POSITION OF THE RESOURCE COMMISSION AT THE GERMAN ENVIRONMENT AGENCY (KRU)

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Indicators in the area of sustainable resource use and circular economy

Principles and requirements for the development of consistent indicator systems

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Principles and requirements for the development of consistent indicator systems

Jahre
Umweltbundesamt
1974–2024

Illustrations

Contents

Summary

This position paper deals with the principles and requirements for the development of transparent, meaningful and consistent indicators and indicator systems in the field of sustainable resource use with a focus on the circular economy (CE). In particular, this should help to evaluate measures in the field of CE in terms of their actual contribution to sustainable development: Indicator systems should provide a rational argumentation to (i) distinguish target-oriented measures from potentially counterproductive measures or measures associated with significant conflicts of objectives when designing CE measures, and (ii) to enable monitoring of the achievement of measures.

Today, there are many proposals for indicators based on different conceptual and methodological approaches in the scientific literature, studies and practical applications of the CE. Especially in view of the current European Green Deal policy, this number is constantly growing. This diversity makes clear that it has not yet been possible to develop a uniform view of how CE monitoring should be carried out in a comprehensive manner. Furthermore, this diversity also reveals a fundamental trade-off of indicator systems: this exists between the desire to comprehensively map as many aspects of sustainability and/or actor-specific perspectives as possible on the one hand, and the increasing complexity and decreasing transparency and communicability of systems with a large number of indicators on the other. A way of dealing with such trade-offs must be found to support decision-making.

In addition, the validity and suitability of each individual indicator must be checked. It must be considered that indicators in the area of sustainability and CE are not measured, but are generated from existing data bases using more or less complex accounting approaches. Validity and suitability are therefore centrally dependent on the methodology chosen for the calculation for an indicator and on the availability of corresponding data bases. This connection is often ignored, which can both severely limit the informative value and understanding of indicators and also means that many proposals for indicators cannot be realized today due to a lack of the necessary data.

Against this background, this position paper contains two parts: **Part I** presents *guidelines for indicators and indicator systems*. These guidelines are intended both to enable the classification of existing CE indicators with regard to their function and informative value and to support the (further) development of target-oriented and consistent indicator systems. Factually,they should support the consistency of an indicator system for the entire CE “from micro to macro” and a uniform understanding of the character of indicators as a basis for communication between different actors.

These guidelines are based on **Part II** of the position paper, which presents *the fundamentals of indicators* in detail. Based on the scientific literature, fundamental and topic-independent definition approaches, characteristics, and structuring approaches for indicators and indicator systems are first summarized. Indicators and methods of sustainability assessment are then presented. In particular, this should clarify the relationship between an indicator and the methodology that forms the basis of its calculation, including with regard to the relevance of system boundaries and the object that is represented by an indicator. Finally, the specific framework conditions of the thematic field of resource conservation and CE are discussed and a current overview of CE indicators at the macro and micro level is given, which highlights challenges and development perspectives.

Part I – Requirements: Guidelines for Circular Economy (CE) Indicator Systems

Guidelines for indicator systems should both enable the classification of existing CE indicators with regard to their function and informative value and support the (further) development of target-oriented and meaningful indicator systems. Factually they should support the consistency of an indicator system for the entire CE "from micro to macro" and a uniform understanding of the character of indicators as a basis for communication between different actors.

These guidelines are based on an understanding of what the CE is. At the policy level, the CE is often described as a "*...production and consumption model in which existing materials and products are shared, leased, reused, repaired, refurbished and recycled for as long as possible.*"[1] . Such a production and consumption model could be seen as an end in itself. At the same time, however, there are clear political statements[2] that a CE is not an end in itself, but a means of achieving key sustainable development goals, in particular climate protection and sustainable resource use (see Part II, Chapter 3.1). These guidelines are clearly based on such an understanding. For this reason, indicator systems for the entire CE "from micro to macro" must be oriented towards these goals, irrespective of the fact that individual indicators at the operational level may be specific to certain measures or groups of actors.

Indicators are therefore primarily used to evaluate CE measures in terms of their target orientation. However, the suitability of an indicator for such an assessment is directly related to the method used to determine it – the accounting system, which, put simply, is determined by system boundaries, calculation rules and assumptions (see e.g. Part II, Chapter 2.3). In addition, the informative value of the calculation result is naturally linked to the data basis used. This interrelation is also included as a basis in these guidelines, as it is essential for the practical application of indicators.

Figure 1 shows the general form of an indicator system that subsumes individual indicators in a consistent form. Such a system is divided into target level and operational level, which have a conceptual connection. At these two levels, indicators represent the quantitative characteristics of key objectives and fields of action, respectively. For the practical application of indicators to support decision-making, appropriate data bases are required for simple calculation.

Based on these explanations, *seven guidelines* are formulated below. Of these, the first three guidelines describe the general framework conditions that must be observed for the development of consistent indicator systems, while the other guidelines concretize this for the area of CE and formulate the requirements for data bases.

Guideline 1: Distinction between indicators at the target level and indicators at the operational level

The distinction between the target level on the one hand and the operational level (level of individual (policy) measures) on the other is central to a target-oriented and consistent indicator system and should be clearly identified (see Part II, Chapter 2.4). The following requirements can be formulated:

Target indicators:

- Target indicators should be selected on the basis of social/political key objectives of sustainable development.
- Target indicators are the same for all levels and all stakeholder groups.

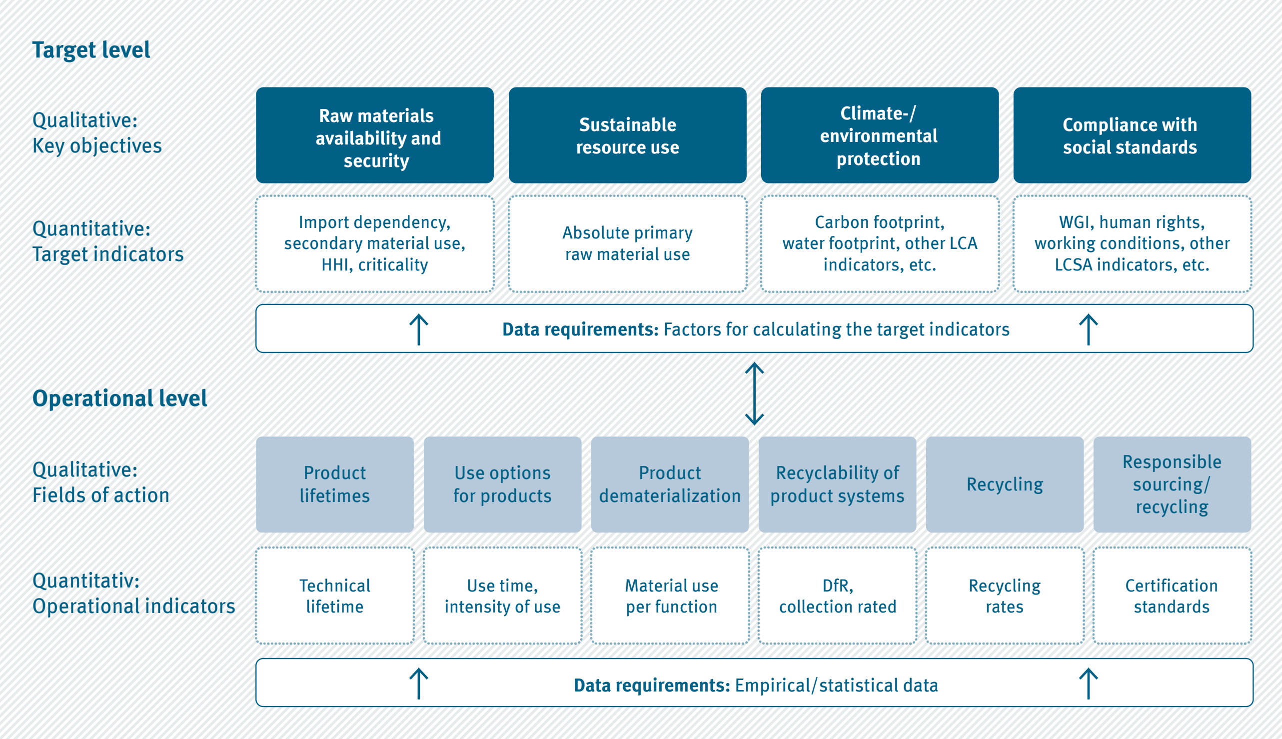
Operational indicators at the level of individual measures:

- Operational indicators should be practice-oriented to a specific field of action[3], but at the same time have a conceptual reference to one or more target indicator(s).
- The selection of operational indicators is made with specific reference to the application in the respective field of action, i.e. to the stakeholder group, object/measure and decision-making context.

