JUST2CE

A Just Transition to Circular Economy

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CHAPTER 15

Environmental, economic and social accounting of Circular Economy

Chapter 15. Environmental, economic and social accounting of Circular Economy

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Abstract

The forthcoming CE paradigm will need metric and assessment methods to investigate its feasibility, performances, and burdens, related to the environmental, social, and economic dimensions. This chapter summarizes some of the most common assessment methods that can be implemented to achieve a widespread understanding of strengths and weaknesses of circular economy initiatives. Each mentioned method answers a specific question and is not exempt from flaws and biases. Therefore, the simultaneous application of different frameworks can result in more accurate and holistic analyses to support a fair transition. This cannot happen without a critical discussion of assessment methods, their capabilities and their vulnerabilities.

Keywords: Assessment methods, circular economy indicators, methods integration, holistic approach

> The transition to a new Circular Economy paradigm will need to overcome the current lack of feasible metrics for a holistic assessment of the social, environmental, and economic features of a just transition.

15.1 Introduction

The announced transition to a CE is expected to shift the global economy from a linear paradigm, ‘take-make-dispose', to a circular one, aiming for a system that would be ‘restorative and regenerative by intention and design'(Ellen MacArthur Foundation, 2012). This would be achieved by implementing pathways within human driven processes and on different levels. However, CE is still far from a broad implementation as an established economy paradigm, and ‘circular' applications and strategies are solely applied within the still ongoing linear paradigm.

A global-wide transition to a CE would need and benefit from a thorough assessment and planning of the actions, pathways and strategies to be implemented for their expected environmental, social and economic effects, outcomes and related implications. ‘Circularity' levels have been approached and measured in different ways over the last years (Vinante et al., 2021), proposing several indices for CE assessment and adapting environmental, social, and economic assessment metrics for circularity evaluation. Nevertheless, a standardized and shared method for CE assessment is still lacking (Kristensen & Mosgaard, 2020), impacting the diffusion of policy resolutions and of the implementation of CE strategies.

Moreover, perhaps a result of the technocratic approach to CE definition, which mainly look at CE as a technologic waste disposal and recovery problem, a wide range of the studies approaching CE measurements focus on the material circularity and resource productivity, accounting for recycling, recovery and reuse of waste and materials (Bastianoni et al., 2023). Such measurements are however incapable of grasping the complexity of the CE paradigm and of simultaneously addressing the 3 pillars of sustainability: environmental, social and economic.

In this chapter, a collection of existing assessment methods suitable for CE measurements from different perspectives is reported, analysed and criticised for their pros and cons. The included metrics are acknowledged as capable of assessing CE strategies, implementations, and networks in a holistic way if performed in an 'integrated' approach, as opposed to their own linear, mono-criteria perspectives.

15.2 Material Flow Accounting

The Material Flow Accounting (MFA) method is acknowledging the law of thermodynamics on conservation of matter. Matter (mass and/or energy) is neither created nor destroyed in transformations. Thus, the relation between the economy and the environment embedding it (**Figure 15.1**) is expressed as a balance between the input matter and the output matter plus accumulation in stocks within the economy (European Communities, 2001). The MFA method thus evaluates the material balance and the performance of the socio-economic metabolism (SEM).

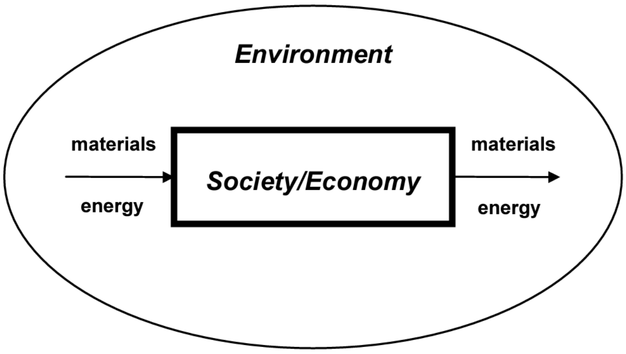

Figure 15.1The economy/environment system (European Communities, 2001)

