM), Beer (1979) explained that all viable systems, in this research the Colombian tannery firm, in order to survive, must comprise five necessary and sufficient subsystems. The operational elements, the tannery process operation including resource uses, designated as System 1, must be as autonomous as possible and behave as a viable system: they must self-organize and self-govern.

It is necessary to develop “meta-systemic functions,” which in the present paper will be called harmonization, to guarantee the self-organizing units interact cohesively with the system’s identity and ethos. This harmonization is represented by indicators of the operational tannery process (system 2), synergy (operational planning of the tannery firm) (system 3), navigation (market relations of the tannery firm) (system 4), and identity, (business strategy of the tannery firm) (system 5).

The VSM diagnostic tool evaluated the organizational viability of successful implementation and scalability of the circularity practice. Interviews with directives and employees of the tannery firm were used as the data source. The analysis confirmed that baseline indicators are not available for any of the elements of the tannery processes, and quality control systems are not in place (system 2), nor is there a clear policy for identifying client needs (system 4). Consequently, the company does not have a clear client profile, and decision-making depends on the intuition of directives, which has not responded with agility to new situations. The manager is responsible for ensuring synergy between the processes (system 3) but is simultaneously involved in all other operational activities, and time spent coordinating activities among processes is nihil. Alignment among administration and operational processes through adequate planning is poor, resulting in a shortage of materials causing interruptions in operations. Communication is mainly informal, and knowledge management is not systemized and limits the employees’ personal experience. Moreover, the company lacks a clear business strategy (system 5), and its development depends on short-term contracts. Innovation takes place to solve crises resulting from operational breakdowns, requirements of environmental authorities, or new commercial opportunities.

It is apparent from the above that in the long term, opportunities for improvement might exert a direct influence on the implementation of circular strategies and the very viability of the company, since, in the absence of adequate tools to manage complexity and insufficient autonomy and agility to make decisions, the probability that an organization will be able to respond effectively is reduced. Aspects such as organizational learning, commitment, adaptation, training, communication, and the management of human resources and interest groups play an essential role in activating CE capacities in companies and achieving sustainability objectives. Figure 15.6 presents the viable system model (VSM) required for organizational viability for implementation and scalability of circular practices in the studied tannery firm.

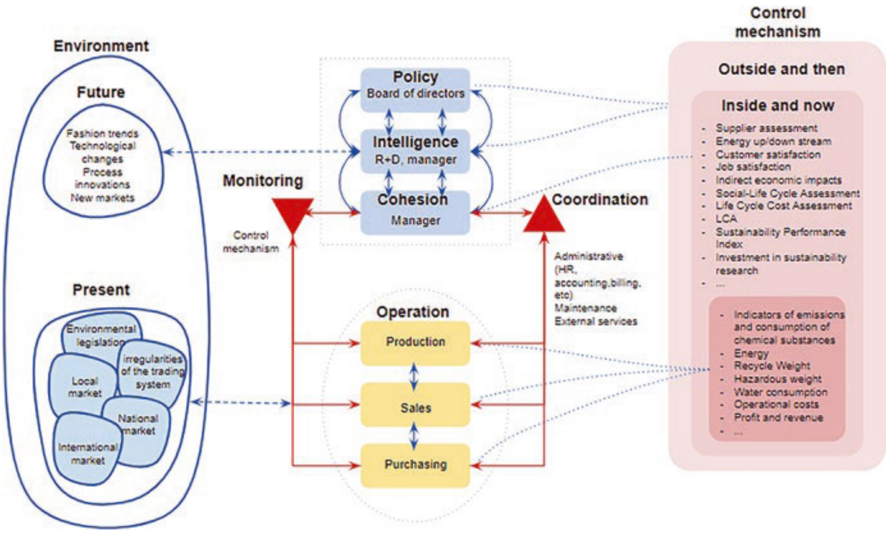


**Fig. 15.6** Viable system model for the case study tannery

### *15.3.4 Implementation and Scalability of Circular Practices in the Tannery Industry*

Building on the forgoing case analysis of the physical, technological-economic, and organizational dimensions of a circularity practice in the tannery process, this section identifies (i) critical resources of the tannery process object of circularity practices, (ii) the identification of circularity practices as opportunities to improve resource efficiency in the tannery industry, and (iii) criteria for feasibility analysis of implementation and scalability of these circularity practices.

Environmental impact in the pickling and tanning process is mainly caused by the chrome (480 kg), salt (576 kg), and sewage, being identified as critical resources for operations in a traditional tannery firm. Exposure to chrome as toxic, heavy metal endangers the health of employees, the surrounding community, and the environment. Rivela et al. (2004) affirm that sewage containing chrome contributes to toxicological effects such as eco-toxicity, acidification, and water eutrophication. Sewage containing salt impacts local fauna and flora alike, as these species cannot tolerate even low salt concentrations in the water. Therefore, the critical resources identified by the research correspond to a generalized environmental concern, and improved circularity makes it possible to help the leather industry develop a more sustainable production system. The high risk for environmental contamination of the critical resources links to challenges of the small- and medium-sized enterprises in the tannery sector to engage in a permanent attempt to produce a cleaner, more intelligent industry instead of disposing of untreated waste products.

Recirculation of waste materials between different tanning processes effectively reduces water consumption and recovering and reusing chemical substances such as chrome and salt, thus an effective alternative to reduce critical environmental impacts. The case analysis showed how the innovation in water reuse equipment requires high production volumes for positive C/B ratios, as shown by the case analysis. Volumes of production scale represent an important barrier to implementing circularity practices in tannery firms classified as small companies. Reuse of water only showed economically feasible beyond production volumes of 1000 hides per month. This limitation resonates with the reality of many companies in the tannery sector around the world that operate under similar conditions, such as those prevailing in Bangladesh where 90% (Moktadir et al., 2017) or Pakistan where 95% of SMEs in the leather sector have fewer than ten employees (Ortolano et al., 2014).

Complementary to cost-benefit analysis, the evaluation of the organizational viability is determined to understand the implementation and scalability of circularity practices in the tannery business. The viable system model (VSM) identifies diverse dimensions of viable organizational systems such as the existence of productivity indicators (system 2), solid coordination and production planning systems (system 3), capacity to respond to market trends (system 4), and business strategy (system 5). These fundamental organizational functions need to be in place in order to implement and scale circularity practices. As illustrated by the case study, the absence of these functions limits the implementation or scalability of circularity practices.

Authors like Zilahy (2004), Stone (2006), and Van Hoof & Lyon (2013) found similar conclusions regarding the dissemination of cleaner production strategies among small- and medium-sized enterprises. Implications of this finding sustain the arguments that promotion of circularity practices in tanneries is closely related to the entrepreneurial capacity of the firm and the existence of systems to control operational, administrative, and strategic processes. Thus, the implementation and scalability of circularity practices in firms follow the logic of technological innovation.

Arguments of organizational viability as a requirement for implementation and scalability of circular practices in tannery firms also explain why only 5% of the practices studied by literature had an industrial application, providing evidence of the challenge involved in determining the organizational criteria required for their implementation. Thus, the VSM tool constitutes a powerful tool for directing the interactions for implementation and scalability of circularity practices.

## 15.4 Closing Remarks

Currently, growing pressure on natural resources and the excessive production of waste and emissions that cannot be assimilated by nature have negatively and increasingly intense effects on the environment. In response, professionals, academics, institutions, companies, and governments, among others, have initiated a move toward a transition to methods and practices that are genuinely sustainable, which indicates that it is not enough to be governed purely by a principle of efficiency, as this will only postpone the inevitable. A complete change to the operational cycle is required: a paradigm change, which is what the circular economy seeks to achieve.

According to a long-term life cycle perspective, circular strategies are specific activities that help improve an organization's environmental performance. However, to improve the impact of these strategies, a holistic approach is required to incorporate the supply chain, including manufacturing systems, throughout multiple product life cycles (Bey et al., 2013). Even when this research only analyzed the optimization of one process, this perspective opens up the possibility of increasing the analysis coverage by including more links in the value chain and analyzing the impacts and implications of greater complexity in the relations and connections involved in the implementation of the strategies.

The selected and analyzed strategies provided valuable information on the implications – not all of which are technical – of implementing initiatives with a CE perspective. These technologies may have additional upfront costs, but these should be offset by the multiple benefits of a cleaner environment, improved labor productivity, consistency in materials quality, and improved international reputation. It can be achieved if the organization responds effectively to these kinds of change, which have organizational implications that are indispensable to the viability of such strategies.

The case study of a tannery in Colombia was particularly representative because of the zone in which it is located. It is a zone that has been affected by high levels of contamination of a water source and a complicated situation involving the presence of illegal tanneries that discharge untreated waste materials in violation of the regulations. The employment of analytical tools meant it was possible to confirm that the presence of chlorides and chrome in tannery wastewaters constitutes a severe environmental concern associated with leather production. The elimination or minimization of these pollutants is an active area of research in the world of leather. Generally, treatment systems for eliminating chlorides and chrome from wastewaters are costly, seriously affecting the viability of the leather tanning industry.

Suppose the CE is to be adopted, first of all. In that case, the system must be viable, starting with an adequate balance between the technical and financial viability of the operations, followed by a compelling connection between internal organizational activities, the maintenance and evolution of competitiveness, fulfillment of the organization's mission and vision, and their relation to the context in which it operates. Because, in order to develop a flexible system capable of adapting to the change of paradigm, such as the CE, it is necessary to facilitate coexistence between the organization and other systems, such as ecosystems, the human sphere, and other technospheres form a part of its surroundings. As was mentioned above, the Colombian case study provided evidence that it is not currently viable to adopt CE practices. However, adjustments are specified to ensure its viability, and the analysis continues to demonstrate the benefits of conducting a comprehensive study to facilitate decision-making.

Finally, an analysis that integrates all the perspectives that come together to influence the effective implementation of the CE in different contexts requires further research to identify tools capable of ensuring the transition from a consumption model to one that is more sustainable. Further analysis of CE practices with a broader scope is also required, involving a larger group of participants in the relevant value chain.

## Annex 1

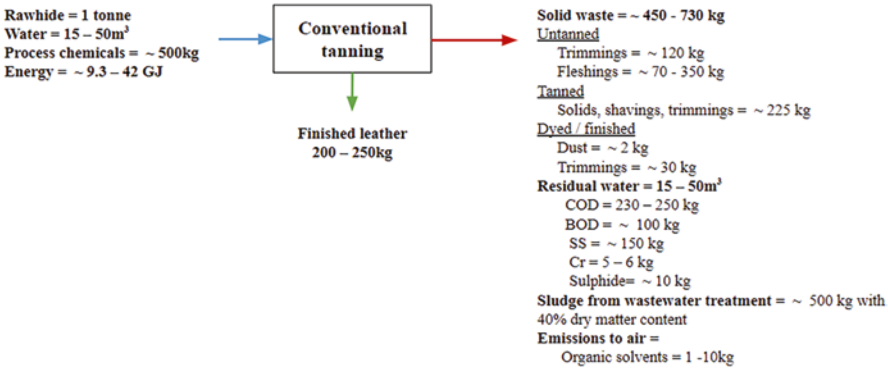


**Fig. 15.7** Overview of material flow in a conventional tannery per ton of leather (Source: European Commission, 2013)

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# Chapter 16
# Circular Economy and Recycling in Peru

**Eduardo De-La-Torre-Jave, Aldo Alvarez-Risco, and Shyla Del-Aguila-Arcentales**

## 16.1 Introduction

The circular economy is based on the principles of eliminating waste and pollution, keeping products and materials in use, and regenerating natural systems. (Ellen MacArthur Foundation, 2020). The circular economy requires two aspects so that it can have good results. First, the change of a production model, where there is sustainable management from the extraction of the raw material in the production processes and the solid waste generated during these processes.

It is necessary to understand that responsible consumption is the other vital aspect of the circular economy. Before acquiring a product, it is essential to "eliminate or avoid" waste generation or, finally, identify its returnability or recyclability characteristics.

Recyclers play a valuable role in the recovery and material valorization of recyclable solid waste, either in homes or businesses through the source selective collection programs of the municipalities to its reincorporation in the recycling value chains.

Something about which little is said is the relevance of the PSF/RS since it is in these programs where recyclable waste can be recovered and valued formally and more safely because we can generate a large percentage of plastic waste that can be recycled. It is not possible, it would be similar to developing single-use plastics

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because they would go to final disposal in the best of cases to landfills, but in reality, most of them go to landfills. The information from the General Directorate of Solid Waste of the Ministry of the Environment for 2019 says that only 3.4% of usable waste was recovered, that is, 18% of usable waste. Unfortunately, this percentage has been considerably reduced in the current. At the current juncture, in many districts, PSF/RS are no longer working, and in most, only 50% or 60% of recyclable waste is being recovered compared to recovery data before the pandemic.

The full reactivation and more significant support to the PSF/RS to recover and value higher volumes of recyclable waste are substantial. The Incentive Plan for improving municipal management has been promoted for 10 years; we cannot deny progress, but I believe that much more can be done since the budget granted to the municipalities does not reflect the recovery of waste recyclable in these programs. On the other hand, the obligation to implement the PSF/RS is mentioned in the DL. 1501; this situation should change in the following years.

## 16.2 Background of the Principles of the Circular Economy in Peru

Before discussing the recovery of waste and recycling, I would like to summarize what was done three decades ago and compare it with the circular economy principles.

### *16.2.1 Principles*

#### 16.2.1.1 Eliminate or Avoid the Generation of Waste

If we are talking about responsible consumption, we can mention that in every meeting or event, the food was served in earthenware, and the cutlery was made of metal, and no waste was generated, except organic waste; plastic plates, cutlery, and bags are currently used or instead of all single use. It has impressed me greatly that they sell fruit juice in a plastic bag with a plastic straw. If you wanted to eat some tamales on the neighborhood corner, they would deliver it to you on the same achira leaf, a biodegradable waste; now they serve it in an expanded polystyrene plate and disposable covered you wish to carry it in a plastic bag.

For the purchase in the markets, you had to bring the baskets of reed, wicker, or rush; according to the geographical area, no plastic bags were used, or if there where you had to pay. The bread was bought in the breadbaskets, or cloth bags were made when the flour sacks were finished. Sales were in bulk; rice, sugar, noodles, beans, and others were sold in paper from sugar bags that were reused or in parchment paper. Now all are in plastic bags or packaging. I remember that to be clean-shaven, the reusable razor was perfect; it lasted many years, and the other alternative was to go to the barber, and the current disposable 1, 2, or 3 blade machines were not generated.

#### 16.2.1.2 Keep Products and Materials in Use

The durability of the products was a characteristic of the equipment or containers that were generated; they had very long life cycles and no planned obsolescence. Examples include incandescent bulbs, toys, radios, televisions, blenders, refrigerators, etc. The term WEEE, waste electrical and electronic equipment, did not exist. Not only because the equipment had a long life, but they were also manufactured so that the parts were changed when they failed. Today it could speak of innovation at the origin because the products from their design were intended for long life cycles. In these times, many products or equipment come with a programmed useful life; otherwise, it is impossible to open the equipment to review it for repair.

The clothes such as jackets, shoes, and slippers were very durable, a better quality of the inputs or materials they were made than the currently manufactured clothes, which mainly use synthetic fibers. *Returnability* was the most common, especially in alcoholic and nonalcoholic beverages. People took your glass bottles to exchange them, or otherwise, you left an amount of money for the containers. Zero plastic containers, nor was it thought that bottled water would ever be consumed. *Repairing* was expected, whether for household appliances, toys, watches, or fixing footwear, it was easy to find an electrician or a shoemaker. Today repairing is not a practice carried out by consumers.

The *reuse* of containers was common, mainly glass; for example, jam containers became very resistant glasses or became vases or store colors. The canning cans were used to store nails or small accessories to fix any damage in the house. Large oil buckets, tubs, or cans were made into beautiful flowerpots. Also, I think it was a generation that was used to reusing everything they could.

## 16.3 Circular Economy, Segregation, Valorization, and Recyclers in Peru

### *16.3.1 Legal Aspects*

#### 16.3.1.1 Circular Economy

In Peru, the term of circular economy appears formally in Legislative Decree 1278, which approves the Law of Integral Management of Solid Waste, promulgated at the end of 2016, as one of the principles and mentions that “The creation of value is not limited to the definitive consumption of resources, considers the entire life cycle of goods. The regeneration and recovery of resources must be efficiently sought within the biological or technical cycle, as the case may be.”

In the regulation of Law 30884, law that regulates single-use plastic and disposable containers or containers, the purpose, it says "orient the use of plastic in our country towards a circular economy, where plastic goods are reusable, returnable to the production system and recyclable or whose degradation does not generate contamination by microplastics or dangerous substances, ensuring their recovery."

Likewise, it instructs the "Ministry of Production to carry out communication, education and awareness actions every six months to manufacturers, importers and distributors of plastic goods on the need to migrate towards the use of non-polluting goods and the recycling of plastic waste and other usable waste within the framework of the circular economy."

Similarly, the Supreme Decree that approves the roadmap toward a circular economy in the industry sector was approved in February 2020, in Policy Measure No. 9.3 called: "Circular Economy and Clean Production Agreements in the industrial sectors, fishing and agriculture," which mentions in the expected result that private economic agents progressively adapt the linear production model so far predominant in the Peruvian productive sector towards a cyclical production model, called circular economy, for extraction, transformation, distribution, use, and recovery of materials, and energy efficiency, among others.

#### 16.3.1.2 Municipal Competitions and Incentive Plan

In the Law of Integral Management of Solid Waste, it is held that municipalities must implement waste management and management programs that necessarily include obligations to minimize and value waste. In Legislative Decree 1501, the obligation for the implementation of said programs is set out. The Incentive Program for the Improvement of Municipal Management (PI) is an instrument of the budget for results to improve the quality of public services provided by the municipalities, unfortunately analyzing the participation of the municipalities during the period 2011–2019. It was decreasing. However, the amount of the distributed budget has been increasing. On average, only 23% of the municipalities have met the goals established by MINAM related to solid waste management, and more than 500 million soles have been distributed during the 2011–2019 period, which is not reflected in the progress of these programs. It is necessary to ensure that the budget is granted to the municipalities for the fulfillment of the goal, specifically of solid waste, and is invested 100% in the programs to guarantee their sustainability.