1 https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits
2 See, for example, the statement by Executive Vice-President Frans Timmermans on the CE Action Plan: "Achieving climate neutrality by 2050, preserving our natural environment and strengthening our economic competitiveness requires a closed-loop circular economy." https://ec.europa.eu/commission/presscorner/detail/de/ip_20_4´20
3 The field of action is understood here as a specific environment of practice that is characterized by its actors and possibilities for action, for example the field of action"Product design" or the "Urban planning" field of action.

Figure 1

Structure of a consistent indicator system in the area of circular economy with example indicators



Key objective: qualitative description of an objective that is formulated at the overall social/political level and that sets an overarching objective for all stakeholders in society/describes an overarching problem area of sustainable development to be addressed.
Target indicator: Quantitative expression of a headline target in the form of an indicator that can be calculated and that represents the headline target.
Field of action: a specific environment of practice that is characterized by its actors and possibilities for action.
Operational indicators: Quantitative expression of a goal at the operational level within a field of action, which can be specific to actors or sub-areas of a field of action. There must be a causal relationship between operational indicators and target indicators.

HHI: Herfindahl-Hirschman Index; LC(S)A: Life Cycle (Sustainability) Assessment; WF: Water Footprint; WGI: World Governance Indicator; DfR: Design for Recycling.

Source: UBA Resource Commission's own illustration based on (UBA Resource Commission, 2023).

Guideline 2: Selection of indicators at the target level
Several key objectives are relevant for the sustainable development of society, which can lead to a large number of target indicators. The selection of target indicators therefore inevitably involves a process of balancing completeness and complexity (see Part II, Chapter 2.4). The following considerations should be followed here:

- While it is perfectly possible to use a large number of indicators for analytical or descriptive purposes, it is necessary to select or prioritize individual indicators or even choose a single (leading) indicator when indicators are intended to support decision-making.

- The selection of one or of few target indicators is made according to the question: which key objectives have major relevence in a respective thematic area, i.e. how relevant is the causal relationship between a thematic area and a specific key objective (and its corresponding indicator). However, other general sustainable development goals can be defined as a framework to be adhered to[4].
- Such a selection or prioritization between the key objectives or the corresponding target indicators should be made in an explicit and easily comprehensible manner.

Guideline 3: Indicator and target value

An indicator is defined by the method/calculation rule ("accounting method") with which it is determined (see e.g. Part II Chapter 2.3). The result applies to a specific point in time or a specific situation and is therefore different for different points in time/situations. In this sense, indicators can be used for monitoring by calculating the indicator value annually, for example. In addition, a target value can be set for an indicator in order to compare the current value of an indicator with the target value set for a specific point in time. It should be noted here:

- Target values can be set both at the target level, for example for the reduction of greenhouse gases at the national level, but also at the operational level, for example for the efficiency of heating systems.
- Not every indicator is necessarily linked to a target value. However, if there are such target values, it is important to note the difference between the indicator itself and its possible target value when communicating about indicators.

Guideline 4: Categorization of CE measures

In the field of CE, indicators are primarily used to evaluate measures, both at the policy level and in the practice of the concrete circular economy. From a systemic perspective, CE measures can be structured into two areas[5]:

- CE in the narrower sense: closing material cycles in the economy by recycling waste.
- CE in the broader sense: a form of economy that is geared towards conserving resources in all areas of the economy and society and in which measures are applied throughout the entire life cycle of products[6].

This distinction makes a significant difference with regard to the respective accounting method and the corresponding indicators:

- In the case of **CE in the narrower sense**, i.e. closing material cycles, all measures are based on the "output" of the economy, i.e. in the waste. Relief effects only occur when there is a substitution of primary materials. Accounting methods and indicators based on them must therefore reflect this substitution.
- In the case of **CE in the broader sense**, measures are based on the "input" of the economy, i.e. they are aimed at reducing the primary materials flowing into the economy. Accounting methods and the indicators based on them must therefore reflect the reduction of the input materials and the associated negative environmental and social impacts in the production and use phase, i.e. they must also cover sufficiency measures, for example.

4 Example: The topic area "Renewable energies" is directly aligned with the key objective "Reducing climate change". For this reason, the target indicator "Greenhouse gas emissions [CO_2-eq]" is set, to which all measures in this thematic area must contribute. As a framework condition, however, it can be required, for example, that these measures must not have any negative effects in the social sphere.

5 The interpretation of the terms "CE in the narrower sense" and "CE in the broader sense" used here was defined on the basis of two criteria in contrast to the vague use in the literature: the scope of waste legislation and the accounting necessity of taking substitution into account. More detailed explanations can be found in Part II Chapter 3.2.

6 This definition of the CE in the broader sense corresponds to the description of the CE in the EU announcements (see section 3.1)

Guideline 5: Specification of an indicator system for the CE

At the target level, an indicator system for the CE is to be designed as follows:

- A target indicator should be selected for at least one of the key objectives climate protection, availability of raw materials and resource conservation, to which the CE is directly aligned (see Part II Chapter 3.1/3.2). Other sustainable development objectives (e.g. from the area of natural resources) can be defined as described above as framework conditions that must be met when pursuing these headline targets.
- Methodologically, indicators should be geared towards a systemic (life cycle-wide) view of the CE in order to map global impacts in the area of climate change and raw materials, regardless of national or economic boundaries ("footprint indicators"). Spatial and temporal displacement aspects and, if possible, rebound effects of a measure should be taken into account (see Part II, Chapter 2.3).

At the operational level, indicators can and should be designed on a measure/sector/actor-specific basis. However, the design of these indicators should include a review of the extent to which an indicator supports the selected target indicators:

- For material cycles in particular, the correlation between the substitution of primary materials and indicators at the target level (e.g. greenhouse gases) must be established and scrutinized. The temporal dynamics of the measures of material cycles must also be taken into account, especially for materials in durable products and infrastructures.
- With regard to the accounting methodology, it is generally important to ensure consistency between indicators/accounting approaches at macro and micro level.

Guideline 6: Dealing with conflicting objectives in the evaluation of CE measures

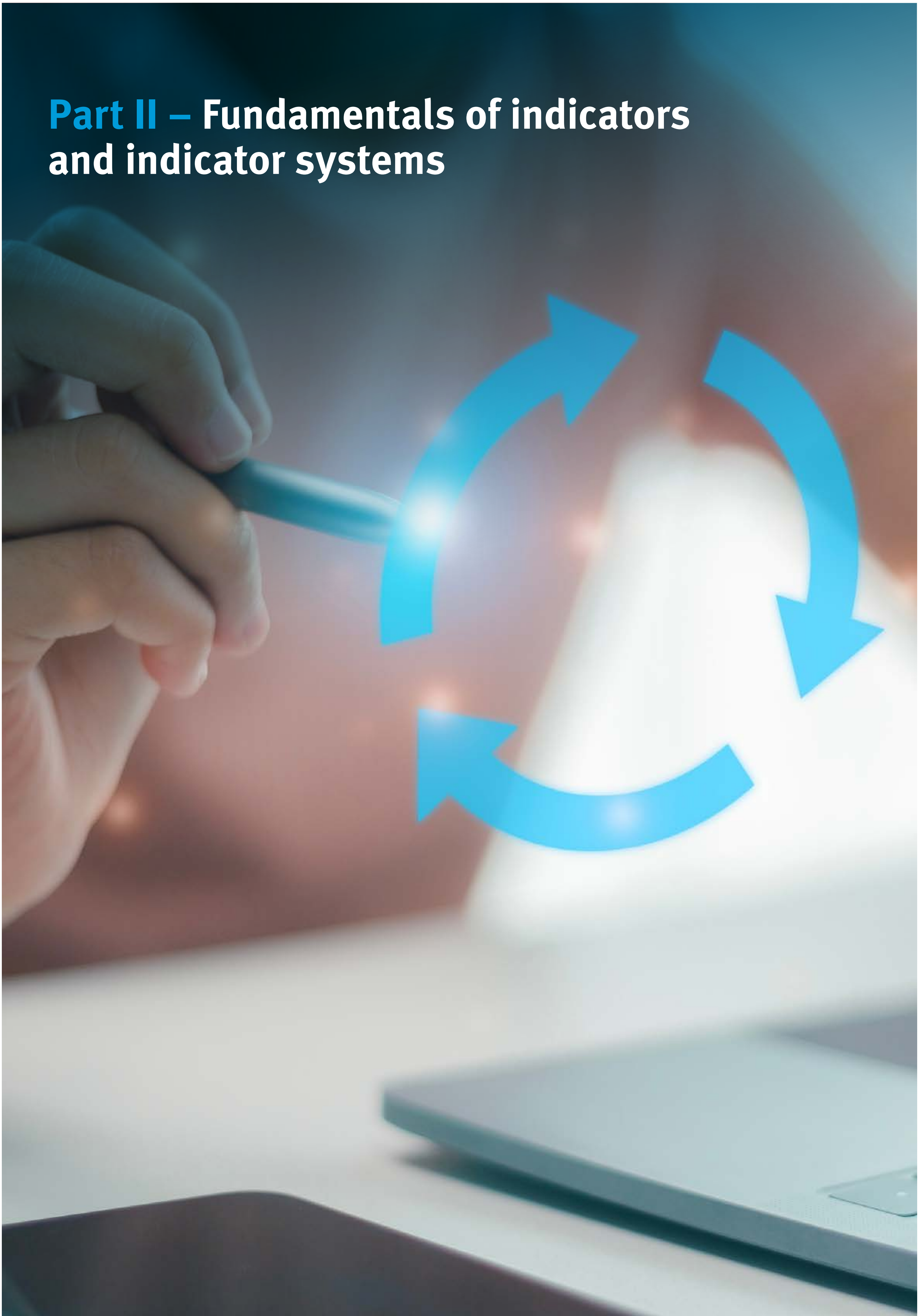
- For a list of key objectives or target indicators to be defined, a prioritization procedure is proposed for dealing with possible conflicts of objectives, as applied conceptually in the EU taxonomy (see Part II Chapter 2.4.3). Such an approach contains three elements:
- Selection of a priority indicator to which a measure should make a significant contribution.
- Requirement for all other indicators that no deterioration may occur.
- Definition of "k. o." criteria that may exclude a measure.