The SEM concept, the basis on which MFA is built upon, dates back to Karl Marx's works, and evolved through time (Fischer-Kowalski, 1998). MFA has been prominently developed and implemented starting from the early 90s, its indicators have been advanced and standardized, and the method has been adopted by several organizations (Krausmann et al., 2017). The MFA method accounts consists of inventories of material inputs in the socio-economic system, changes in stocks within the socio-economic system, and material outputs to the environment and/or other socio-economic systems. It calculates several different indicators, used to assess the pressure on the environment. Some of the calculated indicator are: the Domestic extraction (DE), measuring the materials used extracted domestically; the Total Material Requirement (TMR), measuring all the materials, used and unused, required for domestic production and consumption; the Domestic Processed Output (DPO), indicating the materials released to the domestic environment in the form of waste, emissions, or purposeful outputs; the Material Footprint (MF), accounting for the global material use for domestic consumption; the Materials Stock (MF), calculating the materials accumulated in in-use stocks; the Material Productivity (MP), representing the value added produced per unit of domestic consumption. In recent times, the focus of the discussion has changed to emphasize the importance of considering a production-oriented viewpoint as opposed to a consumption-oriented one. It has become increasingly clear that the consequences of leakage effects and the shifting of burdens, which are connected to the expansion of trade, are exerting a growing influence on the patterns of resource flows (Kovanda & Weinzettel, 2013), by inducing a relocation of industries from developed to developing countries due to rigid policies and increasing prices in developed countries (Safarzynska et al., 2023).

15.3 Life Cycle Thinking

The Life Cycle Thinking (LCT) approach aim at focusing on the entire chain of stages delivering products and/or services, acknowledging that each stage has to potential to reduce environmental, social and economic impacts. It borrows the concept of 'life cycle' from biology, distinguishing every step of the cycle from the others. The LCT framework includes different approaches for the three sustainability dimension, namely the LCA, the LCC and the s-LCA.

15.3.1 Life Cycle Assessment

The LCA method aims at assessing the environmental impacts of transformation processes under human control with a cradle-to-grave approach, starting from the extractions of raw materials to final disposal of waste. The LCA is a worldwide established method for environmental assessment, highly standardized and defined (ILCD, 2010; ISO, 2006a, 2006b). The first life cycle-oriented assessments were performed back in the 1960s, with great developments throughout the 90s and the first years of 2000 (with the development of widely used softwares and databases).

According to the ISOs norms/standard, LCA analyses are performed through a 4-step iterative process (**Figure 15.2**):

Goal & Scope definition: the goal of the study, among other things, is stated. The functional unit (FU) and the boundaries of the case study are defined. The FU is a measure of the function(s) of the studied system. It provides a reference to which the inputs and outputs can be related. The boundaries (physical, geographical and temporal) define which parts of the life cycle and which processes belong to the analysed system. They separate the analysed system from the rest of the technosphere and from the ecosphere.

Life Cycle Inventory (LCI): the LCA study is performed by compiling a careful inventory of the input flows (materials, energy) and of the output flows (products, by-products, waste, emissions) of the investigated system. Data can be directly collected (primary data), retrieved from literature and/or databases (secondary data), coming from calculations and assumptions (tertiary data).

Life Cycle Impact Assessment (LCIA): the obtained inventories are converted into environmental impacts. This is usually performed by means of software applications (i.e., SimaPro, Gabi, OpenLCA), databases (i.e., Ecoinvent database) and impact methods (i.e., ReCiPe Impact Method), the latter providing suitable conversion factors to calculate characterized and normalized indicators. LCA results express the impacts in several environmental compartments as different indices of emissions (carbon equivalent emissions, toxicity emissions, eutrophication emissions, among others) and of resource use (fossil depletion, metal depletion, land use, water use).

Interpretation: the data, result and insights calculated are used to understand the investigated case study. The results are discussed and compared to suitable benchmarks and the hot-spots of the study are highlighted, in order to propose feasible recommendations and improvements.

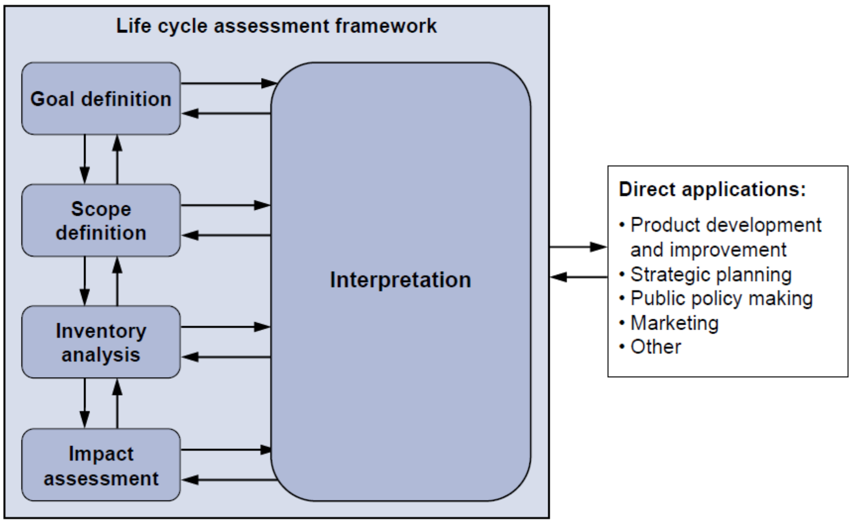

Figure 15.2 The LCA framework (ILCD, 2010)