#### 16.3.1.3 Formalization of Recyclers

Law 29419, which regulates the activity of recyclers approved in 2009 and its regulations a year later, is aimed at protecting, training, promoting social and labor development, and promoting the formalization and associativity recyclers. The Legislative Decree 1278 approves the Law of Integral Management of Solid Waste within the guidelines. It is stated that it must "Promote the formalization of people, operators and other entities that intervene in the management of solid waste without the corresponding authorizations" and "grants the competence to the Municipalities to execute programs for the progressive formalization of the people, operators and other entities that intervene in the management of solid waste without the corresponding authorizations." Including formalized recyclers in solid waste management and handling systems brings various benefits such as:

– Waste pickers with decent work visibility were marginalized, excluded, and discriminated against before their formalization.
– Grant training opportunities.
– Provide better working, safety, and health conditions.
– Improve economic income.
– Save costs of collection, transport, and final disposal of waste to municipalities.

#### 16.3.1.4 Solid Waste Segregation and Recovery

Regarding the segregation of waste in Legislative Decree 1278, which approves the Law on the integral management of solid waste, it is stated: "The municipal waste generator must carry out the segregation of its solid waste according to its physical and chemical characteristics and biological, to facilitate its recovery and final disposal." Regarding recycling, it is stated: "Recycling constitutes a form of material recovery, which consists of transforming solid waste into products, materials or substances, which retain their original purpose or any other purpose." Finally, on the selective collection, it says: "duly formalized recyclers or recyclers' associations are integrated into the management and handling systems of municipal non-hazardous solid waste, which are conducted by municipal authorities."

### *16.3.2 Technical and Operational Aspects to Consider in Segregation and Recycling*

Analyzing what happens in our country, in the field of material recovery of solid waste, specifically on recycling, the following aspects, factors, or conditions should be considered (Fig. 16.1):

#### 16.3.2.1 Environmental Education and Awareness

It is an important aspect and has a lot to do with those above; it is referred to the budget because it is common to hear from municipal officials who do not have a budget to carry out environmental education and awareness activities. If we do not carry out these activities with the population, it is challenging to achieve progress in the separation, recovery, and subsequent recovery of waste in homes and businesses, and it is not a task of 2 or 3 months but medium- and long-term achievements. It is


**Fig. 16.1** Formalized recyclers, Pueblo Nuevo, Chincha. (Source: Eduardo De La Torre-Ciudad Saludable)

also advisable to prepare and design the educational materials that will be used to raise awareness, considering educational, cultural, geographical, and customs aspects mainly so that the information is adequate.

#### 16.3.2.2 Vehicles Used in Selective Collection

The errors are incurred at the time of purchase of vehicles for selective collection. Before acquiring a vehicle, the width and conditions of passability and slope of the collection routes must be verified to avoid inconveniences, especially when acquiring vehicles that cannot have access due to their size or do not have enough power to climb very steep slopes in places in the Sierra. Another aspect to consider is the storage capacity; in many cases, vehicles (motor vans) with a significantly reduced capacity are bought that have to go many times so that they can collect the stored waste, with economic damage to the recyclers in time and fuel consumption. A solution to this is to fit the hopper of the van with metal screens to double its capacity.

#### 16.3.2.3 Recyclable Waste or Waste with Commercial Value

Determining this difference is extremely important to continue with the strategies of recovery and recovery of waste in the municipalities' segregation programs because the waste can be recyclable or with a high percentage of recyclability, but unfortunately, it does not have a commercial value, that is, they do not buy it to transform them. This lack of commercial value may be due to the lack of technology to process them or because containers such as PET, HDPE, and PP plastics have been mixed with other plastics or contain additives that make their recovery very difficult. Another explanation for its lack of value is the glue used on the labels or the same labels made of polyvinyl chloride (PVC).

In many places in Peru, it is common to observe that there is no articulated work of involvement and participation with the recyclers to know and define what waste can be recovered or because of the insufficient knowledge about the recovery of waste by those in charge of directing the municipal programs. Therefore, it is absurd to recover this waste in homes or businesses that eventually reach the conditioning centers and later have to be thrown away, with economic damage to recyclers, since there is unnecessary time and effort in recovery and because you have to make an additional payment for its final disposal. Therefore, it is essential to determine at the planning stage the commercial value of recyclable waste to be recovered for municipal programs to be effective.

#### 16.3.2.4 Types of Recyclable Waste

The waste generation depends on the type of consumption, customs, supermarkets, services, purchasing power, access roads, and others; for example, the generations in the coast, mountains, and jungle are different. However, it is unfortunate to observe how projects are formulated assuming that the generation and type of waste are the same. If we consider Metropolitan Lima, in the same way, the waste generated in urban and peri-urban districts is variable due to the aspects above. For example, in the district of Miraflores, a greater quantity of cardboard/tetra pack is recovered, followed by paper, then glass, plastic, and finally metals; on the other hand, in the district of San Miguel, there is a more significant recovery of PET plastic, hard plastic, paper, cardboard, glass, and metals. Some examples of the most common waste that recyclers recover and value are as follows:

- PET plastic. Containers of water drinks, rehydrating agents, mouthwash, oil, vinegar, disinfectants (Poet brand), liquid dishwasher (Ayudín brand)
- Hard plastic. Yogurt containers, lids of various beverage containers, bleach containers, white disposable cutlery, solid-state dishwasher (Ayudín brand), and butter containers
- Plastic film. Soda and beer packaging
- Paper. White paper, couché paper (magazines, catalogs), mixed paper (ballots, manila envelopes, manila folders, envelopes, cardboard, glossy paper), and newspaper
- Paperboard. Cardboard and cardboard boxes
- Metals. Cans of milk, tuna, canned food, soft drinks, beers, aerosol containers, wires, iron, and pots
- Glass. Bottles of all kinds of liquors and perfume containers
- Jebe. Soles of rubber shoes and slippers (Fig. 16.2)

**Fig. 16.2** Hard plastic waste. (Source: Eduardo De La Torre-Ciudad Saludable)

#### 16.3.2.5 How to Determine the Recyclability of Waste

A myth that must be discarded is that all plastic bags or packaging are not recyclable; however, the plastic film and packaging of many products have good quality and have a reasonable price in the recycling market as such the packaging of detergents, dog food, rice, sugar, soft drinks, beers, and others. Recyclers are experts in determining the recyclability of products in a practical way, and it is a task that they do daily in their packaging centers. One of the characteristics to consider to establish the recyclability of bags or packaging is elasticity. The usual term that the recyclers use is "it's chewy," referring to the plastic stretching like chewing gum. Another way is the sound generated when the bags are squeezed or crushed. If they have a very high-pitched sound, it is not recyclable; an example of this is the noodle packaging.

With waste such as hard plastic (generally yogurt containers), it is determined visually, looking at the base of the container: if it has a line, it is recyclable, but if what is observed is a point, it is not recyclable. If it is necessary to know about the recyclability of PET and HDPE plastics, you can place water in a tank and submerge pieces of this waste: waste that floats is recyclable, and those that sink are not. Also, visually you can tell: if the white PET plastic has much shine, it is a waste that is not recyclable.

#### 16.3.2.6 Segregate for Recycling

It is essential to separate recyclable waste to facilitate the work of recyclers and for the waste delivered to have more excellent recyclability, which allows the recycling process to be more efficient. If we talk about separating, how the waste should be delivered is essential. For example, removing labels, compacting bottles, disassembling cardboard boxes, and rinsing cans and bottles should be standard practices. These conditioned wastes, in the first place, should be delivered to the formalized recyclers who participate in the segregation programs of the municipalities. If these programs do not exist, they can be taken to the nearest recycling points such as supermarkets or public spaces, such as parks or main streets.

#### 16.3.2.7 Waste Prices

Another point to consider is the price of waste, since, if we talk about PET plastic, the highest price is for transparent PET, then green, and finally amber. The same is true of glass. It should also be considered that the price varies according to the type of product that the container has. Examples are oil and vinegar, whose price is lower than the containers used for water or other beverages. The reason is that the transformer companies would use more resources to clean or eliminate the waste from these containers.

On the other hand, it is not the same to commercialize recyclable waste that was recovered in the source segregation programs of the municipalities, which have a higher price, than to buy waste that comes from a dump, since this waste is "contaminated, dirty," especially with organic waste. Finally, it is necessary to mention that prices vary if all mixed waste is sold, as recyclers call "when sweeping"; if colors separate the residuals, they have another value. Also, if compacted, it has another price, especially PET plastic or rigid plastic is crushed. Years ago, the processing companies bought crushed PET plastic, but to ensure the quality of their products and prevent the crushed plastic (flakes) from arriving "contaminated," that is, mixed with other types or colors of PET, currently they are the ones who do the shredding at their facilities.

The distance where the waste is recovered must be considered. Thus, if the jungle region or the southern area of Peru is taken as a reference, it can be mentioned that there are recyclable waste that is not recovered, and others have a price between 50% and 60% less than what companies pay in Lima. This It is because the "freight" that has to be paid to transport the waste to Lima, where the waste is transformed, is very high.

Table 16.1 shows the prices in Peruvian currency (soles), obtained in January 2021 from some places in Peru.

#### 16.3.2.8 Transformation of Recyclable Waste

The transparent PET plastic, especially the containers for water and rehydration drinks, is transformed into new containers after washing, decontamination, crushing, drying to obtain the flakes (flake), and other processes. In Law 30884, which regulates single-use plastic and disposable containers or containers, companies are obliged to manufacture containers whose composition must have at least 15% of PET PCR (post-consumer recycled PET). However, some companies exceed this percentage, and they sell containers with 100% PET PCR, which is very encouraging and challenging for other companies in the field. It is also used as a raw material for the manufacture of food packaging. The PET from oil and vinegar containers is

**Table 16.1** Waste prices

| Types of waste | Cajamarca city | Chincha city | Lima city | Trujillo city | Iquitos city |
|---|---|---|---|---|---|
| PET plastic (when sweeping) | S/. 1.00 | S/. 1.00 | S/. 1.40 | S/. 0.80 | S/. 0.40 |
| PET plastic from oil, vinegar | S/. 0.50 | S/. 0.60 | S/. 0.60 | S/. 0.30 | S/. 0.30 |
| Hard plastic | S/. 1.50 | S/. 1.50 | S/. 2.00 | S/. 1.80 | S/. 0.40 |
| Plastic film | S/. 1.50 | S/. 1.30 | S/. 1.70 | S/. 1.50 | S/. 0.30 |
| Paperboard | S/. 0.20 | S/. 0.20 | S/. 0.35 | S/. 0.15 | S/. 0.00 |
| Paper (when sweeping) | S/. 0.80 | S/. 0.50 | S/. 0.75 | S/. 0.70 | S/. 0.35 |
| White paper | S/. 0.90 | S/. 0.75 | S/. 0.90 | S/. 0.80 | S/. 0.40 |
| Mixed paper | S/. 0.30 | S/. 0.30 | S/. 0.35 | S/. 0.40 | S/. 0.10 |
| Cans | S/. 0.30 | S/. 0.30 | S/. 0.20 | S/. 0.35 | S/. 0.25 |
| Heavy iron | S/. 0.35 | S/. 0.35 | S/. 0.35 | S/. 0.35 | S/. 0.25 |
| Aluminum | S/. 2.50 | S/. 2.70 | S/. 2.70 | S/. 2.80 | S/. 1.00 |
| Glass | S/. 0.10 | S/. 0.05 | S/. 0.10 | S/. 0.05 | S/. 0.00 |

mainly used to obtain polyester fiber to produce blankets, rugs, clothing, backpacks, and merchandise. Cans and all types of heavy iron serve as input for manufacturing metal plates and iron for construction. The recovered paper is the raw material for paper towels and shoe and shoe insoles in other cases.

#### 16.3.2.9 Agreements and Forms of Payment

Generally, the commercialization of the waste is carried out by verbal agreements; it is not common to sign contracts or agreements. There are payments in cash and by bank accounts. In cash, it can be against delivery or after days or weeks, considering the agreement reached and the processing companies make payments through financial banks. It is common for recyclers to receive an advance for the sale of their waste, which hurts their price because the buyer pays the price that suits him since the recycler has already spent the money, and unfortunately, they have to accept the price offered, which is generally less than the current market price.

#### 16.3.2.10 Types of Nonrecyclable Waste

Knowing the types of waste that are not recyclable helps to propose public policies to avoid or reduce their manufacture and helps inform consumers about the materials from which they are made so that they can make decisions before they are purchased. Finally, this knowledge is helpful for them to be discarded in the recovery list in the segregation programs of the municipalities. Here is a list of the most common nonrecyclable waste:

*Glasses*. Window glass, mirrors, glasses, lens glass, spotlights, fluorescent lamps, windshields, and vehicle windows

*Plastics*. Glossy white PET, expanded polystyrene, single-use bags, transparent (brittle) cutlery, white light tubes, ABS-type plastics for electrical and electronic devices, such as computers, laptops, televisions, etc.

*Others*. All packages of snacks, cookies, noodle packages, toothpaste containers, earthenware plates, flowerpots, tracers, cellophane, plastic cups, photos, lighters, egg cartons, tires, slippers with a rubber plant, biodegradable bags, sachet of mayonnaise and the like, and a sachet of shampoo and conditioners

#### 16.3.2.11 Corporate Responsibility

Although responsible companies are changing their containers that were not recyclable, they have launched products with returnable containers. Some companies are marketing a large number of products that are sold in stores and supermarkets with plastic containers, especially white PET that is shown as recyclable, even with the recycling number and symbol, but after they are generated, they have no commercial value primarily because it is a "mixed or blended" plastic as described above.

#### 16.3.2.12 Second-Hand Equipment or Artifacts

The confidence or familiarity of the residents with the recyclers over time is strengthened, and this allows them to deliver equipment or artifacts that the recyclers can fix for a second use or also for sale in the famous "cachina." It is a good practice because equipment or artifacts remain in use. In the valorization of glass, mainly the reuse of bottles of alcoholic beverages, they have a market reduced by price (0.05–0.10) but very interesting for the manufacture of lamps; they are exclusive or not very common bottles that can be sold per unit between 10 and 20 soles, an exciting price for recyclers. Above all, this type of waste is recovered in Barranco, Miraflores, and San Isidro districts.

## 16.4 New Upcycling Technologies

Recycling has been one of the ways of managing plastic waste. Thus, the scientific literature has very recent reports as lithium-ion battery recycling (dos Santos et al., 2021; Yıldızbaşı et al., 2022), structural pavement rehabilitation with recycled materials (Freire et al., 2022), circularity of phosphorus of disposable baby nappy waste (Chowdhury & Wijayasundara, 2021), recycling plastic in construction (Arora et al., 2021; Balletto et al., 2021; Norouzi et al., 2021), recycled polyethylene fishing nets (Juan et al., 2021), plastic recycling and remolding circular economy using blockchain (Khadke et al., 2021), artificial intelligence-based solution for sorting COVID-19-related medical waste streams (Kumar et al., 2021), description of non-household end-use plastics (Kleinhans et al., 2021), post-consumer plastic packaging waste flow (Pimentel Pincelli et al., 2021), and recycling and utilization of polymers for road construction projects (Anwar et al., 2021).

Then other efforts were developed as government experiences of plastic waste (Lacko et al., 2021; Wu et al., 2021), 3D print of plastics (Zhu et al., 2021), review of the European Union's strategy for plastics (Matthews et al., 2021), lean green production for reducing variable costs of plastic (Diaz et al., 2022), chemicals advances of plastic (Aurisano et al., 2021), using worms for plastic agriculture (Gan et al., 2021), regulation of plastic (Syberg et al., 2021), review of bioplastics (Di Bartolo et al., 2021), algae biopolymer (Devadas et al., 2021), prevention of marine plastic pollution (Fadeeva & Van Berkel, 2021).

Also, other topics that were developed included material flow analysis of PET, PE, and PP flows in Europe (Eriksen et al., 2020), incorporation of recycled high-density polyethylene to polyethylene pipe grade resins (Juan et al., 2020), incorporation of recycled high-density polyethylene to polyethylene pipe grade resins (Juan et al., 2020), microplastics in horticulture (Blanke, 2020), waste polypropylene plastic recycling (Bora et al., 2020), case study on plastic bottle closed-loop recycling in the USA PET market (Lonca et al., 2020), green chemistry and the plastic pollution (Sheldon & Norton, 2020), cyanobacterial polyhydroxyalkanoates (Gomes Gradíssimo et al., 2020), plastic recycling in additive manufacturing (Cruz Sanchez et al., 2020), marketing a new generation of bioplastics products (Confente et al., 2020), and ethylene monomer recovery via polyethylene pyrolysis (Somoza-Tornos et al., 2020).

However, various strategies are being developed recently using other types of technology to manage plastics and even creating new products (Romani et al., 2021). In this way, it recognizes the use of *Tenebrio molitor* for plastic biodegradation and biological recovery of new biopolymers, non-fossil-based plastics, such as polyhydroxyalkanoates (PHAs). TM microbiota is a source of plastic-degrading microorganisms and with the advantage of obtaining, in addition to highly pure PHA, protein biomass and rearing waste from which to produce fertilizers, chitin/chitosan, biochar, and biodiesel (Sangiorgio et al., 2021).

Figure 16.3 describes the plastic waste conversion techniques. It can be recognized as conventional and emerging strategies. It is essential to know that it is needed that future research and implementation consider these new strategies to accelerate the transformation of plastic and can reach better and faster outcomes in the management of plastic waste.

Recent efforts of circularity in plastic waste are urgent because the COVID-19 pandemic has exacerbated plastic pollution (Yuan et al., 2021). Next year after the COVID-19 pandemic is an excellent opportunity to prepare plans to allow the circular economy to generate the significant benefits they claim.