Guideline 7: Data basis

In order for indicator systems to have a practical influence on decisions, they must be underpinned by simple but validated calculation tools and data bases for fast and reproducible calculation of the respective indicators (see Part II, Chapter 3.4). To this end, existing databases must be further developed with regard to the following aspects:

- Easy-to-use and quality-assured standard data (e.g. emission factors) as well as simplified but tailor-made calculation methods and tools are required to determine the contribution of CE measures to target indicators (e.g. based on the Life Cycle Assessment (LCA) or footprinting methods), especially for user groups such as small and medium-sized enterprises (SMEs).
- Concrete, empirically proven data for complete recycling chains and the analysis of substitution effects are required for the balancing of material cycles. With regard to the long time periods of material cycles, a distinction should be made between ex-post and ex-ante approaches, which are based on a realistic picture of today's recycling on the one hand and on assumptions for future scenarios of possible recycling on the other.
- Overall, data bases represent the "infrastructure" for the calculation of indicators and thus for the evaluation of CE measures in the context of decision-making processes in politics, the economy and society. The continuous further development and maintenance of a core set of validated data sets should therefore be seen as a public task.

Part II – Fundamentals of indicators and indicator systems



1 Introduction

1.1 Motivation

Indicators and indicator systems play a key role in many policy areas, especially in the context of sustainable development. They are at the interface between science and policy and serve as a control variable in political strategies and for monitoring success. They are also used in communication with the public (Lehtonen, 2015). On the one hand, indicators are intended to provide simple statements, but on the other hand they sometimes represent highly complex issues. This field of tension makes the development of transparent, meaningful and consistent indicators or indicator systems is a challenging task. It also follows that when interpreting indicators for decision support in politics and other practical applications, an understanding of their conceptual foundations and framework conditions is essential.

The aim of this paper is to present the subject area of indicators in such a way that key principles that are important in practice can be understood and their relevance for a specific application context can be assessed. To this end, general definitions and statements from the scientific literature on indicators are first briefly summarized, then structuring systems for indicators or indicator systems in the context of sustainability are presented and finally indicators in the field of resources and circular economy (CE) are discussed.

The function of an indicator is to simplify by serving as a proxy for a complex fact or object. This leads directly to the requirement that there must be a causal relationship between the indicator and the fact or object represented. In addition, several indicators are often selected for interesting facts or objects and combined for a joint application. The causal or argumentative relationship between these indicators within the set and their role in the decision-making process must be clarified.

In the scientific literature, there are numerous works on indicators and indicator systems that deal with the methodology of creating indicators, with factual requirements in different subject areas, and with the concept of the "quality" of indicators. With regard to indicator systems in particular, it is pointed out that their derivation requires more than the simple compilation of individual indicators: *"a set of 'valid indicators' does not guarantee a 'valid set' of indicators"* (Schang et al., 2021). Many publications therefore focus on indicator systems, develop theoretical concepts for their development and validation and shed light on the work process and the involvement of stakeholders. The literature also contains numerous concrete proposals for indicator systems in specific fields of application of sustainability (e.g., for bioeconomy (Jander and Grundmann, 2019), water (Pires et al., 2017) and urban planning (Schebek and Lützkendorf, 2022)).

Despite the comprehensive treatment of indicators in the literature, problems arise in their practical application. Both theoretical concepts and specific indicator systems are highly complex, which requires specialist knowledge and makes communication outside expert circles more difficult. This complexity points to a fundamental trade-off with regard to the design of indicator systems: on the one hand, there is a desire to characterize an object or issue as comprehensively as possible, which leads to a large number of individual indicators. On the other hand, this results in a complex prioritization methodology that limits understanding and transparency. In addition, the necessary data must be available for the selected indicators, which can lead to a high workload or limit the implementation of an indicator system due to a lack of data.

1.2 Definitions and principles of indicators

The above-mentioned **definition of indicators** as proxies for complex facts or objects is generally accepted in the scientific literature, regardless of context or discipline. The following is a brief overview of general definitions and characteristics based on (Schebek and Lützkendorf, 2022). A general definition of indicators in the application context of ecology and environmental planning is given by (Heink and Kowarik, 2010) as follows: Indicators are *"a measure or component from which conclusions can be drawn about the phenomenon of interest"*. Definitions from practice, e.g. in a report by the World Resources Institute (Hammond et al., 1995)[7], by the EEA (Smeets and Weterings, 1999)[8], are consistent in meaning. The glossary of the Federal Agency for Civic Education (BPP, 2023) states: *"An indicator is a measure that indicates (social, economic, political) facts that are not directly measurable (e.g. average life expectancy as an indicator of a country's healthcare provision)"*. The term "parameter" is often used in connection with indicators. In the narrower sense, this stands for directly measurable facts; however, as these directly measurable parameters can also take on the function of an indicator, the terms overlap.

It follows directly from these definitions that the **relationship between the indicator and the object or fact to be depicted** must be justified by a hypothesis or a causal chain of effects (e.g: (Jander and Grundmann, 2019)[9]).

An indicator can be measured or determined directly or derived from several variables ("indirectly" determined). An example of the first case are so-called bioindicators, i.e. animal or plant species that indicate the state of an ecosystem and that are determined by direct observation or counting (Heink and Kowarik, 2010). More often, however, indicators represent derived figures or "indirect" variables that are determined using sometimes complex calculation methods or models. For example, the climate change indicator with the unit CO_2 equivalents is calculated from the contributions of various greenhouse gases using model-based factors Although a clear distinction between direct and indirect indicators is theoretically possible, this does not play a fundamental role in the application of indicators. Heink and Kowarik write *"...however, directness can lie along a spectrum and no uniform criteria for distinguishing between direct and indirect representation can be found in the literature."* (Heink and Kowarik, 2010). In fact, most indicators are not measured or empirically determined in the scientific sense, but derived from several variables using a calculation method. This points to the great importance of modeling for the derivation of indicators.

The indicator itself must be distinguished from a possible target value. While an indicator is primarily descriptive in nature, i.e. it specifies a value determined at a certain point in time and for certain framework conditions, a target value is a normative fixed value of an indicator that is to be achieved or can be used as a benchmark, i.e. it is used for evaluation. There is a connection here to the term benchmark as a generic term for evaluation standards. In the narrower sense, a benchmark is understood as a target value that reflects the numerical expression of an indicator to represent the objectives of a development or a measure (Schebek et al., 2022a). Target values can be derived at different levels and contexts, ranging from political goals to requirements in technical specifications.