The LCA method is capable of delivering the environmental impacts within several categories, related to several environmental compartments, and of connecting the fraction of impacts to the stage producing it. However, it is not useful when trying to assess anything outside the anthropic technosphere (e.g., transformations happening outside the human controlled industrial environment). In addition, even though very standardized, the opportunity for the practitioners to take decisions in very important points of the analysis (e.g., choice of FU and boundaries) might hinder the comparability.

15.3.2 Life Cycle Costing

The Life Cycle Costing (LCC) method is defined as ‘the sum of all funds expended in support of the item from its conception and fabrication through its operation to the end of its useful life’ (White & Ostwald, 1976). Thus, it represents an assessment of the costs over the life cycle of a product or system (**Figure 15.3**). As the other Life Cycle oriented tools, LCC could be used to plan, to optimize, to identify hotspots. It aims at choosing the most cost-effective strategies in order to achieve the least long-term cost of ownerships (Ghagare et al., 2017).

It accounts for two types of costs:

- Internal costs: costs, borne by a stakeholder, happening along the life cycle of products/services related to production, use and end of life;
- External costs: externalities (e.g., environmental and/or social costs) not met by any stakeholder, that should be relevant in decision making.

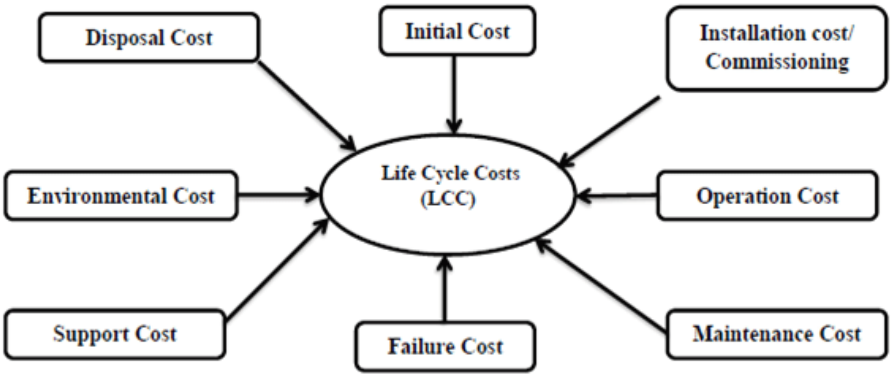

Figure 15.3 LCC major components (Ghagare et al., 2017)

Three variants of LCC have been proposed, to acknowledge the different goals, needs and points of view of different stakeholders: the conventional or financial LCC (cLCC), the environmental LCC (eLCC) and the societal LCC (sLCC) (Hunkeler et al., 2008).

cLCC is a profit-oriented framework used mainly as a decision-making tool, only considering internal costs, and performed in a single actor perspective. It allows manufacturers to subdivide the costs according to production stages and end-of-life activities.

eLCC is more consistent with LCA and ISO standards in terms of FU, boundaries, and including all life cycle stakeholders, meaning that also external costs are included. Thus, eLCC is developed and used to support LCA by adding the economic dimension to the environmental one.

sLCC aims at supporting public authorities and governments in decision making by including selected externalities and assigning them a monetary value. These externalities are from both the environmental and social perspectives, thus including, among others, the cost of repairing environmental and social damage, job quality, wellbeing. In so doing, the sLCC tries to incorporate the costs of the three pillars of sustainability (economic, environmental and social) in a single monetary unit. However, economic costs show a wide spatial and temporal variability, which causes a significant amount of uncertainty in the analysis.