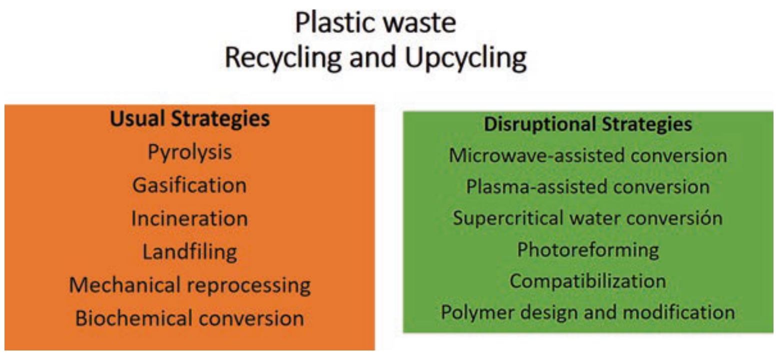


**Fig. 16.3** Conventional and emerging strategies of plastic waste

## 16.5 Closing Remarks

It is essential to propose a moderate and real circular economy because sometimes it is expressed as a solution for all environmental problems and even is proposed as the best solution for all the processes. The teaching and research in the circular economy must be a focus in evaluating new materials for manufacture products based on circularity, but, at the same time, it needs to evaluate in customers and companies the genuine interest and intention to pay for products which would be used for many years and avoid to have a new version of the product. Will the temptation to buy the next laptop or mobile phone model be overcome, or will the desire to be circular be stronger? Let's hope that time shows a genuine intention of people and institutions toward becoming more and more circular and that although it is not in all the processes of an organization, they are a significant percentage. Only a sense of reality allows the circular economy to be honest and implemented in the coming years.

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# Chapter 17
# X Economies: Towards Comprehensive Policy Intelligence Among Economy Visions and Practices in Europe and Latin America

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## 17.1 Introduction

A modern tradition is using X to represent an unknown in La Géométrie by René Descartes in 1637. X economies, as a meta-level concept, thus, denote an unknown number of realigned or newly proposed economy visions and practices, present, or will emerge. However, all claim a transition towards a more sustainable, responsible, and resilient economy than the current instance. In this chapter, each realigned and newly proposed economy vision and practice is conceptualized as *one of the technologies of economy*. For this, we use a meta-level concept: X economies.

X economies, conceptualized as *technologies of economy*, are niche (system) innovations aiming at socio-technical regime-level system transitions and change. Thus, as *technologies of economy*, X economies do not only include technological, social, ecological, organizational innovations but also realigned and newly proposed policies, policy mixes, governance, interacting areas of scientific research, finance, changes in the market user preferences, and changes in financing, production, distribution, and consumption choices and culture, thus societal transformations and

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change. In this respect, "X economies" include and extend "the new economy" umbrella term proposed by DRIFT (DRIFT, 2020).

In this chapter, out of many, we concentrate on six X economies, namely, Circular, Blue, Collaborative, Digital, Feminist, and Social Economy. The choice of these X economies is to cover 17 SDGs where the Social Economy is the economic vision that enables the most significant number of SDGs as it addresses the issues of:

SDG 1. No poverty
SDG 2. Zero hunger
SDG 3. Good health and well-being
SDG 4. Quality education
SDG 5. Gender equality
SDG 7. Affordable and clean energy
SDG 8. Decent work and economic growth
SDG 10. Reduced inequalities

As for Circular Economy, it allows addressing the SDGs relating to:

SDG 11. Sustainable cities and communities
SDG 12. Responsible consumption and production
SDG 13. Climate action
SDG 15. Life on land

Collaborative Economy tackles two of the three objectives of Circular Economy:

SDG 11. Sustainable cities and communities
SDG 12. Responsible consumption and production

As for Blue Economy, it focuses on the objectives relative to water:

SDG 6. Clean water and sanitation
SDG 13. Climate action
SDG 14. Life below water

The Digital Economy, together with being a springboard for the development and spread of alternative economies, allows a focus on SDG:

9. Industry, innovation, and infrastructure

The Feminist Economy has one core objective SDG:

5. Gender equality

This chapter proceeds as follows: Sect. 17.2 covers definitions and status of each X economies in Europe and Latin America. Section 17.3 deepens the literature on these X economies, indicators, and the methodology used to analyze these X economies in these major world regions quantitatively. Section 17.4 provides the results and implications. Recommendations and future research directions are given in the final section.

## 17.2 Review of X Economies: Definitions and Status in Europe and Latin America

### *17.2.1 Circular Economy*

Geissdoerfer et al. (2017, p. 760) define Circular Economy as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops." The Circular Economy's primary purpose is to make an economy more sustainable, which is achieved through durable design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. Products and materials are kept in circulation for as long as possible by designing them to be more durable, reusable, repairable, and recyclable (Schröder et al., 2020). It focuses on minimizing waste through the use of renewable energy, and through more sustainable business models, and at the political level with more sustainable policies (Geissdoerfer et al., 2017).

The European Commission (EC) has launched several efforts, e.g., a resource-efficient Europe roadmap in 2011 for resource efficiency. In 2015, Action Plan for the Circular Economy was introduced, which proposes amendments to legislation relating to waste and landfills as well as new initiatives (McDowall et al., 2017). To this date, all 54 actions under the plan have been delivered or are being implemented. In 2020, a new Circular Economy Action Plan was launched to move towards an even more Circular Economy to attend climate neutrality by 2050 (EU Circular Economy Action Plan, 2020). Overall, Circular Economy has gained particular attention over the last few years, especially throughout countries in Europe. Several member states have foreseen the growing importance of building a future-oriented green agenda and are actively trying to define measures to become climate-neutral, resource-efficient, and sustainably competitive. Germany, for instance, has developed a Circular Economy Roadmap for Germany or Spain where has been defined as a strategy plan "Circular Spain 2030."

Rich in natural resources, biodiversity, and social innovation, Latin America still has not achieved significant steps towards a regenerative Circular Economy. According to the Ellen MacArthur Foundation, Latin America requires a multi-stakeholder approach to bring the region to scale. The Foundation is convinced that Latin America could greatly benefit from a circular development path. The significant lack of statistical data prevents policymakers and other countries' stakeholders from preparing adequately for the shift towards circularity.[1] For a Circular Economy, there exists no one-size-fits-all. Even though the Circular Economy model has gained great political attention in Latin America in recent years, one challenge that Latin America faces is that countries in the region rely on extractive industries such as oil and mining, which will naturally reduce demand as the economies transition to a circular model and hence hurt their revenues (Schröder et al., 2020). However,

[1] Ellen MacArthur Foundation: Circular economy in Latin America (ellenmacarthurfoundation.org)

Mexico has become a regional leader in plastic recycling thanks to its waste management legislation, recycling facilities, and related infrastructure (Chebulgaeva, 2020).

Nonprofit environmental associations in Mexico, such as ECOCE, have partnered up with Unilever, Coca-Cola Company, PepsiCo, and Nestlé, among others, to recycle plastic and educate the Mexican population. They occupy a 60% share of the plastic recycling market in Mexico (ECOCE, n.d.). For instance, to reduce plastic waste, Unilever has cut virgin plastic for its popular brands. Since 2019, Hellmann's mayonnaise has made 95% reused plastic (Chebulgaeva, 2020). The Dutch company Heineken in Mexico is also a case of how companies are transitioning towards circularity. Heineken and Enel Energia Mexico have signed a 10-year contract under which the brewery located in Chihuahua will be supported only by power from renewable sources such as wind and solar plants (Chebulgaeva, 2020). In Brazil, CBPak has begun to produce food containers using a nonedible type of cassava starch. Through partnerships with local composting companies, the containers get collected after a single use and converted into soil enhancers used to regenerate farmland (Chavin & Jeffries, 2017). In Chile, the "Chilean Plastic Pact" led by the Ministry of Environment was signed in 2019, making it the first Latin American country to join the "Plastic Pact" and the third country to implement it along with the UK and France (New Plastics Economy, 2020).

### *17.2.2 Blue Economy*

There is no commonly accepted definition of Blue Economy. In "Principles for a Sustainable Blue Economy" by WWF (2015) states that "For some, Blue Economy means the use of the sea and its resources for sustainable economic development. For others, it simply refers to any economic activity in the maritime sector, whether sustainable or not." WWF states that the Blue Economy "must respect ecosystem integrity." The World Bank and the United Nations Department of Economics and Social Affairs denote the term Blue Economy as the sustainable use of ocean resources and coastal areas to promote economic growth, social inclusion, and the preservation or improvement of livelihoods. It considers diverse activities, e.g., renewable energy, fisheries, maritime transport, tourism, climate change, and waste management. The range of economic sectors and related policies determine whether the use of marine resources and coastal areas is sustainable (World Bank and United Nations Department of Economics and Social Affairs, 2017). Blue Economy is thus a holistic concept which encompasses all sectoral activities related to oceans, seas, and coasts.

In 2008, the EU's Marine Strategy Framework Directive became effective, promoting an ecosystem-based approach, combining marine economic potential while guaranteeing long-term sustainability and requiring national marine strategies from the different member states to improve or maintain "good environmental status" to keep a healthy, productive, and resilient condition of the ecosystem (EC, 2020). In 2020, the EC published the third edition of their annual "EU Blue Economy Report."

The report aimed to provide policymakers and stakeholders support to promote sustainable development of oceans and sustainable usage of coastal resources (EC, 2020c). According to the "EU Blue Economy Report" (EC, 2020c), in 2018, the seven established sectors of the EU-28 (including the UK) Blue Economy directly employed close to five million people, which equals 2.2% of the total employment, and generated around €218 billion in gross value added (GVA), equaling 1.5% of total GVA. Besides the efforts within the EU borders, the EU intends to become a key leader in sustainable blue growth at a global level (EC, 2020a).

The Blue Economy is embedded in the overall EU economy and the UK. Significantly the EU coastal zones will be severely affected by the consequences of climate change. Only with sustained collaborative efforts will it be possible to confront the rising sea levels in Europe. Some examples that emerged as initiatives to mitigate the disastrous effects of sea pollution are the Great Bubble Barrier, CLAIM, or Clean Ocean Initiatives (EC, 2020). Other notable examples of best practices in the context of Blue Economy can be considered Portugal and its first Satellite Account for the sea, the improvements of water services in Bulgaria, or the fund for seafront flood defense structures of the Netherlands. The most significant performance increase of the Blue Economy during the last several years has been observed for the UK, the Netherlands, and France (in terms of gross value added, gross investment, turnover, persons employed). Finally, for a better overview of the different country efforts, the Blue Economy Report of the EC provides a summary of the member states (MSs) participating in different sea basins. According to the EC, a sea basin strategy can be defined as "an integrated framework to address common marine and maritime challenges faced by MSs in a sea basin or one or more sub-sea basins. Sea basin strategies also promote cooperation and coordination to achieve economic, social and territorial cohesion" (2020, p.158).[2]

In Latin America, the ocean-related economy contributes significantly to the GDP, but much potential has not been identified and realized yet (McKinley et al., 2019). In Peru, for instance, with a coastline of more than 3000 km, maritime industries are a vital part of the economy (McKinley et al., 2019), and more than 200 thousand jobs are created merely by the fisheries sector (Christensen et al., 2014). Policies, like the General Fisheries Law (Decree-Law N° 25977, published in 1992), for more sustainable use of these marine and coastal resources have been introduced, but the effectiveness is questioned by the OECD Territorial Report (2016). According to the report, improved environmental and economic policies are required to guarantee sustainable maritime development, resource usage, and diversification (OECD Territorial Report, 2016). McKinley et al. (2019) argue that developing a strategy for the Blue Economy in Peru (McKinley et al., 2019). Gerhardinger et al. (2020) find that a vision of Blue Economy does not yet exist for Brazil and point out the importance of marine spatial planning and potential gaps that need to be addressed when taking environmental sustainability and social equity into consideration.

[2] Source: European Commission. (2020). Blue Economy Report 2020. Publications Office of the European Union. Luxembourg.

### 17.2.3 Collaborative Economy

A Collaborative Economy is often referred to as sharing or peer-to-peer economy. It can be defined as an economy that uses online platforms to match the needs and haves of people in ways that bypass the middleman. Consumers grant other consumers temporary access to underused assets in this X economy, thereby unlocking the asset's value (Botsman & Rogers, 2010; Nwaorgu, 2018). Some valuable indicators that the EC used (2018) to monitor the development of Collaborative Economy among its MSs, and that could easily be extended to the world are the share of total revenue generated by collaborative platforms to national GDP; the share of persons employed in the Collaborative Economy in total national employment; and the number of collaborative platforms per one million residents. There are various reasons why people turn to the Collaborative Economy. The ecological reasons are to reduce the production of goods by moving towards sustainable consumption (Daunoriene et al., 2015). Perren (2015) states that environmental benefits are achieved by using assets that would, otherwise, go unused.

The EC (2017) stated that the market size of Collaborative Economy in the EU was evaluated at €26.5 billion in 2016. The market is composed of five main sectors: finance, transport, accommodation, and online skills. In the EU, in 2016, the four major countries active on the collaborative market were France, Poland, Spain, and Germany. In Europe, in 2015, 32% of European consumers were aware of the Collaborative Economy, of which only 5% had already taken part in it (ING International, 2015). The giant of the Collaborative Economy, Airbnb, has prompted many European countries to adopt new regulations and policies. For example, France has allowed collecting "tourist taxes" and updated its housing law to allow sharing primary residences without authorization. While other regions have introduced new regulations that complicate the use of Airbnb, e.g., Catalonia obliges users to apply for a license, provide a VAT number, and prove that nobody lives in the apartment (Vaughan & Daverio, 2016).

For instance, Estonia has proactively updated its legal framework for Sharing Economy over the last years, intending to support entrepreneurship, and has made significant achievements in implementing shared economy platforms, especially achieving inspiring results in their collaborative digital government platforms. Although this is undermined by extensive efforts in researching and defining taxation regulations for the Sharing Economy, Estonia has shown how it became the first European country to regulate and legalize ride and home-sharing in 2016. Estonia's reform law and tax regulation started to treat taxi and ride-hailing drivers as equals, putting taxis and hire drivers on the common legal ground and significantly improving its citizen transport experience, mobility in urban and rural areas, and overall increasing overall tax receipts.

A Nielsen report (2014) finds that the eagerness to share assets with others in developing regions (Asia-Pacific, 78%; Latin America, 70%) exceeds the eagerness in developed regions (Europe, 54%; North America, 53%). However, despite this eagerness to share and the boom in Internet users between 2000 and 2013 (from 5%

to 50%) (World Bank, 2015), the lack of trust in Latin America remains a significant obstacle to developing a Collaborative Economy. Uber is one of the most widely used collaborative platforms. Present in 71 countries, its main markets are the USA, Brazil, Mexico, and Spain (Uber Estimator, 2020). The CEO of Uber also confided that Latin America is one of their best markets. The more favorable regulations can explain this more robust presence in Latin America than in Europe. In September 2019, a Brazilian labor higher court ruled that no working relationship existed between Uber and its drivers, thereby facilitating Uber's expansion in Brazil (The New York Times, 2019).

### *17.2.4 Digital Economy*

Digital Economy comes with numerous different interpretations. According to the IMF, digitalization has marked a new phenomenon since the start of the 2000s, impacting our societies. The IMF defines this new fast-growing phenomenon as follows: "The digitalization of the economic activity can be broadly defined as the incorporation of data and the Internet into production processes and products, new forms of household and government consumption, fixed capital formation, cross-border flows, and finance. The rapid pace of change has led to concerns about the possible under-measurement of economic activity and economic welfare associated with digital products. The Digital Economy is sometimes defined narrowly as online platforms and activities that owe their existence to such platforms, yet, in a broad sense, all activities that use digitized data are part of the Digital Economy: in modern economies, the entire economy" (IMF, 2018).

The OECD is convinced that mobility, cloud computing, social networking, sensor-nets, and big data analytics are some of the most critical trends in the Digital Economy in current times. These trends aim to establish a future characterized collectively as "smart everything" (OECD, 2014). As the term suggests, "smart" impacts "everything," from grids, homes, business processes, over energy, healthcare, transport, and government, as well as "empowering businesses, consumers, and society at large." The rapid evolution of the Digital Economy and technological change has shown that digital tech has a massive potential to find new solutions to tackle always existing challenges in the world. Digital Economy is not only related to the industry of "pure data gathering," but rather it impacts education, health, governance, society, climate, cooperation, industry, sustainability, and many more. There are many ways in which digitality can contribute to sustainable development, as the United Nations tech report has pointed out. Just think about mobile phone services, technology in agriculture, disaster management, intelligent tools, public transport, sanitation, satellite, and so on – these are just a few examples of where technology and data monitoring already play a fundamental role. However, there is so much more to mention still.

While the EU's Digital Economy has become increasingly adopted in the member states' agendas, Latin America is still lagging in Internet adoption and the measurement of data and ICTs. Therefore, the region must improve its statistical capacity to identify measures required to improve the impact of the new digital era and adequately prepare policymakers for challenges inherent to the Digital Economy. Regional initiatives that have boosted the efficiency of implemented measures were, for example, the digital scoreboard of the EU, which measures the performance of the MSs in a range of different dimensions, from connectivity over digital skills and public services (UN, 2019). In addition, the EU has developed a holistic digital index, the Digital Economy and society index, and its corresponding monitoring framework.

In the last decade, the EU countries have increased access to the Internet, with 87% of households having access to the Internet in 2017 compared to 70% in 2010 (EUROSTAT, 2018a, b). In 2017 it was estimated that only 3% of businesses did not have an Internet connection (EUROSTAT, 2018a, b), showing how digitized Europe has become. Furthermore, ICT education has proved to be a reasonable basis for job opportunities among European countries where 90% of people with an ICT education are employed as ICT specialists (EUROSTAT, 2018a, b).

In Latin America, one notable measure introduced by the Development Bank of Latin America was the Observatory of the Digital Ecosystem in Latin America and the Caribbean. These frameworks are essential to complement the digital ecosystem within these regions. Generally, the countries with the least amount of statistical data and information on the Digital Economy perform especially weak on the country map. Hence, governments need to make substantial progress in investing in impact measurement initiatives. In Latin America, access to financial resources directed to digital entrepreneurship is particularly limited in this region. However, the flow of venture capital funds to Latin America have doubled in 2018 (UN, 2019). Noticeably, the Latin American region has demonstrated great potential and strong dynamism during recent years and consolidated several innovation and entrepreneurship hubs. Leading start-up incubators, which have been vital in fostering this ecosystem, can be found in Buenos Aires, Bogotá, México City, Lima, Santiago de Chile, and São Paulo (UN, 2019). Additionally, there has been a significant rise of so-called tecnolatinas. The newest report of the Inter-American Development Bank recognizes the speed and scope of the transforming digital business landscape within the Latin American region.