7 "As commonly understood, an indicator provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable. […] Thus an indicator's significance extends beyond what is actually measured to a larger phenomena of interest."
8 "...environmental indicators provide information about phenomena that are regarded typical for and/or critical to environmental quality. ...Indicators always simplify a complex reality."
9 "An observable indicator needs to be linked to an unobservable construct through a correspondence rule, meaning a hypothesis regarding the relationship between indicator and construct. The rule can be derived via a causal model that makes assumptions regarding influences on a construct's development"

The terms indicator set, indicator system or indices are used in the literature for the **compilation of indicators**, although there is no clear distinction between these terms. In a publication on indicators for the area of resource efficiency of neighborhoods, the authors propose the following distinction (Schebek et al., 2022a): Simple collections of indicators are described as “open” indicator sets. The aim is to depict different perspectives on an object, e.g. the perspectives of different actors in participatory processes. Double counting does not play a role here, but indicators may not be aggregated for methodological reasons. In contrast, “closed” indicator systems are based top-down on a clearly designed homogeneous conceptual or model-theoretical approach that excludes double counting. Where appropriate, aggregations of different indicators can also be provided here, for which the terms composite indicator or single score indicator have been proposed in the literature (OECD, 2005). In this discussion paper, the term indicator system is used collectively for all compilations of indicators; where necessary, the distinctions described above are made for individual issues.

The **quality of indicators** is discussed in the literature in two directions: on the one hand, the content-related quality: this depends on whether an indicator or indicator set reflects the characteristics of the facts to be represented, i.e. whether a causal relationship can be demonstrated as mentioned above. On the other hand, the procedural aspect of quality is emphasized, which stands for the legitimacy, credibility and salience of indicators (Bauler, 2012). It is also common to describe the quality of indicators using the RACER assessment (relevant, accepted, credible, simple, robust, see e.g. (Nuss et al., 2021).

The procedural aspect of quality in particular (who are the people or groups that develop indicators and indicator systems) reflects social influences and the power-related dimension of indicators. There is a controversial discussion in the literature regarding the development of indicator systems as an expert task versus participatory processes of indicator development (Bauler, 2012; Fraser et al., 2006). (Heink and Kowarik, 2010) point out that if the object is not adequately understood and therefore no causal correlation can be established, indicators are also set normatively, i.e. they then derive their legitimacy primarily from politically set goals and procedural rationality. In any case, transparency and communication based on a clear definition of an indicator and an unambiguous description of the method used to derive it are important for the legitimization of indicators (Schebek et al., 2022a).

2 Indicators and indicator systems in the context of sustainable development – Sustainability Assessment

2.1 Overview

Indicators in the context of sustainable development are rarely collected directly, but are derived using more or less elaborate calculation methods or complex models. Usually, several indicators for different aspects of sustainable development are selected together. These indicator systems, together with the methods/models used to derive the indicators, are referred to in the literature with the overarching, yet vague term **"sustainability assessment"** (e.g. Andes et al. al., 2019; Ness et al., 2007; Singh et al., 2012; Waas et al., 2014). The sustainability assessment can be used for the comparative evaluation of alternatives, but can also include reference or target values: *"a given indicator doesn't say anything about sustainability, unless a reference value such as thresholds is given to it"* (Lancker and Nijkamp, 2000), cited from (Singh et al., 2012).

2.2 Characterization features for indicators

In general, individual indicators can be described and selected by different characteristics, some of which can also be applied to complete indicator systems: thematic, object-related or operational/ application-related.

A **thematic classification** is based on the substantive aspects of sustainable development. Here, criteria or properties of objects are selected on the basis of which an assessment is to be made. In the area of sustainability, structuring is often based on the three dimensions of ecological, economic and social. However, specific areas of sustainability are also formulated, such as in the 17 Sustainable Development Goals of the United Nations[10]. For specific areas of action, a thematic subdivision can be very detailed and extend down to the level of technical parameters, such as the energy consumption of buildings.

Object-related[11] indicators can be grouped according to the facts or objects they represent. These can be organizations such as companies or municipalities, the economy as a whole or its sectors, or individual products. In general, objects can also be selected individually in certain contexts. For example, in the context of planning processes, cities, neighborhoods or urban infrastructures are chosen as objects for indicator systems, the application of which is often linked to involvement in participatory processes (Schebek and Lützkendorf, 2022; Schinkel et al., 2022).

Measures are sometimes referred to as a further group of objects. Terms such as "activities", "strategies" or "projects" are synonymous, i.e. all ongoing processes that are aimed at changing an object. In this sense, they cannot simply be referred to as an additional object group, but have an independent character, which will be discussed later.

Application-related/operational: As a quantitative figure, an indicator is initially described by its dimension or reference value. Characteristic differences between indicators include whether they are defined as absolute or relative quantities or whether they have a time or mass-related dimension. Other criteria relate primarily to the practical properties of indicators. For example, (Niemeijer and de Groot, 2008a) mention systemic criteria (e.g. scientific underpinning), intrinsic criteria (e.g. uncertainty), financial criteria (e.g. costs of data procurement) and strategy/ management-related criteria (communicability).

10 https://www.bundesregierung.de/breg-de/themen/nachhaltigkeitspolitik/die-17-globalen-nachhaltigkeitsziele-1553514
11 This paper uses the term "object", as this linguistically reflects the "passive" character of the description of facts and objects by indicators and is also commonly used in literature and (standardization and other) documents. However, other terms are also used, for example the current standard ISO 14068 – Climate Change Management uses the term "subject", but describes the term "object" in the same way as it is used in this paper.

The characterization features of indicators described above will be illustrated using a common indicator mentioned at the beginning in the text.

Example: "Average life expectancy as an indicator of a country's healthcare provision".

Complex issue to be assessed by the indicator: "health care"

Thematic criterion selected for the indicator: Life expectancy

Object: Country (e.g. Germany)

Application reference of the indicator: Absolute value, for a specific time-period. Other application-related criteria: average life expectancy is an easily accessible and statistically sound demographic variable.

Definition of the indicator: average life expectancy at birth, shown separately for men and women at 38.5 years, according to the results of the current mortality table for Germany.[12]

2.3 System framework and methodologies for deriving indicators

In the field of sustainable development, certain types of system frameworks on which indicators are usually based have developed from different contexts and the interest of decision support and monitoring at different levels. On the one hand, these system frameworks have a reference to the object, but this reference is variable: Indicators for the same object of interest can be formed in different system frameworks. The respective system framework is therefore characterized more by the associated methodological approaches to deriving indicators than by the object itself. Three types can be distinguished here[13]:

System framework nation as a political/economic unit: This system framework is the basis for national statistical systems and national economic accounts based on the territorial principle[14]. In Germany, the so-called environmental economic accounts (UGR) are based on this method[15], which are used to calculate the indicators of the German sustainability strategy, e.g. primary energy consumption or raw material productivity, but also economic and social indicators. The UGR corresponds to the United Nations' international System of Environmental and Economic Accounting (SEEA)[16]. The national inventory reports of international climate reporting according to the system of the Com mon Reporting Framework (CRF) are also based on the territorial principle.

System framework Organization as a legal entity (especially companies): This system framework has developed conceptually from the management systems of organizations (e.g. ISO 9001, EMAS, ISO 14001) and focuses on the direct area of action of the legally delimited organization (in the case of companies taking subsidiaries/shareholdings into account). One example is the "GHG Protocol Corporate Accounting and Reporting Standard", which is widely used today and which is referred to as the GHG Protocol for short[17]. Here, three operational system boundaries (scopes) are defined within the organizational-legal system boundary of an organization, which subdivide the scope of an organization's activities. Scope 1

12 https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Sterbefaelle-Lebenserwartung/_inhalt.html
13 The subdivision described here also corresponds to the system of carbon accounting, in which accounting is carried out at the levels of the economy, the organization (company) and the product (Stechemesser and Guenther, 2012).
14 Territorial principle: Emissions on the territory of Germany, i.e. including foreign companies based in Germany and excluding emissions from German companies based abroad. Source: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/Glossar/treibhausgasemissionen.htm
15 https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/UGR/_inhalt.html
16 https://seea.un.org/
17 https://ghgprotocol.org/standards

comprises the emissions generated directly by the operational activities of the company at its sites, Scope 2 comprises the indirect emissions from the generation of purchased energy (electricity and heat), Scope 3 comprises all other indirect emissions, such as in the supply chain and in the use and disposal of the products manufactured.