15.3.3 Social Life Cycle Assessment

Social Life Cycle Assessment (S-LCA) represents an innovative approach for the understanding of the social burdens linked to the entire life cycle of products and services. Nevertheless, its precise definition remains a work in progress. The most spread definition follows the international voluntary guidelines established through collaboration between UNEP (United Nations Environment Programme) and SETAC (Society of Environmental Toxicology and Chemistry). This definition characterizes S-LCA as an evaluation method (**Figure 15.4**) with the aim of appraising the social and socio-economic dimensions of products, including their potential positive and negative impacts, opportunities and risks, across their entire life cycle, spanning from the extraction and processing of raw materials, through manufacturing, distribution, use, re-use, maintenance, recycling, to final disposal (Andrews et al., 2009). In this context, social impacts are defined as the outcomes of positive or negative pressures on social endpoints, primarily pertaining to the well-being of stakeholders (STAR-ProBio, 2019). These outcomes arise from social interactions woven into the fabric of activities such as production, consumption, or disposal, and are influenced by various stakeholders' preventive or reinforcing actions.

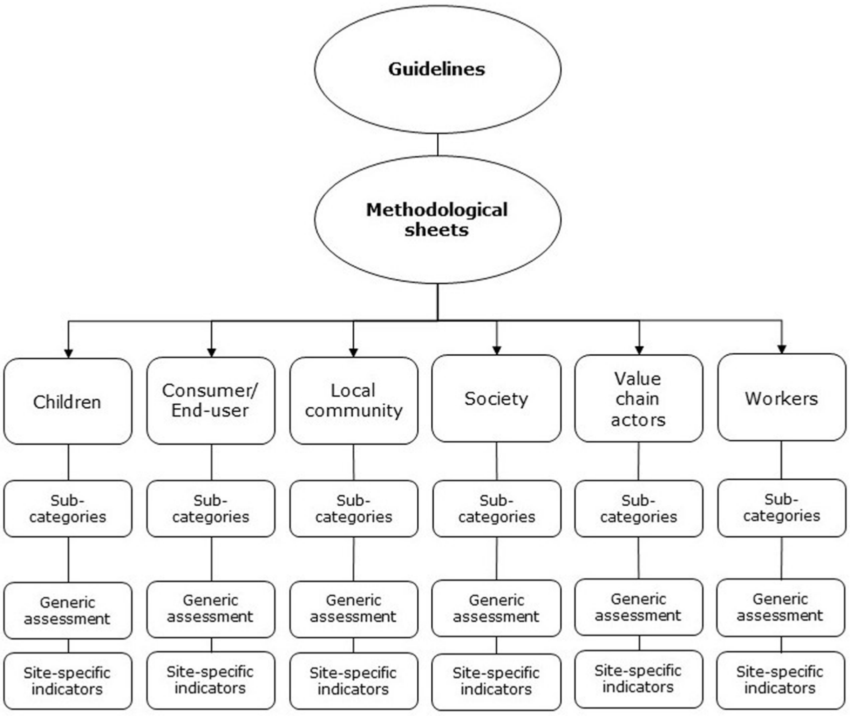

Figure 15.4 s-LCA framework (Lundgren, 2023)

Numerous researchers have put forth different frameworks for S-LCA, all of which demanding comprehensive data. Furthermore, social indicators can be highly subjective and subject to varying interpretations within the literature. This subjectivity could introduce biases, particularly when assigning weighting factors to determine the relative significance of each impact category (STAR-ProBio, 2019), and also prevents the comparability of social indicators across different studies. It was only in 2013 that UNEP and SETAC initiated specific guidelines to standardize knowledge and unify the evaluation methods. Thus, transparency is of utmost importance when conducting s-LCA. The methodology for S-LCA follows the same stages as for Life Cycle Assessment (LCA), as outlined in the ISO framework (ISO, 2006a, 2006b).

S-LCA takes into account aspects such as workplace hierarchies, production management and planning, unemployment, skills and knowledge, societal infrastructure demands, culture, child labor, poverty, and fair-trade practices. To conduct a social assessment, the identification of all the stakeholders involved is crucial, including workers, consumers, the local community, broader society, and value chain participants. The S-LCA impact categories encompass human rights, working conditions, health and safety, cultural heritage, governance, and socio-economic consequences. Impact subcategories are related to the specific analytical topics within these six impact categories for each group of stakeholders. Stakeholders' category can include, among others, prosumers (producers/consumers), local community, workers, society (Kaiser et al., 2022). Organizing an inventory within subcategories is necessary to comprehensively assess the social, sociological, and socio-economic impacts of products throughout their life cycle. This evaluation calls for a diverse range of expertise, spanning sociology, anthropology, sociology, and management sciences (UNEP, 2021; van Haaster et al., 2017; Zamagni et al., 2015).In a just transition perspective, the S-LCA method provides an easy way to collect information about the social implications related to products and services. However, several critical points emerge about participation in shaping the impact categories and the rationale of the method itself.