Tecnolatinas refer to technology-based private companies which have emerged and "were born" in Latin America. The flourishing tecnolatinas that have emerged in that particular geographical context are spreading into sectors like "biotechnology, digital medicine, renewable energy, software security, space tech, fintech and agtech" (IDB, 2017, p.4). Brazil and Argentina are frontrunners in the ecosystem. Overall, more than 5000 tecnolatinas have been identified with an ecosystem value of about US$37.7b. Even though Mexico is still in its early stages of digitization, its journey of digitizing government activities (such as requesting birth certificates online) serves as a perfect example of how the Digital Economy has helped Mexico improve its government productivity (Cesar et al., 2018). In 2009, the Colombian government issued an ICT Law to establish the Information Technologies and

Communications Fund, whose purpose was to finance programs and projects to facilitate universal access and service (OECD, 2019).

Additionally, the Colombian government has put forth four main objectives to achieve by 2022: promoting the digital transformation of society, fostering productivity in the government and business through advanced digital technology, and promoting entrepreneurship for technology-based start-ups (OECD, 2019). As can be identified, there is much movement and a strong dynamism of the Digital Economy within both regions. Europe has been able to identify crucial steps in adapting to the speed of the Digital Economy.

Latin America demonstrates impressive potential but struggles to coordinate adequate government, private sector, entrepreneurs, and other actors to catch up and foster their development. Throughout the last years, Latin America has been undergoing processes of growth and catch-up. According to the CEPAL, as part of the development of this region, it will be critical that these countries address the challenge "of articulating and consolidating their Digital Economy" (CEPAL, 2013, p.8).

### *17.2.5 Feminist Economy*

The Feminist Economy is said to have emerged after Marylin Waring's book, *If Women Counted*, which is seen as the early beginning of a new field. The creation of the International Association for Feminist Economics in 1992 and the publication of the Feminist Economics Journal in 1995 followed a few conferences in the early 1990s. Feminist Economics focuses on well-being, empowerment, and equity as centers of economic analysis. In her paper about Social Provisioning as a Starting Point for Feminist Economics, Marilyn Power describes the five main components and objectives of Feminist Economics as the incorporation of caring and unpaid labor as fundamental economic activities; the use of well-being as a measure of economic success; the analysis of economic, political, and social processes and power relations; the inclusion of ethical goals and values as an intrinsic part of the analysis; and the interrogation of differences by class, race-ethnicity, and other factors. Feminist Economics is thus not only focused on a gender-equitable way of approaching economics, but it also concerns other types of inequalities that may intersect with gender inequality. It is about understanding the process, agency, and outcomes (Berik et al., 2009).

Feminist Economics presents an excellent potential for sustainability. UN Women presents critical factors in which gender equality has to be reached to achieve sustainable development. Empowering women and closing gender pay gaps are the main aims, but other things such as the accounting of unpaid work in GDP can also be important. UN Women states that "It is estimated that if women's unpaid work were assigned a monetary value, it would constitute between 10 percent and 39 percent of GDP." In his article about Unpaid Work and the Governance of GDP Measurement, Daniele Rock explains that "since unpaid labor is disproportionately carried out by women, failing to measure it introduces a gender bias into economic data."[3] In the last decade, considerable progress on gender equality occurred across Latin American countries, including a decreased maternal mortality rate, increased enrollment in formal education, higher labor force participation rate, and increased representation in public leadership (World Bank, 2020).

Between 1990 and 2018, women's labor force participation increased by 25%, leading to a participation rate of 52% in 2018 of women aged 15 and above, compared to 77% of men (World Development Indicators). However, women still work in lower-quality jobs, and their economic opportunities are limited by less access to critical productive assets (World Bank, 2020). Women-owned firms are less profitable, primarily due to differences in education and limited access to resources, and mainly operate in less economically profitable sectors, such as trade, manufacturing, and services (IFC, 2011; Bruhn, 2009). The LAC Regional Gender Action Plan addresses critical gender issues, including the gender pay gap, teenage pregnancies, and violence against women. It suggests three main types of initiatives: (1) identifying opportunities to promote gender equality at the country level, (2) embedding gender in operations to address critical gender gaps, and (3) fostering knowledge activities and data collection on gender (World Bank, 2020).

In Europe, numbers on the gender employment gap show that the best performers are Latvia, Lithuania, and Finland, and the worst performers are Greece, Italy, and Malta (EC, 2018). In general, women in the EU earn more than 16% less on average, varying between 5.2% in Romania and 25.3% in Estonia (EC, 2018). To achieve higher gender equality, the various MSs of the EU have adopted different policies. In Germany, the Parental Allowance Plus and Partnership Bonus measures were introduced to keep women in the labor market, and support equal In Malta, free childcare for parents who work or are in education was established to encourage women to return to work. To establish transparency in wage structures, Poland released a user-friendly app. Companies with more than 250 employees are required to publish figures on pay and bonus pay gaps in the UK, and in Germany, companies with more than 200 employees need to release figures on pay levels on request. An Irish platform encourages young women to enter politics and trains female candidates and leaders to promote equality in decision-making. In Slovenia, a party list for national and local elections and the European Parliament must meet the gender quota. Otherwise, it can be rejected. Moreover, to combat gender-based violence and protect and support victims, several EU member states have launched legal measures, campaigns, and actions in 2017 (EC, 2018).

With the emergence of the feminist movement, women started striving for equality and better living conditions. In their study about Women's Activism in Latin America and the Caribbean, Maier and Lebon (2010) outline the positive changes in the region in the last 50 years.

Good initiatives that can be underlined for gender equality are arising around the globe. Gender budgeting is a strategy of collecting and allocating public resources

[3] Source: https://www.e-ir.info/2019/01/11/unpaid-work-and-the-governance-of-gdp-measurement/

to participate in gender equality. Women's average contribution to GDP in Latin America is 8% lower than the average for Eastern Europe, with respective shares of 33% and 41% (Statista).

### *17.2.6 Social Economy*

Social Economy refers to economic activities driven by values of solidarity and, according to the OECD, "driven by the primacy of people over the capital and democratic and participative governance." The social economy aims to deliver social benefits and satisfy needs through organizations that exist and operate outside (or between) both the market and the state. It develops as a permanent stream of inventions of various social mechanisms, mixing market exchange, state intervention, and collective civil sector organization based on social movements driven by solidarity and reciprocity. The primary societal issues this new economy tries to combat, according to the literature, include but are not limited to the (re)introduction of social justice into the economy, the redistribution of income and wealth within the market economy, or the satisfaction of alienated individual and collective needs (Moulaert & Ailenei, 2005). Social Economy organizations are a crucial pillar for a more sustainable world as their primary "raison d'être" is to eradicate social injustices like inequality, precarious labor conditions, poverty, and many more. Social Economic entities directly target various SDGs and can help achieve them by providing an alternative to the classic Capitalist Economy, which has caused numerous social issues worldwide (Arana Landin, 2020).

The European Economic and Social Committee (2012) reports that the EU countries where the concept of Social Economy is most accepted are Spain, France, Portugal, Belgium, Ireland, and Greece. Spain approved the first European national law on the Social Economy, and France is the birthplace of this X economy. The more recent EU members are less involved in Social Economy. Moreover, in the EU, Social Economy provides paid employment to over 14.5 million people or about 6.5% of the working population. A final important finding testifying to the importance of the Social Economy is that it grew faster than the EU population between 2002 and 2010. Among the actions taken to promote the ecosystems of the social and solidarity economy, in 2020, the OECD has launched an action that will involve all EU countries over 3 years. This action will lead to three primary outcomes: first, an international guide on legal frameworks for Social Economy; secondly, an international guide on measuring social impact for Social Economy; and finally, peer learning partnerships to create opportunities to share knowledge and experience between countries and stakeholders on various topics critical for the development of the Social Economy (OECD, 2020). One of the main challenges in the European context is the struggle against social and labor-market exclusion, according to the EC (2018). One EU institution that has been a crucial institutional body to reinforce structural changes regarding the Social Economy was the European Economic and Social Committee (CIRIEC, 2012). Generally, Social Economy reveals great potential for "activating endogenous development in rural areas" (p.89), which is especially important in the context of Latin America since social exclusion is the primary driver of bad performance in these dimensions. Critical advancements are needed not only in the level of activities but also in developing active social policies. Without an established policy framework to encourage inclusion, investments in social pillars, education, training, the creation of labor market opportunities, and improvement of living standards, concrete actions will not follow. Social Economy in Latin America suffers from fundamental problems that hinder its development: the lack of social and institutional visibility is one of the most serious. Its acknowledgment must solve the lack of institutional presence of its representative organizations by the public administration and other social agents as interlocutors within the consultative institutions on social and economic policies.

The difficulty of systematizing information on the Social Economy, which consolidates its social invisibility, hinders its development in Latin America. It is necessary to know, not just to intuit, the real impact of this economy. This absence of measurements makes it very difficult to highlight its actual social relevance and the comparative difference about other types of enterprises regarding the impact of their economic, social, and solidarity-based actions (Nilsson, 2012). Many Latin American governments are facilitating changes by modifying laws, integrating these behaviors into a new framework of economic culture, promoting their access to public resources, credit, and markets. In Argentina, for example, the "social policy of the Social Economy" has been institutionalized and targets poor sectors or employment problems and aims at their inclusion in the market. This program proposes setting up solidarity funds, promoting microcredit, and strengthening cooperatives and mutual insurance companies, associative spaces, advisory councils, and civil society organizations. As a result, over the last 10 years, the number of government bodies responsible for promoting the Social Economy has multiplied. Thus, in 7 years, 14 out of 24 provinces have created organizational units related to the Social Economy (Coraggio, 2015). Social imbalances are significant, primarily in countries like Honduras or Brazil. Institutional voids, informal economy, and the absence of social protection constitute serious problems within Latin America.

High unemployment rates, poor education quality, high inequality, high mortality rates, and human rights violations will not be solved within a proximate time frame for which social development will continue to be essentially hampered shortly. According to the European Economic and Social Committee, the presence of European states has been decreasing in Latin America, and measures towards Social Economy in that region have been shortened. One assumption in which the authors of this research primarily agree with is the consideration of the Committee that "International cooperation must not simply have the objective of transplanting a particular social model, but rather it should promote a form of development based on existing favorable conditions" (2012). Social Economy has undeniably vast potential to achieve social stability, social resilience, sustainable economic growth, and the closure of the poverty trap yet remains one of the most significant challenges to overcome for policymakers. Therefore, it is indispensable that governments address these elements to reduce social marginalities and inherently work out policies directed towards a more equal and sustainable world.

## 17.3 Data and Methodology

### *17.3.1 Data*

A large part of the indicators in the circular set is part of the environmental category and essentially represents the economic branch since the countries' economies and businesses are challenged to redesign their supply chains, processes, and product innovations. The indicators addressed people's behavior towards "sustainability" to reflect citizen awareness, engagement, and participation in the Circular Economy. Furthermore, the indicators examine the performance of states in transforming their countries towards circularity in terms of investment. Circular material use (CMU) measures "the share of material recovered and fed back into the economy" (2018). A higher CMU rate means a reduced environmental impact. "Municipal waste" is described as wasted collected and treated by or for municipalities (OECD, 2020).

The bought "remanufactured product" is the result of a survey conducted in 26,595 respondents by the EC (2014) who answered about their attitudes towards waste management and resource efficiency. The ecological footprint measures the "ecological assets that a given population requires to produce the natural resources it consumes and to absorb its waste, especially carbon emission" (Footprint Network, 2020). Finally, the last indicator is the Eco-Innovation Index. This composite index captures different aspects of eco-innovation by including 16 indicators into five dimensions: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency, and socioeconomic outcomes. The index illustrates how well individual states perform in these dimensions compared to the EU average (Table 17.1).

The Blue Economy has become the reference of an emerging X economy to understand trends and future opportunities in all activities related to our oceans and seas. Despite notable developments in measurement frameworks regarding fisheries and aquaculture, the Blue Economy is only marginally reflected in the composite index. Many of the countries analyzed do not have access to ocean waters, or there is not sufficient data available yet. The first indicator refers to temporal trends in the mean percentage of each vital site for marine biodiversity covered by designated protected areas. Secondly, the "Degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing" indicator measures progress towards the SDG Goal Target 14.6: "By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries

**Table 17.1** Circular Economy Indicators

| Name | Unit | Category | Source |
|---|---|---|---|
| Circular material use (circularity rate) | Percentage | Environment | Eurostat |
| National recycling rate | Percentage | Environment | OECD |
| Municipal waste | Per year/per capita/in kg | Environment | Politico |
| Ecological footprint | gha/per capita | Environment | Footprint Network |
| Bought a remanufactured product | Percentage of participants | People | EC Survey |
| Eco-industry revenue | Percentage of total revenue | Economy | UNU-Merit Plastics Circularity Index |
| Number of patents related to recycling and secondary raw materials | Absolute value | Economy | Eurostat |
| Eco-Innovation Index | Score | Economy | Eurostat |
| Employment in Circular Economy | Percentage of national employment | Economy | Eurostat |
| Gross investment intangible goods | Percentage of GDP | Government | Eurostat |
| Publications | Number | Publications | Web of Science |

should be an integral part of the World Trade Organization fisheries subsidies negotiation" (UN, SDG Framework). The last indicator is based on the IOC Criteria and Guidelines on Transfer of Marine Technology and refers back to the SDG Goal 14, Target 14.a. aiming to "increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular, small island developing States and least developed countries." (Table 17.2)

For Collaborative Economy, the number of online collaborative platforms available for both regions will be displayed as the interaction indicator between collaborative and Digital Economy (Table 17.3).

Measuring the Digital Economy and its spillover effects are complex since outcomes vary from intangible services to quickly changing dynamics within the sector. Therefore, one way of understanding the set of indicators chosen for the Digital Economy is a broad approach encompassing all how digital technologies impact the economy, institutions, and citizens. This approach ranges from digital skills, over digital equipment/infrastructure, to integrating digital technologies in business operations. The Diversification Index counts how many activities, out of a list of overall 12,[4] have been realized at least once in the previous months. According to

[4] EU Open Data Portal: The 12 activities included in the index are sending/receiving emails, information about goods and services, reading online newspapers/news, information on travel/accommodation services, posting messages to social media, interaction with public authorities, Internet

**Table 17.2** Blue economy indicators

| Name | Unit | Category | Source |
|---|---|---|---|
| Coverage of protected areas in relation to marine areas (exclusive economic zones) | Percentage | Environment | UN Economic Commission for Europe |
| Degree of implementation of international instruments aiming to combat illegal, unreported, and unregulated fishing | Score (Level of implementation: 1 lowest, 5 highest | Government | Food and Agriculture Organization of the UN |
| National ocean science expenditure as a share of total research and development funding | Percentage | Government | Global SDG Indicator Platform |
| Publications | Number | Publications | Web of Science |

**Table 17.3** Collaborative Economy indicators

| Name | Unit | Category | Source |
|---|---|---|---|
| Revenue of the Collaborative Economy | Percentage of GDP | Economy | EU Report[a] |
| Employment in Collaborative Economy | Percentage in National Employment | Economy | EU Report |
| Investment in Collaborative Economy | Million Euros | Government | EU Report |
| Publications | Number | Publications | Web of Science |

[a]Technopolis, Study to Monitor the Economic Development of the Collaborative Economy at sector level in the 28 EU Member States, 2018

the Digital Agenda, the Diversification Index is computed at the individual level for those individuals having used the Internet in the last 3 months.

On the other hand, the "Digital Skills" among the populations provides an indicator to what extent the population possesses sufficient digital skills within a country, ranging from 1 (no skills) to 7 (great extent). These digital skills include, for example, computer skills, basic coding, or digital reading. In terms of digital integration in education, the indicator "computers used for educational purposes," as the title indicates, gives insights into the number of students per computer at ISCED 1 Level. ISCED is the reference international classification of education programs, for which Level 1 refers to primary education, evaluating the integration of digital technologies at the early stages of education.

As will be seen in the further analysis, this figure presents significant country differences but considers comparisons among EU countries. Moreover, the results indicate that the number drops at higher ISCED levels. IMD World Digital Competitiveness Ranking measures the capacity and readiness of 63 economies "to adopt and explore digital technologies as a key driver for economic transformation

banking, telephoning or video calls, selling goods or services, purchases of content (films, music, software, etc.), purchase of goods, purchase of services.

in business, government and wider society" (IMD, 2020). The IMD Ranking establishes clear trends and a detailed reflection on the country level among criteria such as Internet bandwidth speed, the agility of companies, and upon. A detailed description of the single indicators can be retrieved from the IMD World Digital Competitiveness Ranking 2020 Report. Global eCommerce includes a wide range of multiple influencing factors such as global logistics, shopper spending, shopping demand, cross-border operations, etc. For the scope of this research, it was exciting to establish the connection between eCommerce and individuals, to evaluate the dynamics and frequency of online shopping with 147,531 respondents. Global Connectivity Index is assessed annually based on ICT investment, ICT maturity, and digital economic performance. The GCI divides 79 nations into three clusters: starters, adopters, and frontrunners (Table 17.4).

Finally, to evaluate the effectiveness in the delivery of public services, the e-Government Development Index incorporates data on dimensions that allow people to benefit from online services: "the adequacy of telecommunication infrastructure, the ability of human resources to promote and use ICTs, and the availability of online services and content" (UN, 2019). e-Government Development Index measures the "readiness and capacity of national institutions to use ICTs to deliver

**Table 17.4** Digital economy indicators

| Name | Unit | Category | Source |
|---|---|---|---|
| Diversification index for the activities realized online by Internet users | Absolute value | People | Digital Agenda EU |
| Digital skills set among populations (2019) | A score between 1 (no skills) and 7 (great extent of skills) | People | World Bank |
| Computers used for educational purposes ISCED level 1 | Number of students per computer – desktop, computers, laptops, notebooks, tablets | People | European Union Open Data Portal |
| Standard fixed broadband coverage/availability | As a percentage of households | People | Digital Agenda EU |
| Number of fixed broadband subscriptions | Number per 100 inhabitants | People | OECD |
| Individuals using the Internet | Percentage of population | People | World Bank |
| Digital Competitiveness Ranking | Score Ranking 0–100 | Economy | IMD World Digital Competitiveness Ranking |
| eCommerce: individuals ordering goods or services online | Percentage of individuals aged between 16 and 74 | Economy | Eurostat |
| Global Connectivity Index | Score Ranking 0–120 | Government | Huawei GCI 2019 |
| E-Government Development Index (EGDI) | 4 EGDI groups with 16 rating class breakdowns | Government | United Nations |
| Publications | Number | Publications | Web of Science |

public services" and is mainly directed and beneficial for policymakers, researchers, and representatives of civil society and the private sector to evaluate the status quo and derive potential actions of improvement.