System framework for the life cycle[18] of products as a conceptual unit: In contrast to the two aforementioned frameworks, this system framework is not based on a legally justified demarcation, but on the idea of the physical life cycle of products from raw material extraction to disposal ("life cycle thinking", "cradle-to-grave"). The corresponding methodology is Life Cycle Assessment (LCA) according to ISO 14040/44. The so-called product system is assessed, which includes all relevant processes for the production, manufacture, use and disposal of a product that are linked by material and product flows. Against the backdrop of multi-stage and globally distributed production and consumption patterns, this system framework is "horizontal" (or cross-cutting), i.e. the respective product system includes processes from different nations/economic areas and organizations/actors. The system framework of the life cycle is also the basis of so-called footprints of products, such as the carbon footprint[19] and the water footprint[20]. These follow the methodology of the LCA with minor modifications, but are limited to a selected environmental impact.

The system framework of nations or economic areas is also referred to as the *macro level*, while the organizational framework and the life cycle of products are often referred to as the *micro level*. As can be seen from the above, the motivation for the three types described is the orientation towards a specific decision-making level and its relevant actors, which is why all three approaches are justified and have a practical relevance.

As a result, indicators based on all three approaches exist in the area of sustainability. The differences between the three levels are significant and fundamental, both in terms of the processes/issues covered by the system framework and the methodology used and the data basis required. For this reason, indicators that were derived using different system frameworks/methodologies cannot simply be transferred to one another.

The described systematization is made more complex by current approaches for "mixed forms", for example footprints of nations and organizations. These mixed forms are clearly characterized by the methodology, namely by the life cycle approach of products. Statements for the system framework of a nation or organization are derived by adding up the results of all life cycle analyses for those products that are consumed or produced in a "basket of goods" by the legal entity of a nation or organization. In addition, the term "meso-level" is occasionally used for product / production / consumption / needs sectors. However, one of the three approaches mentioned above is also used for accounting, usually the life cycle approach using a "basket of goods".

The problem of compatibility between indicators of the three system frameworks/methodologies is a major and current challenge for research and practice. On the one hand, indicator systems should be user-oriented and therefore apply user-specific system boundaries and methodologies. On the other hand, a common target system should apply to the topic of sustainability, which must necessarily be

18 Referred to as "life cycle" in DIN EN ISO 14040/44
19 Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification (ISO 14067:2018); German and English version EN ISO 14067:2018
20 Environmental management – Water footprint – Examples of the application of ISO 14046 (ISO/TR 14073:2017); Text German and English Edition 2019-01

formulated at the societal and thus macro level. One approach discussed here is an orientation towards global targets and target values, which goes hand in hand with systems for deriving target values for benchmarking at the respective levels or with the development of stakeholder-specific indicators that have a conceptual link to these global goals. Global targets based on scientifically based definitions of the limits of the carrying capacity of the natural environment were proposed with the concept of planetary boundaries (Rockström et al., 2009). The Earth Commission[21] is currently working on updates to many targets and limits (Rockström et al., 2021). The 17 Sustainable Development Goals of the United Nations[22], which are underpinned by a total of 232 indicators for the national level, should be mentioned as politically agreed targets. Systematics for deriving specific targets for individual actors are referred to in the literature as “absolute sustainability assessment or absolute environmental sustainability indicators” (Bjørn et al., 2020, 2015). The Science-Based Target Initiative[23] pursues a top-down approach in order to derive specific target values for companies from the global climate target. Overall, however, it should be noted that there is still a long way to go in terms of method development and data provision before generally recognized and practicable global target values and systems of attribution to actors are achieved.

2.4 Structuring approaches for indicator systems

2.4.1 General requirements

Indicator systems comprise a large number of indicators that must always apply to the same system boundary and the same object. In general, the development of indicator systems is caught between two conflicting demands (as already mentioned): on the one hand, the respective subject area should be described as comprehensively as possible, which leads to a large number of indicators in complex subject areas. On the other hand, indicator systems serve to support decision-making, which makes it necessary to limit them to ideally one or a few indicators. This area of conflict results in the need for a structure both for the selection of indicators and to support decision-making.

2.4.1 Selection of indicators

The selection of indicators for indicator systems has the objectives of: (i) achieving an adequate representation of the subject area for the selected object, (ii) in the case of closed indicator systems, ensuring the independence of indicators in terms of content, and (iii) adapt the indicator system to the decision context. (Sala et al., 2015) point out that the decision context together with object/level determines the selection of a method for determining an indicator.

In this context, particular attention must be paid to the **distinction between the objects themselves and the measures that affect them.** This is discussed in detail in a handout for indicators in the field of resource-efficient neighborhood development[24] (Schebek et al., 2022a). With regard to the object, it is a question of assessing the condition or characteristics of the object at a certain point in time (e.g. before or after refurbishment). The corresponding decision-making contexts are either the identification of the need for action or monitoring with regard to a desired target state. In contrast, for a measure its ability to contribute to achieving the target is evaluated.

21 https://earthcommission.org/
22 https://sdgs.un.org/goals
23 https://sciencebasedtargets.org/
24 Measures are defined as: all technical, design, organizational, social and financial activities/installations/actions that have a targeted effect on the neighbourhood and lead to changes inside or outside the neighbourhood (Schebek et al., 2022a).

This connection between the choice of indicators and the decision-making context is presented as an example for planning processes. The German Environment Agency's guideline on corporate environmental indicators (UBA, 1997) can serve as an illustration, which distinguishes between three classes of environmental indicators: environmental impact (environmental performance) (evaluated using, e.g., figures on material use energy use), environmental management (e.g., using data on the number of environmental training courses conducted), and environmental status indicators to assess the quality of the natural environment. In this case, the objects of an assessment are either the company itself or the environment on which it has an impact. Key figures of environmental management describe measures ("activities") of the company and are *"internal control and information variables which, however, do not provide any information about the actual environmental performance of the company"* (UBA, 1997).

Content-oriented structuring approaches are based on the above-mentioned thematic or object-related criteria and are aimed at causally closed indicator systems. Accordingly, such indicator systems are usually developed by groups of experts. A frequently used structuring approach is causal networks, which represent the causes, consequences and reactions of the environment to societal influences in a systemic way (Niemeijer and de Groot, 2008a). The best-known system is the *Driving Forces-Pressures-States-Impacts-Responses (DPSIR) model* developed by the OECD and EEA (Niemeijer and de Groot, 2008b). Although originally intended for the country level, this concept of a causality network can be seen as a universal concept for the representation of the interaction between the environment and society and the development of corresponding indicators (Binder et al., 2013). It has also been used for decision-making at the regional or local level (Tscherning et al., 2012). In (Schebek et al., 2022a), the DPSIR model is used to substantiate the relationship between different types of indicators for the target level and the measure level.

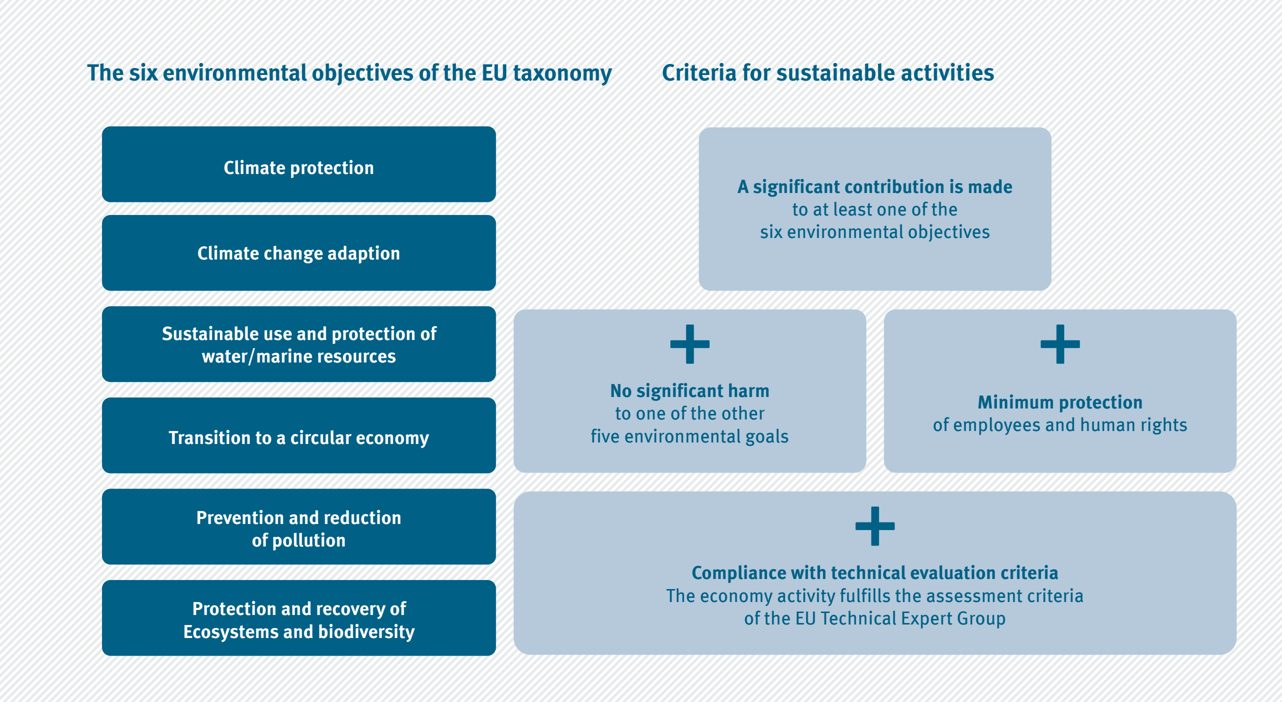
2.4.3 Prioritization for decision-making