15.4 Emergy Accounting

The Emergy Accounting (EMA) method is a thermodynamic based type of analysis that assesses the ecosystem support to transformation processes. It accounts for differences in quality of the different kinds of resources, materials and energy, based on the work from the biosphere for their generation (Odum, 1996). EMA applies an upstream perspective in accounting for direct and indirect contributions to systems, resource generation, ecosystem services and societal aspects (Santagata et al., 2020). It is defined as the 'the available energy of one kind, usually solar, directly or indirectly used in a system for transformations leading to a product or a service' (Brown & Ulgiati, 2004a; Odum, 1996). The unit of emergy is the solar emjoule (sej). The total emergy (U) is the entire environmental support to transformation processes. It is calculated by multiplying an inventory of input flows by appropriate conversion factors, called Unit Emergy Values (UEVs). These factors, measured as sej/unit-of-input, express the environmental support to generate 1 unit of input flow. UEVs are calculated by dividing the total emergy U of a process by the yield of product/service delivered. When UEVs are expressed as sej/J, they are referred to as 'transformities' (Odum, 1996). By default, the transformity of solar energy is equal to 1 sej/J. UEVs are calculated with reference to a Global Emergy Baseline (GEB), expressing the total emergy driving the biosphere. The most recent and accepted GEB is equal to 12.0E+24 sej/year (Brown & Ulgiati, 2016). The resources used in transformation can be classified as locally available renewable (R), locally available non-renewable (N) and imported non-renewable (F), the latter also including the support from direct and indirect human labour (L&S, Labour and Services) (**Figure 15.5**).

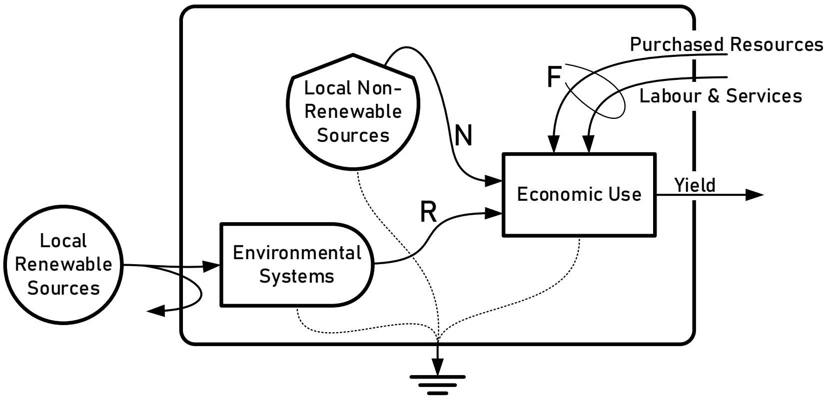

Figure 15.5 EMA framework

This classification allows the calculation of several based indicators (Brown & Ulgiati, 2004b), as, among others:

- Emergy Yield Ratio: EYR = U/F, measuring the performance in providing a yield by investing outside resources.
- Environmental Loading Ratio: ELR = (N+F)/R, quantifying the load of a system on the environment.
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- Environmental Sustainability Index: ESI = EYR/ELR, assessing the ability of using the least share of imported resources with the minimum load.

- Renewable fraction of emergy used: %REN = R/U. It indicates the fraction of emergy from local renewable resources.

EMA indicators provide insights about the process sustainability at the biosphere scale (Santagata et al., 2020). The EMA method is very powerful when considered as an alternative theory of value, as value is assigned not from an economic point of view but based on the biosphere 'work' in delivering things. It also includes important information from a just transition point of view, as the accounting of direct and indirect human labour and of the local/imported resources. However, the EMA method suffers from a lack of a shared UEVs database and from a still not standardized accounting procedure.

15.5 Net Present Value and Internal Rate of Return

The Net Present Value (NPV) method is used to assess and to rank the feasibility of projects and investments. It takes into account the time value of money, referring to the difference between the present value of all cash inflows and the present value of all cash outflows. As a general rule, a project is accepted when NPV>0 and rejected when NPV<0 (Bora, 2015).

The NPV is calculated as in Eq.1, where I represent the initial cost, b_t is the future net benefits, r is the discount rate and T is the length of the period of time:

$$Eq.1): \qquad \mathrm{NPV} = -\mathrm{I} + \sum_{t=1}^{T} b_t \left(\frac{1}{1+r}\right)^t$$

The NPV is often used to model the economic feasibility of environmental interventions. However, it represents an aggregated indicator, not always suitable for the inclusion of different, frequently contrasting, aspects (Knoke et al., 2020).