The choice of indicators is made using the five critical components in the general definition of Feminist Economics. An indicator of well-being can be found in the people's category, while differences in incomes and time spent on unpaid work are found in the economic category. In the government indicators, women in parliaments and legal frameworks to enforce gender equality scores are reported, the latter being based on four categories found in the SDGs: marriage, public life, violence, and employment (Table 17.5).

Social Economy is a concept that contributes significantly to a more sustainable world in dimensions such as environmental resilience (proportion of the population with access to renewable electricity), socioeconomic development, and equality (Gini coefficient, the growth rate of real GDP per capita, government spending on essential services), employment (unemployment rate), health (under-5 mortality rate), and many more. One indicator that might not be self-explanatory within this set of indicators is the agricultural export subsidies indicator. This indicator forms part of the corresponding SDG indicators; specifically, it is included in the second SDG goal, "Zero Hunger" (Indicator 2.b.1). Respectively, this indicator attributes significant weight to preventing trade restrictions and distortions in agricultural markets (Table 17.6).

For the different interactions gathered from the literature, one indicator per X economy is utilized (Table 17.7).

These indicators are chosen concerning matching keywords and the potential of the interactions. These indicators present the potential for interaction between two X economies.

**Table 17.5** Feminist Economy indicators

| Name | Unit | Category | Source |
|---|---|---|---|
| World Happiness Report | Score on 10 | People | WHR |
| Percentage of women in managerial positions | Percentage | Economy | World Bank |
| Difference of time spent on unpaid work | Percentage difference between genders | Economy | OECD + CEPAL |
| Gender pay gap | Percentage difference between genders | Economy | UNDP |
| Percentage of seats held by women in national parliaments | Percentage | Government | SDGs |
| Legal framework score to enforce gender equality in four areas | Score on 100 | Government | SDGs |
| Publications | Number | Publications | Web of Science |

**Table 17.6** Social Economy indicators

| Name | Unit | Category | Source |
|---|---|---|---|
| The proportion of the population with access to (renewable) electricity | Percentage | Environment | UN Statistics |
| The proportion of population below the international poverty line | Percentage | People | ILO |
| Under-5 mortality rate | Number of deaths per 1000 live births | People | World Bank |
| Gini coefficient | Percentage | People | World Bank |
| The annual growth rate of real GDP per capita | Percentage | Economy | World Bank |
| The unemployment rate, by sex, age, occupation, and persons with disabilities | Percentage | Economy | World Bank |
| The proportion of total government spending on essential services, education | Percentage | Government | SDG Open Dataset |
| Agricultural export subsidies | Millions of US$ | Government | SDG Open Dataset |
| Publications | Number | Publications | Web of Science |

**Table 17.7** Interactions indicators

| Name | Unit | Category | Source |
|---|---|---|---|
| Percentage of renewable energy in total energy production (DE, CE) | Percentage | Environment | EIA |
| Hydroelectricity net generation by total electricity produced (BE, DE) | Percentage | Environment | EIA |
| Number of collaborative platforms (DE, CE) | Ratio per one million population | People | IDB publication for LA + EU report |
| Leased or rented a product instead of buying it (CE, SE) | Percentage | People | EC Survey[a] |
| Employed ICT specialists by sex (DE, FE) | Percentage | Economy | |
| Interaction publications (ALL) | Number | Publications | Web of Science |

[a]Carried out by TNS Political and Social Network in the 28 member states of the European Union on behalf of the EC, DG Environment

## *17.3.2 Methodology*

Based on the literature review and the individual study of each X Economy, a set of indicators for the potential impact measurement of each X economy was developed. The individual study of each X economy established a holistic overview of the thematic areas included and provided a first framework for deciding on potential indicators. On this basis, quantitative data research on regional and the country level was undertaken. Based on data availability, the countries that missed data on more than 30 indicators overall were excluded from the database to avoid distortions in

**Table 17.8** Countries in the X Economy Index

| Latin America | | Europe | | | |
|---|---|---|---|---|---|
| Argentina | Honduras | Austria | France | Luxembourg | Slovenia |
| Bolivia | Mexico | Belgium | Germany | Malta | Spain |
| Brazil | Panama | Bulgaria | Greece | Netherlands | Sweden |
| Chile | Paraguay | Croatia | Hungary | Norway | Switzerland |
| Colombia | Peru | Cyprus | Iceland | Poland | Ukraine |
| Costa Rica | Uruguay | Czech Republic | Ireland | Portugal | United Kingdom |
| Ecuador | Venezuela | Denmark | Italy | Romania | |
| El Salvador | | Estonia | Latvia | Serbia | |
| Guatemala | | Finland | Lithuania | Slovakia | |

the final index composition. Therefore, the analyzed and evaluated countries were reduced to the set of 16 Latin American countries and 33 countries in Europe (Table 17.8).

The supplementary file provides a detailed description of the methodological approach of calculating the X Economy Scorecard, the Category Scorecard, and the final Composite Index – the X Economy Index Scorecard.[5]

## 17.4 Findings and Analysis

### *17.4.1 Interactions Among X Economies*

Each X economy is investigated over the Web of Science. Keywords of the 500 most cited articles for each X economy are used to characterize each X economy. Subsequently, 15 additional lists are created, each one representing a keyword interaction set between two X economies. Each of these keyword lists (2000–5000 keywords) is compared to find the number of common keywords featured in both X economies (Table 17.9).

The number of keywords appearing in two X economies is compared to the total number of nonredundant keywords in X economies, revealing a percentage of keyword interactions for these two X economies.

The selection criterion for interaction analysis is primarily the most significant percentage of keywords matching the two interacting X economies, especially for Circular Economy. Several interactions were also chosen despite not yielding the highest percentage as passages for Circular Economy (e.g., Collaborative Economy and Digital Economy). For qualitative analysis, matching keywords explain the interaction between two X economies based on how often the matching keywords recurred in both X economy lists. To the recurrence criteria, we added the relevance

[5] Source: Indicator visualization, data, and methodology are accessible at The Lab » X-ECONOMIES (merit.unu.edu)

**Table 17.9** Number of matching keywords between X economies

| | Blue Economy | Circular Economy | Collaborative Economy | Digital Economy | Feminist Economy | Social Economy |
|---|---|---|---|---|---|---|
| Blue Economy | **1612** | 286 | 213 | 210 | 111 | 276 |
| Circular Economy | 286 | **2814** | 391 | 306 | 137 | 385 |
| Collaborative Economy | 213 | 391 | **2240** | 443 | 165 | 322 |
| Digital Economy | 210 | 306 | 443 | **2191** | 173 | 324 |
| Feminist Economy | 111 | 137 | 165 | 173 | **902** | 185 |
| Social Economy | 276 | 385 | 322 | 324 | 185 | **2523** |

and specificity of the keyword about X economies. In this way, five keywords are selected that would best describe the interaction between two X economies.

#### 17.4.1.1 Circular Economy x Blue Economy

The most direct interaction between these two X economies is the so-called Marine or Blue Circular Economy. It is understood as implementing a Circular Economy in ocean areas (Ding et al., 2020). It aims to balance sustainable economic benefits with long-term ocean health and shift from cleaner, recycling-based industrial production to sustainable marine development and management (Keen et al., 2018). Marine plastic pollution has been identified as a threat to marine life (Carson et al., 2011), food chains (Schröder et al., 2019), and therefore to the planetary boundary (Villarrubia-Gómez et al., 2018). Single-use plastics and insufficient recycling are the main drivers (Schröder et al., 2019). Circular Economy aims to reduce the consumption of goods and plastic waste, wherefore it qualifies as a realistic way to address marine plastic pollution (Mendenhall, 2018). The acknowledgment of marine plastic pollution as a threat and the need to tackle it with a Circular Economy approach has been mentioned more often by different governments worldwide in recent years (Schröder et al., 2019).

#### 17.4.1.2 Circular Economy x Social Economy

Conducted keyword matching analysis revealed that “climate change,” “management,” “sustainable development,” and “urbanization” areas are the most common and relevant keywords for these two X economies. The concept of sustainable urban development displays the core interaction. It addresses the increasing need for resources and urges for more sustainable approaches and resource management (Agudelo-Vera et al., 2011) and therefore includes Circular Economy into Social Economy. Rapid urbanization and increasing living standards harm the natural environment in various ways, such as altering ecosystems, changing regional climates, and destroying wildlife habitats (Grübler, 2003). Urbanization is currently based on tremendous resource consumption and waste production that go far beyond natural limits (Agudelo-Vera et al., 2011), and the Circular Economy approach does not yet play a significant role in urban development (Agudelo-Vera et al., 2011). For sustainable urban development, it is necessary to coordinate Social Economic development and ecological, environmental development (Fan et al., 2019) and integrate resource management into urban planning (Agudelo-Vera et al., 2011).

#### 17.4.1.3 Circular Economy x Collaborative Economy

Both X economies aim to reduce the consumption of goods, promote a reduction in their production, to create a sustainable future. Both X economies aim to increase the value of goods by giving them a second life or increasing the number of people benefiting from their consumption through sharing. However, Circular Economy is an economy that encompasses much more than reducing consumption/production of goods, whereas a Collaborative Economy is seen only as a means to achieve a Circular Economy (Cohen & Muñoz, 2015). Although environmental protection is generally not the primary purpose of Sharing Economy platforms, sometimes the latter can still achieve some of the Circular Economy objectives (Taranic et al., 2016). For example, people using platforms that allow for the sharing of accommodation when traveling, such as Airbnb, generate 61–89% less GHG emissions, consume 63–78% less energy, 12–48% less water, and avoid the creation of waste by 0–32% compared to people staying in hotels (Frenken, 2017).

#### 17.4.1.4 Collaborative Economy x Digital Economy

Interaction and importance between the Digital and Collaborative economies have grown in recent years (Sutherland and Jarrahi, 2018). In their paper, Chen and Wang (2019) consider the Sharing Economy built on the Digital Economy. Sharing has been around for a long time; however, the digitalization of such is a recent phenomenon. Findings by Sutherland and Jarrahi (2018) show that digital technology is a critical element of the Sharing Economy, for instance, in online platforms such as Airbnb and Uber, where people can offer their services and request a service. Some benefits that digitalization has brought to the Collaborative Economy have been generating flexibility among users, have made matchmaking between client and customers more accessible lowering transaction costs, have extended its reach in terms of population and underutilized assets, and have helped to build trust among users through the sharing of information (Sutherland and Jarrahi, 2018). In the following section, multiple manners in which these two X economies interact will be discussed.

Furthermore, the interaction between these two economies has given the Collaborative Economy a greater purpose beyond sharing underused assets, which is the power of the data created in the digital systems (Chen and Wang, 2019). Such data from sharing platforms can give access to user behavior and can be analyzed to determine how they create value for consumers and firms, which in the long run can be used to create more value for the stakeholders involved. Here, we can see how the Digital Economy boosts the value created by the Collaborative Economy and how it can assist firms that can create more value.

#### 17.4.1.5 Digital Economy x Feminist Economy

Specifically, digital entrepreneurship is a form of entrepreneurship that is aimed at underrepresented segments of the population. For instance, women are often marginalized and discriminated. Digital entrepreneurship is a way to overcome discrimination based on gender. Indeed, using the Internet helps overcome the lack of entrepreneurial resources and experience (Martinez Dy et al., 2018). Moreover, the anonymity of the Internet benefits women by preventing all kinds of gender-related restrictions in obtaining information, disseminating knowledge, inserting one's content, and expressing one's own opinions (Sorgner et al., 2017). Such activity appears to offer an equalizing, even emancipatory, route to socioeconomic integration.

Furthermore, distance education offers new educational opportunities, regardless of gender. Another area that enables women to better integrate into the economic world is online banking, which provides new and easy ways to transfer money and access loans. For example, Suri and Jack (2016) discussed the effects of using the M-PESA mobile banking service in Kenya. The results of their study show that women benefited more from the positive effects of this service (e.g., loan opportunities, exit from agriculture to the service sector, savings) than men. Finally, communication via the Internet helps women gain greater self-confidence and strength and learn new role models (Sorgner et al., 2017).

### *17.4.2 Overall Score*

Top performing countries are found in the geographical scope of Europe, with the best performers being Germany, the UK, the Netherlands, as well as the Northern European countries scoring exceptionally high in Social and Digital Economies.

#### 17.4.2.1 Results

Most Latin American countries occupy the bottom of the scorecard, with Uruguay performing exceptionally well. It should be remembered that the greenest scores close to "10" in the different pillars of the index do not indicate impeccable performance but rather accentuate an exceptional status quo and potential in this respect relative to other countries (Tables 17.10 and 17.11 and Fig. 17.1).

**Table 17.10** Percentage of matching keywords between X economies

| | Blue Economy | Circular Economy | Collaborative Economy | Digital Economy | Feminist Economy | Social Economy |
|---|---|---|---|---|---|---|
| Blue Economy | | **6,46%** | 5,53% | 5,52% | 4,42% | 6,67% |
| Circular Economy | **6,46%** | | **7,74%** | 6,11% | 3,69% | **7,21%** |
| Collaborative Economy | 5,53% | **7,74%** | | **10,00%** | 5,25% | 6,76% |
| Digital Economy | 5,52% | 6,11% | **10,00%** | | **5,59%** | 6,87% |
| Feminist Economy | 4,42% | 3,69% | 5,25% | **5,59%** | | 5,40% |
| Social Economy | 6,67% | **7,21%** | 6,76% | 6,87% | 5,40% | |

#### 17.4.2.2 External Validity

In order to assess the external validity of the final composite index, the introduced indicator is compared to recognized benchmark indices such as the Environmental Performance Index (EPI), the Sustainable Development Index (SDI), the Social Progress Index (SPI), the Sustainable Governance Index (SGI), and, finally, the Global Green Economy Index (GGEI) by running a Pearson correlation analysis. The EPI is a collaborative project of the Yale Center for Environmental Law and Policy and The Center for International Earth Science Information Network (CIESIN) at Columbia University's Earth Institute.[6] The EPI is produced in collaboration with the World Economic Forum. The United Nations created the SDGI to update the Human Development Index to monitor the development of the Sustainable Development Goals.[7] The SPI has been introduced by the nonprofit Social Progress Imperative and measures the well-being of society.[8] The SGI is a set of indicators that the Bertelsmann Stiftung has developed,[9] and finally, the GGEI, which Dual Citizen LLC publishes, a private U.S.-based consultancy, is the most widely recognized indicator in this dimension internationally.[10] The introduced X Economic Index correlates at a 1% significance level with these listed benchmark indices in this chapter (Table 17.12).

[6] Environmental Performance Index: EPI Team | Environmental Performance Index (yale.edu)

[7] Sustainable Development Goals Index Sustainable Development Report - Sustainable Development Report (sdgindex.org)

[8] Social Progress Index: Social Progress Imperative

[9] Sustainable Governance Index: Sustainable Governance Indicators (SGI) (bertelsmann-stiftung.de)

[10] Global Green Economy Index: Global Green Economy Index (dualcitizeninc.com)

**Table 17.11** X Economy Index (XEI) in Europe and Latin America

| | Blue | Circular | Collaborative | Digital | Feminist | Social | Interactions |
|---|---|---|---|---|---|---|---|
| **LA Average** | 4,68 | 4,84 | 4,91 | 2,71 | 4,13 | 4,20 | 4,74 |
| **Argentina** | 3,60 | 3,75 | 3,95 | 3,55 | 6,04 | 4,80 | 3,85 |
| **Bolivia** | 2,40 | 3,76 | 3,95 | 1,15 | 5,27 | 3,81 | 3,85 |
| **Brazil** | 5,52 | 4,29 | 5,71 | 2,83 | 4,16 | 3,67 | 5,46 |
| **Chile** | 4,56 | 3,43 | 4,39 | 4,31 | 3,08 | 5,21 | 4,25 |
| **Colombia** | 4,10 | 5,27 | 4,39 | 2,64 | 3,95 | 3,90 | 5,13 |
| **Costa Rica** | 2,57 | 3,87 | 3,95 | 4,48 | 4,83 | 4,49 | 5,66 |
| **Ecuador** | 5,55 | 7,17 | 4,39 | 2,29 | 5,78 | 4,23 | 4,85 |
| **El Salvador** | 3,46 | 6,70 | 3,95 | 1,09 | 5,24 | 4,88 | 4,58 |
| **Guatemala** | 3,83 | 6,93 | 3,95 | 1,23 | 2,16 | 4,41 | 4,37 |
| **Honduras** | 3,58 | 7,27 | 3,95 | 1,58 | 4,91 | 3,43 | 4,26 |
| **Mexico** | 4,76 | 4,57 | 4,83 | 3,20 | 4,35 | 5,01 | 3,61 |
| **Panama** | 2,72 | 6,48 | 3,95 | 2,28 | 5,36 | 4,46 | 5,27 |
| **Paraguay** | 2,54 | 5,79 | 3,95 | 1,74 | 3,89 | 4,53 | 5,61 |
| **Peru** | 3,68 | 4,97 | 4,17 | 2,14 | 4,11 | 4,50 | 4,57 |
| **Uruguay** | 4,18 | 6,93 | 3,95 | 4,75 | 4,29 | 4,52 | 5,62 |
| **Venezuela** | 3,20 | 6,25 | 3,95 | 1,47 | 2,69 | 3,87 | 4,60 |
| *EU average* | 6,07 | 5,62 | 5,45 | 5,93 | 5,32 | 5,14 | 5,01 |
| *Austria* | 4,55 | 4,88 | 4,10 | 6,28 | 5,08 | 5,68 | 5,77 |
| *Belgium* | 5,65 | 5,04 | 3,92 | 6,28 | 5,98 | 5,47 | 5,20 |
| *Bulgaria* | 4,66 | 4,76 | 3,77 | 3,66 | 4,67 | 5,01 | 3,99 |
| *Croatia* | 5,65 | 3,79 | 4,55 | 3,96 | 3,88 | 5,01 | 4,93 |
| *Cyprus* | 4,39 | 3,98 | 4,23 | 5,02 | 2,60 | 4,81 | 3,75 |
| *Czech Republic* | 4,55 | 5,42 | 5,43 | 5,31 | 3,93 | 3,59 | 3,77 |
| *Denmark* | 6,13 | 3,85 | 4,01 | 7,58 | 6,74 | 5,80 | 5,39 |
| *Estonia* | 4,91 | 3,66 | 7,27 | 6,19 | 4,90 | 5,98 | 5,65 |
| *Finland* | 4,79 | 4,35 | 4,06 | 6,98 | 6,42 | 5,30 | 5,27 |
| *France* | 6,98 | 5,68 | 5,71 | 6,64 | 5,93 | 4,97 | 4,77 |
| *Germany* | 7,01 | 6,27 | 5,78 | 7,07 | 5,99 | 5,77 | 5,44 |
| *Greece* | 5,68 | 3,79 | 5,19 | 4,41 | 3,03 | 3,99 | 3,95 |
| *Hungary* | 4,70 | 4,83 | 3,94 | 4,27 | 4,28 | 5,72 | 3,26 |