In the case of indicator systems with a large number of individual indicators, decision support means answering the question of which of these indicators have priority for the decision. In some cases, it is easy to see that individual indicators, e.g. technical indicators, are rather auxiliary variables or have limited significance, while others are central to the decision. However, often this is not immediately clear, and in the interests of transparent decision support, it is always necessary to make the prioritization of indicators explicit. This requires a **hierarchical categorization/structur**e of indicators according to their relevance for decision-making. A key approach is the hierarchical categorization between target indicators and operational indicators. Target indicators are oriented towards an overarching target system consisting of socially/politically defined sustainable development goals as described above. In contrast, operational indicators describe the characteristics of an object or a measure that – particularly from the perspective of the actor – represent properties or developments that contribute to the overarching goals, such as the efficiency of the energy transition. An example of such an indicator system is the hierarchical framework of the sustainability assessment proposed by (Sala et al., 2015), in which a clear distinction is made between the indicators at the target level and at the operational/measure level. Prioritization is also necessary at the target level for transparent decision-making if several target indicators are set in a system. This can be done, for example, by defining a list of a few "core indicators" based on arguments (see e.g. (Lützkendorf and Balouktsi, 2017)). The key aspect here is the legitimization of the target indicators, which ideally takes place in a participatory or consensus-based democratic process.

Figure 2

EU Taxonomy:

Classification of the sustainability of economic activities based on six environmental goals and four criteria.



UBA Resource Commission's own illustration based on https://eu-taxonomy.info/de/info/eu-taxonomy-grundlagen and https://www.weshyft.com/die-eu-taxonomie-fur-nachhaltiges-wirtschaften/.

In this context, methods of multi-criteria decision analysis (MCDA) are also being developed, which can in principle be used in all application contexts (see e.g. (Geldermann and Lerche, 2014; Schär, 2018)). Many of these methods are based on challenging mathematical approaches that are not easy to understand and difficult to communicate. User-friendliness and transparency are particularly important here, especially with regard to the transfer of value judgments of the groups and individuals involved into the weighting factors used in the MCDA.

A current example of a prioritization process without the use of weighting factors can be found in the EU taxonomy[25], here at the level of headline targets, on the basis of which the sustainability of an economic activity is to be reviewed. To this end, the EU taxonomy specifies six environmental objectives (respective headline targets) (see Figure 2).

The classification of economic activity is based on four criteria that are set in relation to these key objectives: (1) the economic activity contributes to at least one of the six environmental objectives, (2) the economic activity does no significant harm to any of the environmental objectives, (3) the economic activity meets a minimum of safety standards to avoid a negative social impact and (4) the economic activity meets the technical screening criteria developed by the EU Technical Expert Group.

25 https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

3 Indicators of the Circular Economy (CE)

3.1 Background: Circular economy and natural resources

The term circular economy (CE) is now an integral part of sustainability policy, both at European and German level. Although the term itself could simply be seen as an English translation of the German term "Kreislaufwirtschaft", it has recently been interpreted much more comprehensively than the classic circular and waste economy. This broader view has been implemented in policy in particular through the EU Green Deal (EC, 2019), whose objective is formulated as follows: *"Transition the EU to a modern, resource-efficient and competitive economy with zero net greenhouse gas emissions by 2050"*[26]. A key element of the Green Deal is the circular economy: *"Part of the Green Deal is a climate-neutral circular economy in which economic growth is decoupled from resource use."*[27]. The main objective of the CE within the Green Deal is therefore to conserve natural resources.

The concept of natural resources was introduced into environmental and sustainability policy by various EU thematic strategies, in particular the *EU Thematic strategy on the sustainable use of natural resources (2005): (COM(2005) 670 final)*[28] *and* the *Roadmap to a resource efficient Europe (2011) (EU Commission)*[29]. Based on this, the following definition can be found in the German Environment Agency's (UBA) glossary of resource protection[30]:

"Resource that is part of nature. These include renewable and non-renewable primary raw materials, physical space (land), environmental media (water, soil, air), flowing resources (e.g. geothermal, wind, tidal and solar energy) and biodiversity. It is irrelevant here whether the resources serve as sources for the manufacture of products or as sinks for the absorption of emissions (water, soil, air)."

This definition, which also forms the basis of the EU Green Deal, includes several resources as equally important protected goods. It thus clearly goes beyond the colloquial use and geoscientific definition of resources as raw materials. However, this distinction is not always clearly maintained in practice; for example, renewable and non-renewable raw materials are often referred to as natural resources. The latter use of the term goes back in particular to the International Resource Panel (IRP) founded by the UNEP in 2007, which defines resources as follows: *"Resources – including land, water and materials – are seen as parts of the natural world that can be used in economic activities to produce goods and services. Material resources (see above) are biomass, fossil fuels, metals and non-metallic minerals"* (UNEP IRP, 2024).

With this in mind, the Acatech Circular Economy (CE) Roadmap Germany quantifies the relationship between the circular economy and the environmental impact of raw material use as follows (CEID, 2021):

"In concrete terms, the promotion and refinement of natural resources account for 50 percent of global greenhouse gas emissions and 90 percent of land-use-related biodiversity loss and water stress (UNEP IRP, 2019) "publisher": "United Nations Environment Programme" (UNEP). In this context, the CE offers Germany an overarching narrative that can link economic and environmental policy in response to this new dynamic and thus make a significant contribution to achieving the goals of the European Green Deal (EC, 2019) (in particular climate neutrality by 2050)."

There is also a close connection between the concepts of natural resources and raw materials due to the connection between CE and strategies for securing raw materials at European and German level.

26 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_de
27 https://ec.europa.eu/commission/presscorner/detail/de/ip_20_420
28 COM(2005) 670 final Thematic Strategy on the sustainable use of natural resources. {SEC(2005) 1683}. {SEC(2005) 1684} https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005:0670:FIN:EN:PDF
29 http://ec.europa.eu/environment/resource_efficiency/about/index_en.htm
30 https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/4242.pdf

The German raw materials strategy defines three pillars for the supply of raw materials to the German economy, one of which is the "use of secondary raw materials from recycling"[31]. The recently adopted EU regulation on critical raw materials (Critical Raw Materials Act, CRMA) includes the specific target of providing 25% of raw material requirements from recycled materials each year[32].

Despite the relevance of CE for achieving various environmental goals and the goal of securing raw materials, no legally binding CE definition has been established at EU level. The following CE description can be found consistently in EU announcements[33] and also in the new Taxonomy Regulation (Art. 2)[34]:

"An economic system in which the value of products, materials and other resources in the economy is maintained for as long as possible and their efficient use in production and consumption is improved, thereby reducing the impact of their use on the environment and minimizing the generation of waste and the release of hazardous substances at all stages of their life cycle, including through the application of the waste hierarchy".