The Internal Rate of Return (IRR) is a financial metrics representing the return that can be earned on the capital invested in the project (Withers et al., 2009). Is therefore used to estimate the profitability (or the potential profitability) of projects (Mellichamp, 2017). At first, the IRR was meant to calculate the annual return on a purchase paid in cash and sold a certain number of years later. Basically, it represents the percentage rate earned on each economic unit invested for each period it is invested (Schmidt, 2013). The IRR formula solves for the interest rate that sets the net present value (NPV) equal to zero (Eq.2), where N is the total number of periods, n is a single period between 0 and N, and CF is the cash flow in period n.

$$Eq.2): \qquad 0 = \sum_{n=0}^{N} \frac{CF_n}{(1+IRR)^n}$$

Thus, the IRR metric incorporates the return performance of different sub-periods in a single value, without giving information on the patterns of the considered cash flows (Newell, 1986). The IRR value is used to support the decision of accepting a project if the IRR is higher than the cost of capital. It is also used to rank projects: the higher the IRR, the higher the rank (Magni, 2010).

Both the NPV and IRR methods might be used as a first analysis of the economic profitability of circular economy strategies, but their strict mono-dimensional perspective fails in acknowledging the important social and environmental aspects necessary for a just transition.

15.6 Gender Equality Assessment

Women's empowerment, inclusion and engagement is a long-recognized topic, acknowledged, among others, in global conferences (United Nations, 1995) and by the UN Sustainable Development Goals (United Nations, 2018), in particular SDG 5: 'achieve gender equality and empower all women and girls'. The 1995 Beijing Conference is particularly significant for the shift from the discourse of Women in Development (WID), a mainly economic perspective, to Gender And Development (GAD), with a widened approach including welfare, equity, anti-poverty and empowerment (MacArthur et al., 2021). Studies about gender equality show qualitative and quantitative approaches, or a mix of the two. Among others, one of the most prominent tools is the Gender Equality Capacity Assessment Tool proposed by the UN Women Training Centre (UN Women, 2014). The tool is used to assess the aptitude of organizations and individuals towards gender equality and empowerment of women. The analysis is performed by means of questionnaires, surveys, interviews and test, in order to evaluate policies, strategies and procedures. However, the implementation of these directly collected primary data might be time and resource demanding, and not always easy to be carried out. The results are then compiled into reports for dissemination. The surveys usually include general information, educational background, previous experience and knowledge about gender equality and women's empowerment, and personal opinions about the learning styles and needs to improve the awareness about the topic. A similar questionnaire-based approach is adopted by the Gender Equality Assessment Tool developed by Save the Children, used to support the organization sponsorship programming. It consists of four questionnaires and an Action Plan Template. The questionnaires include sub-categories relevant for the sponsorship programs, with a self-rating of 0 to 3 and the possibility to provide justification for the self-assigned rating. The Action Plan is then used to understand, among other things, timeframe, next steps and key staff (Save the Children, 2020). Large-scale quantitative research about gender-related issues is quite rare, mainly because of the limited data to support statistical type of analyses of the complex and intersecting patterns of inequalities related to gender, class, ethnicity, and age. Still, quantitative and statistic indicators could be useful in tracing the change of rate and patterns of these issues in different levels of society (Scott, 2010). For a comprehensive discussion about gender, justice, and Circular Economy, see Martínez Álvarez & Barca (2023) and chapter 18 of this volume.

15.7 Conclusions

The transition to the CE paradigm will involve all aspects of human societies. Thus, suitable methods for tracing and assessing the expected change will be needed, capable of acknowledging all the different sectors, i.e., economic, social, and environmental, and their intercorrelations and networking patterns. Each method answers a single, particular question. Taking into consideration the capabilities, the specificity and also the limitations of all or some of the involved methods (i.e., lack of standardization, high reductionist approaches, mono-criteria perspectives, etc.) is a powerful strategy to become able to reach a widespread point of view for a holistic understanding of the issues to be overcome. The quantitative/qualitative assessment of a just transition to Circular Economy would need the implementation, and the integration, of different metrics to include and consider the environmental, social and economic dimensions of a fair transition. Although the scientific literature presents different attempts for a multidisciplinary approach to the Circular Economy, more efforts from a regulatory point of view are needed to make these efforts significative.

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