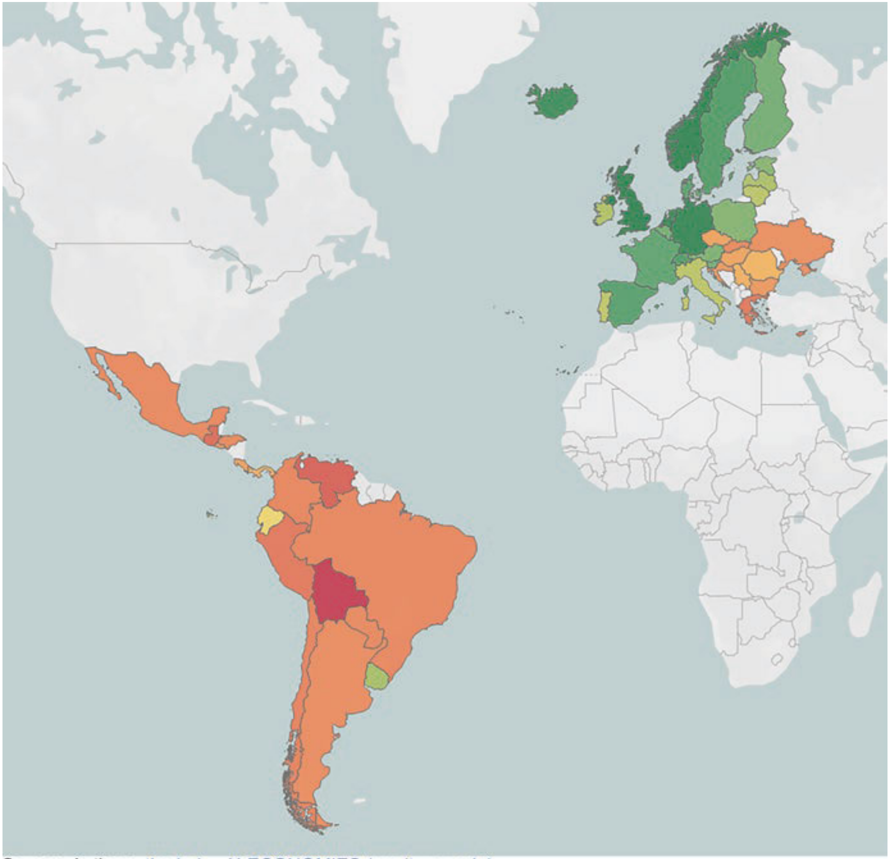
## 17.5 Results and Implications

The proliferation of X economies responds to specific challenges of the dominant political-economic system of the twenty-first century. As we reach planetary boundaries, the global community struggles with achieving progress, e.g., measured in terms of Sustainable Development Goals. While X economies are very diverse economy visions aiming at different transitions, they still share a similar goal: building a pathway towards a more reliable, resilient, and sustainable system and society.

**Table 17.11** (continued)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Iceland* | 4,28 | 5,90 | 3,95 | 7,10 | 6,96 | 6,38 | 5,05 |
| *Ireland* | 5,26 | 4,34 | 3,84 | 6,01 | 4,98 | 6,01 | 4,42 |
| *Italy* | 6,78 | 5,76 | 4,97 | 4,89 | 4,19 | 4,38 | 5,38 |
| *Latvia* | 4,82 | 4,28 | 7,20 | 4,82 | 5,60 | 5,23 | 5,42 |
| *Lithuania* | 5,11 | 4,43 | 3,94 | 5,01 | 5,35 | 5,44 | 5,43 |
| *Luxembourg* | 4,55 | 5,35 | 6,22 | 6,46 | 4,92 | 5,03 | 6,17 |
| *Malta* | 4,60 | 2,86 | 4,67 | 5,37 | 3,41 | 4,08 | 4,05 |
| *Netherlands* | 6,66 | 6,09 | 4,70 | 7,54 | 5,96 | 6,05 | 5,29 |
| *Norway* | 5,96 | 4,42 | 3,95 | 7,43 | 7,59 | 6,14 | 6,50 |
| *Poland* | 5,38 | 5,96 | 7,38 | 4,69 | 5,45 | 6,15 | 3,95 |
| *Portugal* | 6,12 | 4,80 | 4,74 | 5,25 | 4,97 | 5,19 | 4,70 |
| *Romania* | 5,21 | 5,06 | 4,23 | 4,07 | 3,73 | 4,95 | 5,10 |
| *Serbia* | 2,40 | 5,77 | 3,95 | 3,62 | 4,30 | 6,02 | 3,77 |
| *Slovakia* | 5,15 | 4,16 | 4,41 | 4,35 | 4,20 | 4,05 | 4,09 |
| *Slovenia* | 5,91 | 6,31 | 3,72 | 5,42 | 6,18 | 5,87 | 4,06 |
| *Spain* | 5,78 | 5,75 | 6,97 | 5,91 | 6,30 | 4,70 | 5,93 |
| *Sweden* | 6,04 | 4,78 | 5,42 | 7,61 | 5,14 | 5,78 | 5,74 |
| *Switzerland* | 4,52 | 5,62 | 4,83 | 8,01 | 5,99 | 4,71 | 5,60 |
| *Ukraine* | 2,66 | 5,86 | 3,95 | 3,65 | 3,72 | 4,92 | 3,44 |
| *United Kingdom* | 8,26 | 6,04 | 6,49 | 7,58 | 6,11 | 4,84 | 5,85 |
| RELATIVE WEIGHT | 5 | 20 | 5 | 19 | 14 | 20 | 17 |

This chapter thus presents an overview of six X economies and their emerging interactions in Europe and Latin America. Entrepreneurs and governments, and policymakers can use the results to identify economic, ecological, and social sustainability challenges and possible solution designs. The results apply universities to introduce beyond disciplinary, team science efforts to capture multifaceted needs for next-generation scientific knowledge creation and use. The implications are particularly of interest for governments and policymakers as they point out the need for developing comprehensive policy intelligence for governance of X economies and their interactions with citizen engagement. These indicators offer use for authorities in Latin America and Europe to determine their current standing concerning various X economies and analyze how they can improve with a view on their interactions. Policy intelligence about X economies, their interactions, and how to improve their performance requires designing, developing and implementing new data sources, indicators, policy mixes, and engagement and evaluation methods necessary to capture interactions among X economies for system transitions and societal transformations.



Source: Authors, the Lab » X-ECONOMIES (merit.unu.edu)

**Fig. 17.1** X Economy Index (XEI) in Europe and Latin America (Overall). (Source: Authors, the Lab » X-ECONOMIES (merit.unu.edu))

**Table 17.12** XEI external validity

| | EPI | SDGI | SPI | SGI | GGEI |
|---|---|---|---|---|---|
| Correlation[a] | 0.76 | 0.72 | 0.76 | 0.81 | 0.61 |

[a]At 1% significance level

## 17.6 Concluding Remarks and Future Research Directions

Due to significant potential of X economies to contribute towards a more sustainable world, governments in Europe and Latin America are called for embracing the opportunities offered by these economy visions, practices, and interactions. For these significant world regions to support creating and implementing these new visions to ensure sustainable growth opportunities, governments need to ensure the required legal and financial frameworks and conditions, underlying data requirements, scientific knowledge production, and use beyond disciplines via team science. While Circular Economy and Digital Economy have been widely encouraged through efforts in including these new visions and indicators in the countries' agendas, especially at the European level, other X Economies, e.g., Feminist, Collaborative, Blue, and Social Economy, are still relatively emergent, and existing data far from elaborate. In terms of the system transitions and change literature, transformative social and economic innovations prove successful and aligned with niche innovations and landscape conditions. One example is the framework of the SDGs if supportive institutions are in place and if the transition process takes political, economic, social, technological, ecological dimensions and actors into a severe account, all of which need to be accompanied by factual data and policy actions to be monitored and evaluated.

Some of the X economies are still niche (system) innovations yet undeniably growing, gaining important centralities in emerging policy discourses and markets via entrepreneurs while expanding geographically. At the same time, X economies yet often raise issues about existing legal and regulatory frameworks and blurred the lines of institutional efforts or applied policies. There is a high potential for countries to capture fast-growing markets and engage in sustainable visions of growth, undoubtedly needed, especially in Latin America, where levels of poverty, ecological degradation, and socioeconomic instability are relatively high.

Recommendations for countries to address low performance scores in the distinctive categories require a detailed individual assessment of performance to address societal, environmental, and economic challenges within each country setting; thus, it is also a political challenge. However, X economies are still in their emergence stages. Their development will depend on governments' public policies and many actors, including private sector financiers, incumbents, start-ups in goods and services development and trade, and behavioral and consumption patterns of a local and global society. Thus, transnational cooperation in finance, goods and services development, and trade could be one set of policy domains and recommendations to encourage policymakers to work collaboratively on designing, implementing, monitoring, and evaluating sustainable strategies for system change and societal transformations. In order to lead the path towards a more sustainable world, a multifaceted policy intelligence approach is needed to ensure sustainable growth coupled with socioecological progress for a more resilient world than the current instance.

## Appendix 1: Interactions Keywords Matching Example

= Number of articles addressing the Collaborative and Digital Economies, per keyword and per country

| | Collaborative Economy x Digital Economy | | | | |
|---|---|---|---|---|---|
| Country | Keyword | | | | |
| | Peer to peer | e-Commerce | Innovation | Platform | Access |
| **Europe** | | | | | |
| Austria | | 2 | 13 | 3 | 2 |
| Belgium | | 2 | 3 | 7 | 3 |
| Bulgaria | | | | 1 | 1 |
| Croatia | 2 | 3 | 5 | 3 | 3 |
| Republic of Cyprus | | 1 | | 1 | 2 |
| Czech Republic | | 2 | 5 | 2 | |
| Denmark | 1 | | 4 | 5 | 3 |
| England | 8 | 4 | 44 | 32 | 22 |
| Estonia | 3 | | | 1 | |
| Finland | 1 | 2 | 11 | 8 | 1 |
| France | 2 | 5 | 10 | 11 | 3 |
| Germany | 2 | 3 | 15 | 17 | 3 |
| Greece | 1 | 1 | 3 | 3 | 4 |
| Hungary | | | 1 | 2 | |
| Iceland | | | | | |
| Ireland | | 1 | 2 | 4 | 2 |
| Italy | 1 | 4 | 17 | 15 | 2 |
| Latvia | 1 | 1 | 3 | 2 | 1 |
| Lithuania | 1 | | | 1 | 1 |
| Luxembourg | | | 2 | | |
| Malta | | | | | |
| Monaco | | | | | |
| Netherlands | 4 | 2 | 7 | 8 | 3 |
| North Ireland | | | | | |
| Norway | 3 | | 1 | 4 | |
| Poland | 1 | 3 | 14 | 4 | 1 |
| Portugal | 1 | 1 | 7 | 7 | 3 |
| Romania | | 6 | 17 | 10 | 15 |
| Scotland | | 1 | 4 | 1 | 3 |
| Slovakia | | 1 | 8 | 6 | 2 |
| Slovenia | | | 5 | 1 | 1 |
| Spain | 11 | 4 | 32 | 41 | 18 |
| Sweden | 5 | 2 | 4 | 8 | 3 |
| Switzerland | 1 | 1 | 6 | 8 | 4 |
| Wales | | | 2 | 2 | 2 |
| **Latin America** | | | | | |
| Argentina | | | 1 | | |
| Bolivia | | | | | |
| Brazil | | 2 | 5 | 3 | 1 |
| Chile | | | | | |
| Colombia | | 1 | 1 | 1 | 2 |

| | Collaborative Economy x Digital Economy | | | | |
|---|---|---|---|---|---|
| Country | Keyword | | | | |
| | Peer to peer | e-Commerce | Innovation | Platform | Access |
| Costa Rica | | | | | |
| Cuba | | | | | |
| Dominican Republic | | | | | |
| Ecuador | | | 2 | | |
| El Salvador | | | | | |
| Guatemala | | | | | |
| Guyana | | | | | |
| Haiti | | | | | |
| Honduras | | | | | |
| Martinique | | | | | |
| Mexico | 1 | 1 | 4 | 1 | 2 |
| Nicaragua | | | | | |
| Panama | | | | | |
| Paraguay | | | | | |
| Peru | | | 1 | | |
| Suriname | | | | | |
| Uruguay | | | | | |
| Venezuela | | | | | |

## Appendix 2: Index Methodology

| Steps | Calculation | Explanation |
|---|---|---|
| 1. Data gathering | Adding sorted data per country into Excel | |
| 2. Create descriptive statistics | Average<br>Standard deviation<br>Standard deviation*3<br>High = Average + Standard deviation*3<br>Low = average – standard Deviation*3<br>3rd Quartile<br>1st Quartile | In order to get a better understanding and prepare the data for further analysis, descriptive methods were applied |
| 3. Normalize data by calculating the *Z*-score | Calculate the *Z*-score: (observation – average) / standard deviation. Then calculate the final score by dividing the value by 4, adding 0.5, and multiplying by 10.<br>= ((*Z*-score/4) + 0.5) * 10 | By calculating the *Z*-score, the data values get normalized to enable further comparability. By multiplying the resulting number by ten, the range is expanded, which allows the scorecard to have values between 1 and 10 |
| 4. Restrict data | Establish a maximum *Z*-score of 2 and a minimum *Z*-score of −2<br>Adjust outliers | In order to restrict the range of the values between 0 and 10, the maximum and minimum *Z*-scores must be established to deal with outliers |
| 5. Invert scores if necessary | Subtract the value calculated in the previous steps of 10 when necessary | As for some indicators, high values are negative; this needs to be reflected in the score. We established the indicators for which this was the case and inverted their score |
| 6. Apply the allocated weighting | Apply the corresponding weighting/ sub-weighting from the economy and categories | The scored results of each indicator are grouped into subcategories (environment, people, economy, government). Afterward, the weight of each subcategory is taken, which gives every country a score in the respective subcategory |
| 7. Calculate final score | Apply the economy weighting and the category weighting to each country | The weighting of the individual scores of each subcategory results in the final overall score for each country<br>We take an individually allocated weight of each sub-indicator (previously defined and displayed in the following table) |
| 8. Determine external validity | 1. Calculate the Pearson correlation coefficient in Excel<br>2. Use it to calculate the t statistic (based on the number of pairs in the test)<br>3. Use the TDIST function to calculate the p-value based on the degrees of freedom and the t statistic | By correlating our scorecard with established indicators, we can check for external validity. The correlation is calculated at 1% significance |