Even if this description sounds rather operational and such a production and consumption model could be seen as an end in itself, by embedding it in the context described above, it is very clear that a CE is not an end in itself, but a means of achieving key objectives of sustainable development, in particular climate protection and the conservation of natural resources. With the **Circular Economy Action Plan (CEAP)**[35], the CE was defined in particular as an integral part of the Green Deal and thus of climate policy. The foreword to the CEAP specifies the connection between the circular economy and the goals of the Green Deal[36] as follows: *"Expanding the circular economy [...] will be instrumental in achieving climate neutrality by 2050, decoupling economic growth from resource use while ensuring the EU's long-term competitiveness and leaving no one behind".* Section 6 further specifies this through the measures within the CEAP:

- Analysis of the impact of the circular economy on climate change mitigation and adaptation;

31 https://www.bmwk.de/Redaktion/DE/Artikel/Industrie/rohstoffstrategie-bundesregierung.html
32 https://www.consilium.europa.eu/de/press/press-releases/2024/03/18/strategic-autonomy-council-gives-its-final-approval-on-the-critical-raw-materials-act/
33 See e.g. EU Parliament: https://www.europarl.europa.eu/news/de/headlines/economy/20151201STO05603/kreislaufwirtschaft-definition-und-vorteile Eurostat: https://ec.europa.eu/eurostat/web/circular-economy
34 https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:32020R0852
35 https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en
36 See also (Schebek et al., 2022b).

- Improve modeling tools to capture the benefits of the circular economy for reducing greenhouse gas emissions at EU and national level;
- Strengthening the role of the circular economy in future revisions of national energy and climate plans and, where appropriate, as part of other climate policy measures.

This correlation is clearly formulated in the Acatech Roadmap CE (CEID, 2021): *"Thus, the successful implementation of a circular economy is not an end in itself, but combines climate and resource protection with cultural change, the increase of competitiveness and raw material independence as well as the creation of jobs and local value creation in the sense of sustainable win-win solutions."*

The above description of the CE as an economic system shows how broadly such a transformation must be approached: *"The transition to a circular economy represents a fundamental, societal transformation process that can only succeed through the participation and cooperation of all actors."* (CEID, 2021). In this context, indicators and indicator systems play a key role both in the design of strategies and in monitoring their implementation. The position paper of the Resource Commission on the substitution rate states (UBA Resources Commission, 2019): *"Indicators are an essential component of political action. They are used to review measures or activities such as political programs and strategies and to evaluate their success or failure. An effective indicator system is necessary to measure the success of a waste management system or a circular economy."*

3.2 Target orientation and measures of the circular economy

As the previous section shows, the concept of the CE is **goal-oriented**, i.e. it functions as a key strategy for achieving the goals of resource conservation in general and climate protection in particular. It follows that an indicator system for the CE must be fundamentally aligned with the key objectives of the CE and thus structured hierarchically. These key objectives are the same for all levels and all actors. However, different and/or actor-specific are: (i) target values that describe the characteristics of the headline targets at certain levels or for certain actors (e.g., sector targets in climate protection) (ii) operational indicators that support the control or monitoring of the success of measures in specific fields of action and for certain groups of actors (e.g., recycling rates as a target for actors in the waste management industry).

CE measures are therefore an important structuring feature of CE indicators at the operational level. The CE itself is often described as a combination of measures in the sense of strategies or fields of action. The terminology of so-called "R-strategies" is common, initially formulated as 3R strategies (*reduce, reuse, recycle*) (Kirchherr et al., 2017), later broken down further to a 9R or 10R scheme (Potting et al., 2017). (Moraga et al., 2019) speak of a CE in the narrow sense, which refers to ("*...the technological cycle of resources*"), while the CE in the broader sense encompasses the entire economy ("*...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.*") (Moraga et al., 2019). Looking back on its historical development, the CE in the narrower sense can be seen as the further development of the waste/disposal industry into the "circular economy" with a focus on recycling and closing material loops, while CE in a broader sense refers to the new concept of a CE as a form of economy, as is the basis of current EU policy under the Green Deal and CE Action Plan.

Such a localization of R-strategies can be found in a similar way in other scientific publications as well as in political documents. For example, (Kristensen and Mosgaard, 2020) distinguish an inner and an outer circle of CE. They assign the measures (reuse, repair or maintenance) to the inner circle, while the outer circle includes recycling/material cycles and thus corresponds to the CE in the narrower sense. In the political sphere, the waste hierarchy, which was first introduced as part of the EU Waste Directive in 2008[37]and adopted into German waste law, described a differentiation and ranking between different circular economy measures. in current EU policy, the Technical Working Group of the Platform on Sustainable Finance describes four so-called "high-level categories of substantive contributions to CE (along the circular economy loop)": Circular design & production; Circular use; Circular value recovery, and Circular support. While three of these categories relate to the economy as a whole, the category of circular value recovery is geared towards the recycling of waste and thus corresponds to the classic field of the circular economy. In this respect, **recycling**, i.e. the material recovery of waste with the aim of recovering materials and raw materials, remains an indispensable component of CE, but must be located within the other strategies of CE in the broader sense[38].

As described above, a distinction between CE in the narrower and broader sense is common, but there is a lack of clarity in the literature with regard to the classification of individual measures. However, a clear structuring into **CE measures in the narrower and broader sense** is essential from two points of view:

i. The distinction between prevention on the one hand and recycling, energy recovery and disposal on the other is directly linked to the **legal concept of waste:** all prevention measures are effective where no waste exists in the legal sense, i.e. in the economy as a whole, while the other measures – both material and energy recovery and disposal – are linked to the legal concept of waste. Within the measures applicable to the concept of waste, as the waste hierarchy states, the top priority is recycling, i.e. material utilization, which corresponds to CE in the narrower sense.

ii. The distinction between recycling and other CE measures in the broader sense is central to the **methodology for calculating** savings in resources and greenhouse gas emissions (see (VDI, 2022)). While avoidance measures (e.g. reducing the use of materials or using products for longer) lead directly to savings in raw materials, the effect of recycling is indirect: the material recovery of waste leads to the provision of secondary materials, which is initially associated with expenses for collection, transportation and processing. A reduction in the consumption of raw materials and environmental impacts only occurs when these secondary materials actually replace primary materials. For accounting purposes, this means taking into account the technically achievable substitution rates as well as an economic analysis of the absolute quantities of a secondary raw material that are available at a given time.

37 Directive 2008/98/EC of the European Parliament and of the Council of November 19, 2008 on waste and repealing certain Directives (Text with EEA relevance).
38 This understanding of recycling is also the basis of the UBA Resource Commission's paper "Opportunities and limits of recycling in the context of the circular economy: framework conditions, requirements and recommendations for action" (UBA Resource Commission, 2023).

3.3 Overview of CE indicators and indicator systems

In recent years, the dynamics and introduction of the CE concept into political strategies has led to numerous proposals for CE indicators and indicator systems, the complete review of which would go beyond the scope of this paper. In the following, therefore, review articles from the scientific literature are first used to provide a general overview, before the next section presents the indicators and indicator systems currently used in practice. The relevant indicators and developments are presented in this report.

The literature shows the **wide variety of CE indicators and indicator systems** that have been developed for different levels and specifying numerous operational indicators for different measures and different actors with different terminologies. Mo raga distinguishes between indirect and direct CE indicators (Moraga et al., 2019), with the former representing target indicators, while direct indicators are defined at the operational level. (Pacurariu et al., 2021) point out that CE indicator systems have been conceptualized, classified and analyzed in a very short period of time and therefore no generally accepted terminology has yet emerged. Overviews of CE indicator systems with structuring approaches in levels or measures can be found in (Corona et al., 2019; Helander et al., 2019; Moraga et al., 2019; Saidani et al., 2019). With regard to the **thematic classification** of CE indicators, it can generally be said that, at the operational level, these include both quantity-related indicators focused on substance and material consumption as well as economic or management-related indicators. **At the object level**, the Acatech Roadmap (CEID, 2021) follows in a compilation of so-called "Metrics for Circularity" at the three levels described above: nation (referred to here as the macro level), organization (referred to here as the micro level) and product. The terms micro and macro are used differently in the literature. In (Ghisellini et al., 2016; Kirchherr et al., 2017; Saidani et al., 2019) the following interpretation can be found:

- Macro: Nations, regions, cities
- Meso: business areas, industrial symbiosis/ "eco-industrial parks"
- Micro: companies, products, components, materials, consumers

This interpretation is based less on methodologies and more on (economic) **actors**. From this perspective, the macro level stands for the state actor, while the term micro focuses on companies and consumers as actors. The term meso, on the other hand, is obviously vaguely defined, as evidenced by the fact that hardly any indicators are proposed specifically for this level.