## Appendix 3: Weighting

| | | | Indicator | Sub Weight | Total weight |
|---|---|---|---|---|---|
| Blue | Environment | Coverage of protected areas in relation to marine areas (Exclusive Economic Zones) (%) | 1 | 1 | 5 |
| | Government | Degree of implementation of international instruments aiming to combat illegal, unreported and unregulated | 1 | 2 | |
| | | National ocean science expenditure as a share of total research and development funding (%) | 1 | | |
| | Publications | Number of Publications written - Web Of Science | 2 | 2 | |
| Circular | Environment | Circular material use (Circularity rate) | 1 | 12 | 20 |
| | | National recycling rate | 5 | | |
| | | Municipal Waste per year per capita in kg(EU 2018) | 1 | | |
| | | Ecological Footprint per person gha | 5 | | |
| | People | Bought a remanufactured product | 1 | 1 | |
| | Economy | Eco-industry revenue, in % of total revenue | 1 | 4 | |
| | | Number of patents related to recycling and secondary raw materials (2015) | 1 | | |
| | | Eco Innovation Index (2019) | 1 | | |
| | | % of circular jobs in employment of total employment (2017) | 1 | | |
| | Government | Gross investment in tangible goods (percentage of gross domestic product) related to circular economy | 1 | 1 | |
| | Publications | Number of Publications written - Web Of Science | 2 | 2 | |
| Collaborative | Economy | Revenue collaborative (share of GDP) | 1 | 2 | 5 |
| | | % of collaborative economy jobs in national employment | 1 | | |
| | Government | Investment in collaboarative platforms | 1 | 1 | |
| | Publications | Number of Publications written - Web Of Science | 2 | 2 | |
| Digital | People | Diversification index for the activities realised online by internet users (Data Year 2014) | 1 | 9 | 19 |
| | | Digital skills set among populations (2019) | 2 | | |
| | | Computers used for educational purposes ISCED level 1 (Number of students per computer - desktop, comput | 1 | | |
| | | Standard fixed broadband coverage/availability (as a % of households) 2019 | 1 | | |
| | | Number of fixed Broadband subscriptions per 100 inhabitants(LA: 2018 Europe: 2019) | 2 | | |
| | | Individuals using the Internet (% of population) (2017/2018/2019) | 2 | | |
| | Economy | Digital Competitiveness ranking score 2020 | 3 | 4 | |
| | | eCommerce: Individuals ordering goods or services online (% of individuals aged 16-74) 2019 | 1 | | |
| | Government | Global Connectivity Index (Score 2019) | 2 | 4 | |
| | | E-Government - Development Index (EGDI) Rating Classes given in Details | 2 | | |
| | Publications | Number of Publications written - Web Of Science | 2 | 2 | |
| Feminist | People | World Happiness Report | 2 | 2 | 14 |
| | Economy | Access to power : % women in managerial positions | 2 | 6 | |
| | | Difference of time spent on unpaid work (% of difference between men and women) | 2 | | |
| | | Gender pay gap (% difference of average income between men and women) | 2 | | |
| | Government | Legal Framework to enforce gender equality in 4 areas (Marriage, Public Life, Violence, Employment) | 2 | 4 | |
| | | % of seats held by women in national parliaments | 2 | | |
| | Publications | Number of Publications written - Web Of Science | 2 | 2 | |
| Social | Environment | Proportion of population with access to (renewable) electricity | 2 | 2 | 20 |
| | People | Proportion of population below international poverty line | 3 | 7 | |
| | | Under-5 mortality rate | 2 | | |
| | | Gini Coefficient | 2 | | |
| | Economy | Annual growth rate of real GDP per capita | 2 | 5 | |
| | | Unemployment rate, by sex, age, occupation and persons with disabiities | 3 | | |
| | Government | Proportion of total government spending on essential services, education (%) | 3 | 4 | |
| | | Agricultural export subsidies | 1 | | |
| | Publications | Number of Publications written - Web Of Science | 2 | 2 | |
| Interactions | Environment | Social x Circular Percentage of renewable energy in total energy production | 3 | 5 | 17 |
| | | Blue x Circular Hydroelectricity net generation by total electricity produced | 2 | | |
| | People | Digital x Collaborative Number of collaborative platforms (per 1 million population) | 5 | 6 | |
| | | Circular x Collaborative Leased or rented a product instead of buying it | 1 | | |
| | Economy | Feminist x Digital - Employed ICT specialists by sex | 1 | 1 | |
| | Publications | Social x Circular - Number of Publications by Key Words Matching | 1 | 5 | |
| | | Blue x Circular - Number of Publications by Key Words Matching | 1 | | |
| | | Digital x Collaborative - Number of Publications by Key Words Matching | 1 | | |
| | | Circular x Collaborative - Number of Publications by Key Words Matching | 1 | | |
| | | Feminist x Digital - Number of Publications by Key Words Matching | 1 | | |

## Appendix 4

We acknowledge that further research is needed to capture the relation between X economies across the globe. This chapter can, thus, serve as a framework for future research. The limitations encountered can be divided into five major categories: (1) the set of X economies, and the countries scrutinized, (2) the choice of indicators used to measure the development of X economies, (3) the availability of measurable data necessary to evaluate X economies, (4) the dimensions chosen to categorize indicators, and (5) the weighting decided for each indicator set, category, and X economy. It could be argued that the analysis of six X economies and their interactions is insufficient to illustrate the complexity of the emerging X economies and their contribution to a more sustainable and resilient economy. While the most material topics to capture the landscape of X economies, there are still many dimensions and interconnections that could be included in subsequent research, such as the impact of Green Economy or Youth Economy. These limitations call for further research on the interactions and impact of the emerging new economies. Our framework could be optimized by adding more relevant economies for more countries to get a complete overview of X economies around the globe.

Furthermore, as data availability increases, the categorization and the weighting of each indicator can be modified. One possibility to better justify the weighting and categorization would be to formally test the empirical impact of the indicators on specific societal issues in different categories. By doing so, it would be possible to validate the importance of each indicator and set the weighting accordingly. While this framework can be the starting point for further research on all new economies in all countries globally, our index also offers vast opportunities for more specific investigations. X Economy Index could, for example, be used to establish the relations between a new economy and a specific sustainability issue, hence giving implications for policymakers and businesses.

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# Chapter 18
# Globalization and Circular Economy

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## 18.1 Why Globalization?

The process of globalization has been the consolidation of a long historical process and different phases throughout its development and capitalism. Therefore, we can say that globalization is not a term or a new process but rather the rhythm with the which has defined the integration of economies, markets, and regions; this has allowed the flow of goods and services, capital, people, and information, which has been characterized by the creation of a world market that has no borders. Likewise, it can be said that it is "… the unit of centrifugal and centripetal forces, which in their actions deepen the interdependence links between economies and countries, without the disappearance of inequalities on a global scale, nor the particularities of each nation" (Romero & Vera-Colina, 2013, p. 250).

In addition, globalization can be called a multidimensional phenomenon because it arises from the behavior of seven dimensions under which its analysis is possible: economic (commercial and financial), political, social, cultural, military and safety, and environmental. All these dimensions are closely linked by their different actors, generating an interdependence due to their interconnection (Ahcar, 2006), which leads us to consider the concept defined by Keohane and Nye (2000). Then, globalization is the phenomenon of increasing multiple networks of interdependence between regions of the world, in its various dimensions, considering the reduction of transport costs and the communications and the processes of liberalization and opening of the markets.

Despite the interdependence networks generated globalization itself, it does not develop; naturally, it is the consequence of a series of commitments between the

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different actors of the state and the multi- and global business system that allow the development of a two-way network of interrelationships between dimensions that include all countries (Chavagneux, 2004; Ahcar, 2006). Under this interdependence, different effects such as the butterfly and the domino caused different positive or negative movements in the various dimensions of the globalized world.

The interdependence between the different actors, economies, and markets is caused, according to Levitt (1983), by technology considered an essential aspect of the advance of globalization. It means a new commercial reality and the ability to incorporate the economy of those countries that one day did not belong to the world economy (Soviet Union, China, and others), thus expanding globalizing capitalism. According to the World Trade Organization [WTO] (2013), technology is not the only integrating factor that determines the globalization process but the political forces that helped control and cushion integrationist pressures.

The impact of globalization cannot be evaluated for a year or a decade, and if we consider interdependence as a characteristic of globalization, we could say that our analysis should have existed before the Greek civilization. During the Neolithic period (10,000 B.C. to 7,000 B.C.), agriculture and pastoralism became very important and trading communities lived at great distances. During the third and fourth millennium BC, the Mesopotamian civilization did not have many natural resources; therefore, the people who lived there needed to trade (metals, wood, building stone, grains, textiles, precious metals, and others) with the neighboring countries to acquire the resources they needed to live (Huwart & Verdier, 2013). This trade interdependence grew worldwide due to the metropolises and their colonies, but the great powers defended their commercial sectors by applying protectionist measures (mercantilism).

The civilizations of the Mediterranean took advantage of their geographical location to trade their surpluses with other peoples, and it was the Phoenicians who stood out for initiating the first studies of nautical and cartography, which allowed them to create commercial maritime routes. While in the Middle East, trade was considered a way of life, as it was the exchange of culture through the transmission of customs and knowledge (Chanda, 2007).

From the Neolithic period until the Second World War, it was assumed that the power of a state depended on its reserves of precious metals, and international trade was the means to obtain the necessary resources for subsistence and wealth. However, globalization can also be delimited since the Industrial Revolution (eighteenth century) as a first stage where the colonial system is consolidated, which allowed new markets and technological development to begin in the energy, textile, metallurgical, and transportation sectors accompanied by changes in agriculture, demographics, and the advance of international trade. A second stage started at the end of the nineteenth century with the gold standard, bilateral agreements, the new multilateral economic institutions that fostered the development of national economic and social policies. Likewise, it was accompanied by new industries, innovations, and processes such as the chemical, steel and food industries such as refrigerators, the use of oil as fuel, electricity for lighting cities, and the transmission of electromagnetic and acoustic signals (WTO, 2013). The nineteenth century marked a new world economic scenario defined not only by the regions which were defined and separated not only by geographical lines but, more importantly, by social, political, and cultural lines that gave each of them the minus a minimum of coherence and unity while distinguishing between them (O'Rourke & Findlay, 2007).

During globalization and its different stages, it was not always accompanied by a constant expansion; not all were considered positive effects because each economy was subject to its policies and global policies and the events that generated economic instability international. We can mention how the First World War generated various imbalances at the international level (fall of the gold standard and economic barriers, among others) that generated economic instability and deglobalization. Also, it caused the absence of leadership and a viable recovery plan that would restore stability at the international level (Kindleberger, 1973), resulting in significant economic and political insecurity that allowed the Second World War to occur. There was deglobalization during the interwar period, followed by re-globalization after 1945. Technology continued to advance, having essential contributions in the transport and communications sectors. The Bretton Woods system, the opening of China to the world in 1979, and the end of the cold war in 1989 were factors that determined the recovery.

According to Mulder & Albaladejo (2021), the third phase of globalization began at the end of the twentieth century. This new phase is characterized by the generalization of free trade, transnational companies (integrated production systems), the expansion and mobility of capital, and a notable trend toward the homogenization of development models and restrictions on the movement of manpower. In the twenty-first century, globalization led companies to make decisions and generate strategies such as defining their objective as a global company, producing for the local market and starting in the global market, decentralization, the market, product strategies, and another great challenge companies.

In the same way, companies being part of the integration of economies are favored by the lower tariff barriers, the mobilization of production in search of lower costs, technological and telecommunications developments, the importance of risk management and development, and the recognition of intellectual property. The traditional economy ceased to have an economic logic due to the advances in information and communication technologies. It led companies to begin to consider intangible values such as knowledge, information, innovation, intelligence, and talent applied to the creation, production, value of merchandise, and distribution of products (goods or services) that all involve the use of new technologies (Márquez de la Rubia, 2017).

Globalization is considered a phenomenon governed by the actions and relationships of human beings. At present, it is not developing fully due to the socioeconomic imbalances that arise from decisions in politics, consumption, and production of the different actors, who could be increasing inequalities (Ahcar, 2006). The phenomenon of globalization does not guarantee equality, justice, environmental preservation, prosperity, and security. It has generated protests and demonstrations from different groups (environmentalists, environmentalists, defenders of protectionist labor and social systems, the primary sector of developed countries, and others) who seek that interdependence continues but under a new modality in which a new one has developed an environmentally friendly and peaceful way of life (Márquez de la Rubia, 2017).

Today there are different positions concerning globalization, and new concepts have given rise to new trends and research. Globalization has allowed new currents to develop in search of different globalization based on sustainable and equitable socioeconomic growth. Environmental care is one of the factors of most significant concern due to the emission of greenhouse gases increasing and how toxic waste is eliminated. New models are developed in search of efficient management in industries, companies, and consumers to apply recycling and waste reduction. One of these models is the so-called circular economy, where the economy, society, and environment are integrated.

## 18.2 The Circular Economy in a Globalized World

It has been investigating, analyzing, applying, and looking for a development with a more responsible strategic vision with the environment for a few decades. Globalization has allowed production, trade, and financial processes to increase their volumes of transactions through advances in transportation and communications, thus generating an interdependence between economies. They have also developed business models that have substantially impacted ecosystems, thus harming the world's economic, social, and ecological development. Due to the effects of globalization, the linear economic model of taking resources from the environment (producing, consuming or using, and eliminating) has been recognized as unsustainable due to its creation of waste and even less so if it is desired to direct economies toward social global economic development.

Today we live and just to mention some of the problems generated through globalization are environmental (loss of diversity, water, air, and soil pollution), resource depletion (excessive use of land), economic challenges (informality and market deficiencies), and from the social point of view (unemployment, working conditions, and inequalities), which leads to the non-sustainability of companies and economies (Geissdoerfer et al., 2017). Therefore, this leads us to think about creating awareness in the state, companies, and people that change is required through globalized actions that allow policies, laws, actions, and strategies to integrate global sustainability.

The circular economy is a model searching sustainability through planning, responsible, innovative, and ecological processes. Also, it includes the reuse of materials generating less waste and recycling and sustainable distribution.

None of these processes will be viable if the global population is unaware of the damage we are doing to ourselves and change is not generated in search of sustainability. For this reason, new models are necessary to improve the satisfaction of consumer needs and their new trends after experiencing the coronavirus pandemic but always with one orientation: economic-social growth.

It is so during October 2016, at the Habitat III conference, which took place after 20 years, that countries around the world approved the historic New Urban Agenda that sets a new global standard for sustainable urban development and guides global efforts to achieve Sustainable Development Goals in the era of climate change. At the beginning of February 2018, national and municipal leaders met again at the ninth session of the World Urban Forum (WUF9) in Kuala Lumpur, Malaysia, to continue with more in-depth discussions on Cities 2030 Cities for all: Implement the New Urban Agenda.

## 18.3 How Did the Circular Economy Originate?

The circular economy represents the most recent attempt to conceptualize economic activity and environmental well-being sustainably Murray et al. (2017). Like globalization, the circular economy is not a new concept and has different scopes in the various concepts developed by the authors. However, it can be said that there is a consensus that the concept has been important since the 1970s (Wautelet, 2018; Korhonen et al., 2017; Geissdoerfer et al., 2017). They also agree that Boulding (1966) creates an awareness of an open economy in contrast to a closed economy and describes the earth as a closed circle, inferring that the economy and the environment must coexist in equilibrium. Likewise, it is affirmed that the concept was originally a Chinese concept (Murray et al., 2017; Yuan et al., 2008) that arises from the paradigm of industrial ecology that models industrial processes using the flow of material and energy through them. It can also be said that despite different concepts related to the circular economy, they all have in common the concept of a closed-loop cyclical system and based on ecological aspects, environmental economics, and industrial ecology.

Some authors focus their analysis on the relationship between circular economy and sustainability, as Korhonen et al. (2017) do, where they consider the concept of circular economy from the bias of sustainable development, considering three dimensions, the economic, environmental and social:

> The circular economy is constructed from societal production-consumption systems that maximize the service produced from the linear nature-society-nature material and energy throughput flow, which is done using cyclical materials flows, renewable energy sources, and cascading type energy flows. A prosperous circular economy contributes to all three dimensions of sustainable development. (pp.37–46)

The circular economy has a great inspiring force, and it is essential to consider it a model for global sustainability. However, even though the circular economy concept has not finished developing, new questions will still arise regarding the flows of materials that exceed the limits created by man. The complexity will increase when new uses are found for existing flows, a fundamental circular economy principle. The environmental impacts of biofuels, biomaterials, and other eco-efficiency initiatives that have not yet been resolved should also be evaluated. The circular economy could be solving challenges in the global economy, which will be the basis for project proposals for scientists, politicians, and business actors interested in advancing sustainable development through the circular economy (Korhonen et al., 2017).

Today many economies, sectors, and companies have been investing and developing and promoting the circular economy, which has allowed the creation of more than 114 definitions, each one aimed at improving production, distribution, and consumption processes, always applied in search of a sustainable development that leads to environmental quality, social equity, and economic growth (Kirchherr et al., 2017, pp. 224–225). Nevertheless, it must be considered that many companies do not understand the definition of circular economy as a systemic change but as a small adaptation/distortion of the status quo to ensure its impact on the market (Kirchherr et al., 2017; Ness & Xing, 2017). Kirchherr defines the circular economy as:

> An economic system replaces the concept of "end of life" with reducing, reusing, recycling, and recovering materials in the production/distribution and consumption processes. It operates at the micro-level (products, companies, consumers), the mid-level (eco-industrial parks), and at the macro-level (city, region, nation, and beyond) to achieve sustainable development, thus simultaneously creating environmental quality, prosperity, economic, and social equity, for the benefit of current and future generations. It is enabled by innovative business models and responsible consumers. (p. 229)

The concept of circular economy seen historically is shown in Fig. 18.1.

## 18.4 Globalization, the Coronavirus, and the Circular Economy

In 2020, the coronavirus pandemic generated a strong recession worldwide, affecting supply chains and trade both in terms of imports and exports, and that is how in 2021, society calls for a conscious recovery with change, which means that governments and global policies must be directed toward environmentally sustainable societies, which allow the improvement of the health and standard of living of people. The circular economy is considered a solution to increase resilience and mitigate future crises (Schröder et al., 2020). Although the global economic slowdown has led to a drop in carbon dioxide emissions, the United Nations Environment Program declares that these are temporary consequences of the COVID-19 pandemic and that a real positive impact requires a systemic transformation in production and consumption habits toward a cleaner environment (Mulder & Albaladejo, 2021).

It is how the question arises: Are economies, companies, and consumers willing and ready for a change? Even though there is initiative and support for the application of a circular economy model on the part of the state and companies, such is the case of the European Union and Latin America, progress is still minimal, otherwise with China and the Netherlands that have a significant advance in a circular integral development but far from reaching it (Mulder & Albaladejo, 2021; Kirchherr et al. 2018; Geissdoerfer et al., 2017).

2018 **Circular economy and sustainability**

2017 **Kitchberr**
´The circular economy as an economic system that replaces the concept of "end of life" with reducing, reusing, recycling, and recovering materials in production/distribution and consumption processes

2014 **European Parliament**
'Towards a Circular Economy: a zero-waste program for Europe'

2014 **France parliamentarians**
They pledged to form a 'circular economy club' and make France a leading company in the circular economy.

**UK Government**
It offered encouragement on the principle of a circular economy but refused to endorse the Circular Economy initiative

2012 The **UK is the Isle of Wight**-based NGO, the Ellen Macarthur Foundation.
Circular business models identify four sources of value creation within a circular economy.

2011 **Mathews and Tan**
"The goal of the eco-initiatives is to eventually establish a so-called circular economy, or what is otherwise known as a 'closed-loop economy."

2009 **China**
'Circular Economy Promotion Law 'took effect, with the aim of 'improving resource utilization efficiency, protecting the natural environment and realizing sustainable development.'

2008 **Yang and Feng**
Circular Economy an "abbreviation of Closed Materials Cycle Economy or Resources Circulated Economy."

2002 **China**
16th National Congress of the Communist Party of China set out an ambitious development plan, known as a 'circular economy, the term was defined in the legislation in China as a means of reducing, reusing, and recycling activities conducted in the process of production, circulation, and consumption

1991 **Robert**
''Most environmental problems are based on the same systemic error, linear processing of the material. Until resources are processed in cycles, either by society or by biogeochemical processes, the global economy and public health will continue to deteriorate."

**Fig. 18.1** History of the concept of circular economy. (Adapted from Wautelet (2018), Kirchherr et al. (2017); Korhonen et al. (2017); Murray et al. (2017), and Geissdoerfer et al. (2017))

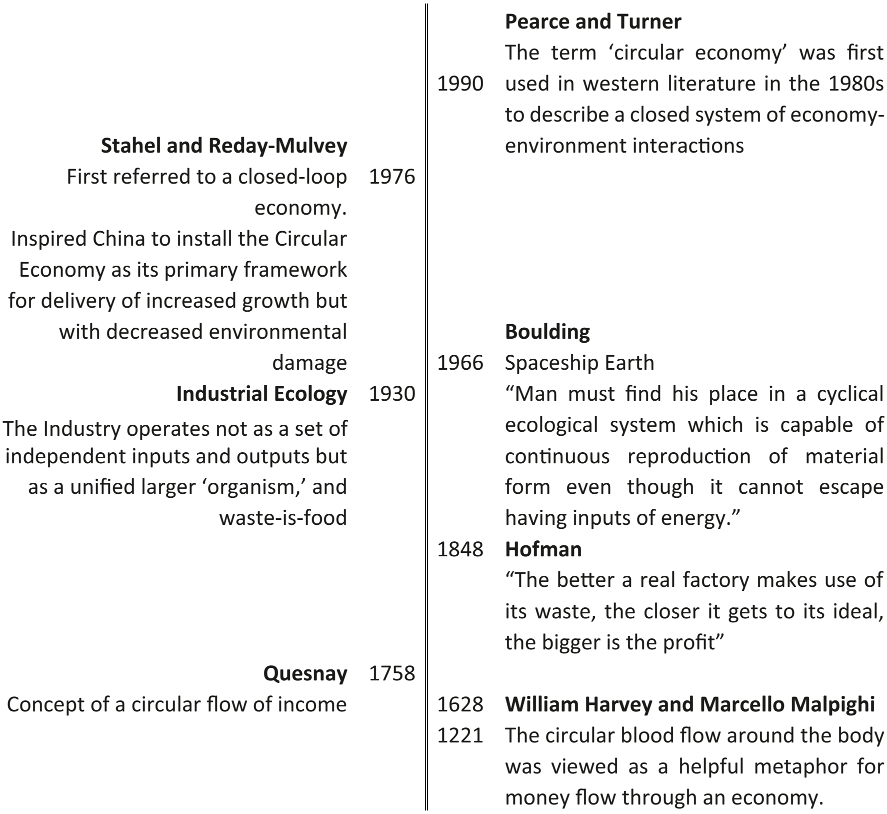


**Fig. 18.1** (continued)

In Latin America, different public policy strategies have been generated, such as General Law of Circular Economic in Mexico (Senado de México, 2019) and the Regulations for the environmental management of packaging and packaging waste, encouraging innovation and eco-design in Colombia (Ministry of Environment and Sustainable Development, 2018), among others. It should be noted that in the Forum of Ministers of the Environment of Latin America and the Caribbean, they formed a regional Coalition of Circular Economy, which means that the different countries will generate strategies, plans, and initiatives to promote the circular economy, but still all of these are in a transition process (Mulder & Albaladejo, 2021).

Economies that promote the circular economy can generate more business activity and, therefore, more employment and improved environmental conditions, less waste, better economic sustainability, and lower raw material requirements (Rossi et al., 2020). Government support through circular economy legislation could reduce resource use, waste generation, and the release of carbon dioxide by businesses. The paradigm shift is not possible only through the effort of a single entity; it requires the levels of participation and commitments at the sectoral, regional and governmental, and intragovernmental levels (Upadhayay & Alqassimi, 2018).

In the literature related to the business sector, the lack of incentives is the main barrier to the circular economy's implementation and development. According to De Jesús and Mendonç (2018), incentives or drivers encourage the development of the circular economy, while barriers are technical, financial, regulatory, or cultural factors that limit the transition to the circular economy. Incentives and barriers can be divided into soft (social, institutional) and complex (technical, economic). Likewise, de Jesús and Mendonç point out that technical capabilities are a primary factor in developing the circular economy, and technical solutions are essential for designing optimal product life cycle scenarios for new products and processes. Therefore, technological challenges are a vital barrier to the circular economy transition. Technological barriers can be related to the lack of appropriate technology and technological gaps between design and production (Gao et al., 2006) and untrained personnel (Geng et al., 2010). Therefore, we can say that the transition to the circular economy is closely related to technology and Industry 4.0 (digital technologies such as blockchain, 3D printing and automation, cloud computing, and big data analytics) and capabilities. Technology is essential for developing a circular economy model (using information flows and analysis to reduce waste, recycling materials, applying more efficient manufacturing processes, and reverse logistics).

The circular economy and technology could incentivize the development of new business models driven by COVID-19, allowing the business world to reinvent itself in the face of the pandemic and new consumer behavior. The circular economy principles are found in more and more companies, but they are still weak (Zamfir et al., 2017). Companies need to redesign and restructure their current processes to reduce the consumption of resources, thus developing a competitive advantage. Innovation in "smart solutions" is required to enable a circular economy (Ellen MacArthur Foundation, 2016) and communication and information.

We can then say that public policies and companies have been working about the circular economy, but so far, the analysis has always been focused on supply and demand. How does the consumer perceive the change toward the circular economy? In the analysis of the circular economy, the consumer has a significant role as they can also have several roles (buyer, seller, distributor, collaborator, and many others). Whatever the role or roles of the consumer within the economy, their participation is essential for achieving the objectives of a circular economy (Sijtsema et al., 2020). Faced with the changes generated by the pandemic, consumer behavior has changed, and entrepreneurs who develop a circular economy expect consumption to change and what is related to what consumerism and consumer goods mean for consumers (Spangenberg & Lorek, 2019). The transformation toward a circular economy requires changes in both the production and consumption systems. Studies agree that there is limited interest and awareness about the concept and application of a circular economy model (Sijtsema et al., 2020; Spangenberg & Lorek, 2019; Kirchherr et al., 2018), which could be one of the reasons why the circular economy is not being implemented and developed.

However, when implementing a circular economy model, we can also consider the traditional concept of consumption changes (Camacho-Otero et al., 2018), which would lead to the consumer, without considering it, changing their way of consuming and purchasing a product. Today people have a habit of buying, using, and throwing away, but if the consumer thought of a circular economy, he/she could be considering reusing, repairing, restoring, or recycling, as the consumer today also has a habit of consumerism or the acquisition of products or services for reasons of personal image, which could change to sustainable consumption (Maitre-Ekern & Dalhammar, 2019; Edbring et al., 2016; Andrews et al., 2018; Spangenberg & Lorek, 2019).

A significant commitment to the consumer society is expected together with a change in values. COVID-19 has allowed an evolution in consumers that could be facilitating the path to a circular economy without necessarily knowing its concept in its entirety. However, the attitudes, perceptions, and intentions about the product's characteristics, production, processing, and sustainable resources allow the beginning of a change in how a good or service is acquired (Sijtsema et al., 2020) (Fig. 18.2).

Do companies in the state recognize this substantial change that is being generated in the consumer? The focus is not necessarily mainly on supply, production

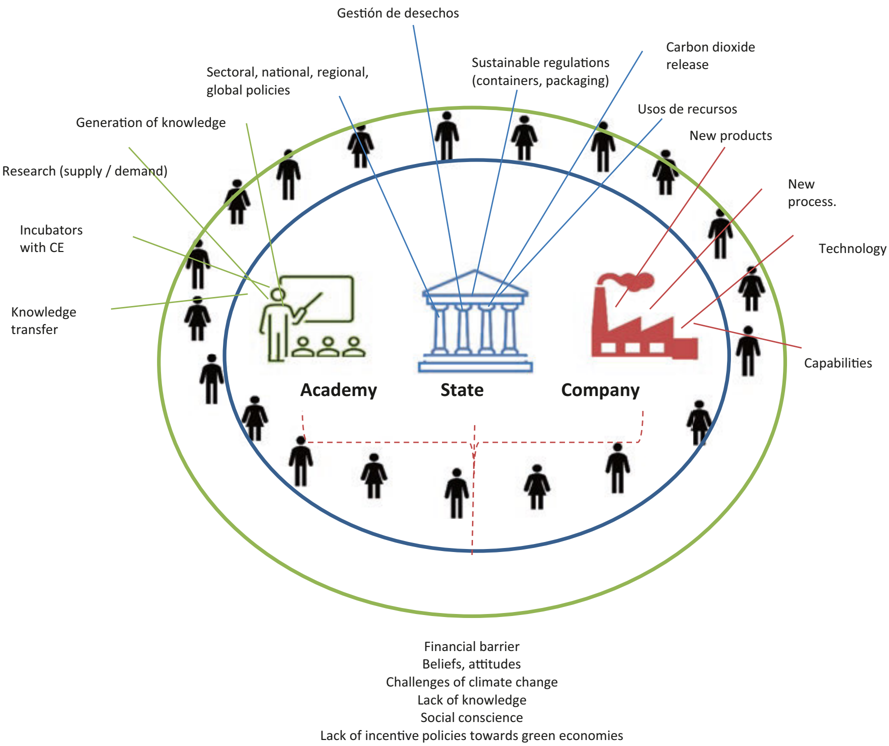


**Fig. 18.2** Necessary factors to consider implementing a circular economy model

processes, minimizing costs, and generating competitive advantages on waste management. However, the analysis is not complete if the last link in the supply chain is not an interpreted value, the customer, this link being the least analyzed and is the one that makes decisions and turns according to their levels of need and satisfaction. According to studies carried out, the conclusions are reached that the consumer shows a lack of interest, has little knowledge, and is considered passive carried by the brands and other characteristics that come from the production of the product (Kirchherr et al., 2017; Ghisellini et al., 2016). The consumer's characteristics (personality traits, values, and ideologies) influence consumer perceptions that ultimately define the acceptance of circular solutions. The offer leads to defining the perception and intention of purchase, likewise influencing the experience of other consumers and its impact on the use of the product. The risks and the lack of knowledge of circular solutions affect the purchase decision and the norms and attitudes (Kirchherr et al., 2017).

Before COVID-19, the consumer had a perception of consumption, but the COVID-19 situation changed its perception of the product or service and its pay, creating more concern about caring for the planet and producing and consuming sustainably. Entrepreneurs must analyze and understand the new consumer experience management to meet their new expectations and needs, both functional and emotional, which may arise after COVID-19 passes to a better life. The new characteristics generated in the consumer an approach to the circular economy and a change that the entrepreneur must analyze to stay in the market (Table 18.1).

**Table 18.1** The new COVID-19 consumer and its relationship with the circular economy

| Consumer | **Before COVID-19** | **During COVID-19** | **Fundamentals of circular economy** |
|---|---|---|---|
| | Applying a linear model acquire, use, and dump | Application of reuse, share, lend | Principles of the circular economy concept |
| | Consumption related to brands | Action or reaction purchases | Need-based purchases |
| | Consumerism | Increased interest in health and wellness products | Safety minimize risk |
| | Empowered consumer | Restricted purchases on many items | A thinking consumer |
| | Smart shopper | Risk-free products, higher quality | Acquisition of ecological, natural products |
| | | They look for experiences and emotions | Sustainable consumption |
| | Before COVID-19 | New e-commerce experience | Market digitization |

## 18.5 Closing Remarks

The circular economy offers an opportunity for intersectoral diversification to generate added value domestically, contributing to SDG 8 (sustainable economic growth and decent work), SDG 9 (sustainable industrialization), and SDG 12 (sustainable consumption and production). An inclusive circular economy can also support achieving the social SDGs, including SDG 1 (eliminating poverty) and SDG 10 (reducing inequalities).

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# Chapter 19
# Closing Remarks

**Aldo Alvarez-Risco, Marc A. Rosen, and Shyla Del-Aguila-Arcentales**

Throughout this book, information has been presented and described on potential approaches for allowing the circular economy to increase in implementation and impact and, at the same time, on underlying mechanisms that help to improve processes from physical-chemical and thermodynamic points of view. Likewise, efforts have been made to show the evolution over time of the circular economy; to establish the theoretical foundations for circular economy 3.0, which seeks to maximize value retention of resources; to replace virgin material inputs with secondary resources and to launch new business model incentives; and to describe the 10Rs hierarchy of the circular economy value proposal. The 10Rs are refuse, reduce, resell/reuse, repair, refurbish, remanufacture, repurpose, recycle, recover, and remine. The understanding provided by the last point is necessary to classify efforts that can contribute to the practical implementation of the circular economy.

In this way, the book *Towards a Circular Economy: Transdisciplinary Approaches for International Business* focuses on a new conceptualization of the circular economy, while in a scholarly way critiquing the concept. In addition, the book explains the practical scope of the circular economy and the need for more examples, case studies, and evidence from real circumstances. Such knowledge can aid the implementation process for measures, based on results of past scenarios and demystifying

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overly optimistic positions, thereby providing thorough and impartial evaluations of actions and progress on them.

Waste management has been revised in this book to show the connection with the circular economy, noting various efforts that have been made and detailing strategies used in programs at local and regional levels. Highly relevant coverage is provided of the contribution to the circular economy of the efficient management of energy, which also contributes to the United Nation's Sustainable Development Goals (SDGs), specifically SDG 7, which aims to "ensure access to affordable, reliable, sustainable and modern energy for all." It is recognized by many that, in the COVID-19 pandemic and post-pandemic period, there is an energy crisis. The circular economy is relevant and shows the need to develop processes and products in a circular way that generate energy savings. The roles of governments, companies, and consumers are important for achieving the efficient use of energy resources and for developing and exploiting eco-efficient and sustainable resources.

Evidence of the changes caused by the COVID-19 pandemic is observed in the sending and receiving of goods. The supply chain and its management have been significantly impacted due to isolation and health restrictions. But it is precisely in this situation that the circular economy takes on importance as a means to address the limitation of resources, to save time and energy, and to generate green options for the marketplace. Public policies that have been developed around the circular economy are of great importance, since they allow the allocation of resources in the countries that are supportive of the implementation of the circular economy. Public policies have a significant influence on green management planning in a country. Governments can use, among other methods, crowdsourcing to assist in developing public policies. This implies that governments act with the participation of all relevant stakeholders, including companies, universities, and citizens. As an example, experiences with public policies of the government of Colombia are presented, demonstrating the benefits and achievements.

The United Nations encourages the development of actions based on sustainability. These include environmental strategies, and a circular economy approach is helpful and can provide a resilience mechanism against COVID-19. Changes made in the management of plastic, widely used as a protection measure in the pandemic period, provide a good opportunity to reduce pollution and to foster new productive sectors that increase numbers of jobs and help reactivate economies hard hit by the pandemic. Sustainable production is a key means to reduce environmental pollution, but it is not always easy to achieve since it requires investments from companies (e.g., for altering equipment, modifying processes, changing raw materials). Based on the SDGs, it is necessary to promote sustainable production, which can be done with business mentoring programs to guide step by step the conversion of usual processes into ecologically benign processes. The transformation of production is likely to become increasingly required by countries, generating in the immediate future the demand for certificates of sustainable production for products, especially those intended for export.

One requirement for a society to change its actions is appropriate education and training of its professionals and citizens. For this reason, education plays on an increasingly important role in permitting governmental and global objectives to be achieved regarding sustainable development and the circular economy. Universities, as a consequence, have been developing various programs to contribute to the SDGs, selected depending on such factors as the preferences of the universities, the types of careers envisioned for students, and the specializations of their educators and researchers. Various initiatives of universities are reviewed in the book to promote the circular economy in a practical, for instance, through green entrepreneurship programs and at some universities circular economy courses. However, it is recognized that progress requires a holistic approach that not only seeks to improve environmental indicator scores but also facilitates the achievement of social and economic goals in a country, in part through the efficient use of resources.

Research on the circular economy at universities is likely continue to increase in the future and will need to analyze broader aspects, such as the potential benefits as well as barriers. Furthermore, research is required into the roles of the various actors from many disciplines involved, in order to obtain a greater beneficial impact from the circular economy. This will likely also involve determining the curricular subjects that should be part of education programs in order to ensure the workforce has the abilities needed to implement viable circular economy measures.

The experiences of implementing the circular economy in Colombia are considered in this book as they are instructive, describing proposed regulations, coordination between players, preliminary results, and proposals for a higher level of implementation. The role of long-term planning for the implementation of the circular economy is detailed and found to be important, since it allows governments to attain the resources needed and implement specific regulations to encourage a circular economy. Isolated efforts in a country generally are inadequate for achieving the circular economy. Rather planning and budgeting are needed for implementing broad circular activities. When circularity activities are carried out without planning, the optimal results are likely not achieved. Not only is this problematic in terms of lost potential, but it can needlessly discredit the idea of the circular economy and cause fewer people and institutions to seek its development.

Another very practical example covered in the book is the description of the experiences in the UK with respect to the circular economy, emphasizing circular activities already implemented. New opportunities to increase the circular actions of companies and citizens in the UK are also identified and analyzed, detailing the step-by-step circular measures used in the implementation. Recycling processes have achieved benefits in many jurisdictions across the world, but there are still many specific aspects of recycling that need to be better understood to make the process more efficient. Experiences with recycling in Peru are also detailed in the book, providing examples of improved processes that can be replicated elsewhere.

The processes of globalization and, more recently, deglobalization have generated multiple changes in business dynamics, creating new opportunities in some areas and leading to replacements in others. Similarly, the ecological know-how that is attained in some regions of the world can be shared with others so that the learning process is shorter and more structured, especially compared to trial and error approaches. This can lead to the minimum reasonable environmental damage. In this sense, the review of circular practices in Europe and Latin America are valuable examples, in terms of their similarities and differences, which allow the developments of future scopes of activity on the circular economy.

The authors hope that the detailed and broad review of the development of the circular economy provided in this book motivate institutions and people to change their behaviors and that they can foster more research into circularity proposals. This can allow applications of the circular economy to become increasingly realistic and customized and can contribute to global environmental commitments and needs.

# Index




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