In the following, the terms macro- and micro-level are used in their actor-related meaning and organizational/company-related and product-related indicators are combined at the micro-level. For the **macro level**, (Pacurariu et al., 2021) refer to an OECD report in which several hundred CE indicators from 29 sources are compiled (as of 2014); a current OECD report includes 474 CE indicators at national, regional or municipal level, including indicators for companies and business models (OECD, 2021). The status of indicators at national level is assessed in the Acatec Roadmap CE as follows (CEID, 2021): *"However, the analysis shows that only a few metrics, mainly for recycling and recovery, are currently proposed for assessment at the national level – and even these are in most cases for assessment of the actual physical circularity. In addition, there is currently a lack of both calculation methods and data for most of the proposed metrics in connection with the other circular strategies such as rethink/redesign, repair, reuse and remanufacturing. Furthermore, only a few metrics are proposed in the literature for evaluating the environmental, economic and social impact of a circular economy. It is also questionable whether the proposed metrics are able to measure the contribution of circular economy activities to reducing impacts at a national level."*

Overviews of indicators **at the micro level** can be found in (Kristensen and Mosgaard, 2020; Moraga et al., 2019). These include indicators at both the organizational level and the product level. A current compilation of CE indicators and tools can be found on a website of the French engineering school CentraleSupélec[39]. (Ibáñez-Forés et al., 2022) note that there has been a significant increase in publications on indicators at the organizational

39 https://circulareconomyindicators.com/advisor.php

level over the last ten years, both in the scientific literature and in public and private initiatives. CE strategies are suggested as a way of structuring at the micro-level (Kristensen and Mosgaard, 2020) and the authors conclude from a detailed literature analysis that there is no single method for measuring CE at the micro level. (Kristensen and Mosgaard, 2020) also note for the micro level that recycling indicators have a longer tradition in waste management, whereas the consideration of CE measures in a broader sense is developmental. (Pacurariu et al., 2021) write that the wide variety of types, dimensions and sustainability aspects can make it difficult for companies to find their way through the indicator jungle. (Kristensen and Mosgaard, 2020) emphasize that diversity and lack of certain indicators *"...is an obstacle to the further diffusion and implementation of CE, as it is difficult to measure progress towards CE goals in organizations."*

At both the macro and micro level, it can be seen that indicators are primarily proposed for the area of recycling. These indicators are related as absolute or relative values for material flows, usually waste in the legal sense. At the macro level, indicators for political control are often linked to normatively set targets (so-called quotas[40]). One advantage of a material flow-based approach is that material cycles in the economy encompass all actors and thus combine micro and macro levels. Material flow analysis (MFA) is a suitable scientific method for balancing material cycles. However, there are a number of methodological problems for the practical determination of material flow-related indicators and normative quotas, which are dealt with in (UBA Resource Commission, 2023, 2019) and DGAW 2024[41] .

On the one hand, the question arises as to where indicators should be set. There are two different approaches to this: Recycling rates are defined within the legal framework of the waste management industry and describe the proportion of a waste stream that is recycled after processing.

In contrast, substitution rates, as defined in (UBA-Ressourcenkommission, 2019), quantify the ratio of secondary raw materials used to the total material input used in the economy. In contrast to recycling quotas, they therefore provide information on the actual amount of primary raw materials substituted. Another question is whether quotas should relate to the total mass of waste or to the substances of interest contained in waste, especially critical raw materials. Linked to the indicators is the system boundary in which they are to be determined. The data is usually based on national statistics. However, this ignores problem shifts at the international level. For this reason, the UNEP International Resource Panel called for the establishment of a global or life cycle-based approach for CE indicators as early as 2011 (UNEP IRP, 2011). Currently, (Nuss et al., 2021) proposed a monitoring system for Germany for natural resources based on the life cycle approach, which should recognize possible trade-offs between different resource categories, regions or environmental impacts.

In general, there is criticism in the scientific literature that the connection between operational CE indicators and sustainability objectives is not sufficiently proven. As a result, authors such as, e.g., (Haupt and Hellweg, 2019) criticize that material flow or quantity-based recycling targets have not yet been shown to be related to environmental relief and call for the balancing of CE measures on the basis of life cycle assessment (LCA). (Panchal et al., 2021) conclude from a review of the literature that a direct link between CE indicators and a reduction in environmental impacts has not yet been shown. The use of LCA for the evaluation of CE indicators is therefore a very topical issue, but one that still poses a whole range of methodological challenges (Saidani et al., 2022).

40 Although the term quota actually refers to the target value, it is usually equated with the indicator both in the scientific literature and in the political environment. Example: the XXX Regulation requires a recycling rate of 50% as a normative target value. The current indicator value is determined each year with the statement: "In 202X, a recycling rate of 47% was achieved".
41 https://dgaw.de/de/akademie-der-kreislaufwirtschaft/veroeffentlichungen

3.4 Data basis for CE indicators

The above descriptions of indicators in general and for the CE in particular make it clear that a large number of different data bases are usually required to calculate an indicator. In scientific studies, data research is often the most extensive and labor-intensive part, even though many scientific databases can be used today. However, if indicator and indicator systems are to have a practical impact, then the time and effort involved in scientific studies is not possible. Instead, it must be ensured that indicators for decision support can be calculated using simple but validated calculation tools and on the basis of validated, easily accessible data. To this end, the question of which types/types of data/data sets are required and where these can be easily obtained in practice is crucial.

The distinction between the target level and operational level of indicators is also important for the question of what types of data are required. For the calculation of indicators for the headline targets, which are the same for all actors as shown, factors can be provided in the unit of the indicator. A well-known example is emission factors for greenhouse gases. These can be provided in databases, which require regular checks to ensure that the data is up to date, but on this basis have a certain universal usability over a certain period of time. The continuous further development and maintenance of a core set of validated datasets can therefore be seen as a public task.

At the operational level, a greater variety of data is available that is specific to fields of action (e.g. on the basis of specific statistics (e.g. in the area of waste management). However, this can also include internal company data whose accessibility is limited. The consolidation of data under consideration of ownership and the safeguarding of confidentiality is a current state of research on digitization, so that practicable solutions can be expected in the future.

Overall, it can be said that data bases represent the “infrastructure” for the evaluation of CE measures in the context of decision-making processes in politics, business and society. This is an extremely relevant topic at the moment, also because there are increasing reporting obligations in the EU (e.g. EU Taxonomy, Corporate Sustainability Reporting Directive (CSRD), etc.). On the one hand, this increases the need for data (e.g. emission factors), while on the other hand, reporting obligations will also result in more data being made public in the future, which can form the basis for databases.

3.5 CE indicators in practice (status 2024)

The following presentation focuses on the situation in the EU, which is currently characterized above all by the activities of the EU Commission as part of the European Green Deal and CE Action Plan (CEAP) in conjunction with the objectives of the policy on (critical) raw materials.

At the macro level, the EU has presented a list of 10 indicators as part of the Green Deal as a so-called "monitoring framework" (EC, 2018). This includes indicators related to quantity material flow as well as economic and management indicators. In EU statistics, this monitoring framework is broken down more into individual indicators[42]. In the area of material flow-related indicators, the "Circular Material Use Rate (CMUR)" and the "End-of-Life Recycling Rate (EOL-RIR)" (for individual raw materials) define the contribution of recycled materials to the demand for raw materials. Both are determined on the basis of material flow analyses for the EU material system analysis. In principle, the determination of these indicators is based on the territorial principle. In 2023, however, the revised CE monitoring framework included two further indicators based on the life cycle principle, the *material footprint* and the *consumption footprint*.

The indicators of the EU Monitoring Framework are to be implemented as "levers" within the various legislative requirements of the EU, which could be done either as a normative requirement or as a monitoring/reporting requirement. Accordingly, the EU's monitoring framework provides the background for numerous individual specifications for different material flows and economic sectors, in particular for the six priority economic sectors (key industries) named in the CEAP. In the Battery Directive, quotas for individual raw materials were set for the first time and the specification of individual indicators was concretized (UBA Resource Commission, 2023). Raw material consumption poses a special problem: on the one hand, this is seen directly as a key objective and presented with the target indicator of (abiotic) raw material consumption. On the other hand, it is argued that the actual key objectives are the availability of raw materials on the one hand and the environmental impact or consumption of natural resources on the other, and that suitable indicators should be selected for this.

At the micro level, the use of indicators and indicator systems by companies has so far been voluntary, especially in the context of environmental or sustainability reporting. Against this backdrop, the relevance of corresponding indicator systems was primarily due to the dissemination and acceptance of indicators and the organizations that developed them or offered tools. Examples include the Ellen MacArthur Foundation (EMF) with the "Material Circularity Indicator"[43]and the World Business Council for Sustainable Development (WBSD) with the Circular Transition Indicators[44]. The Green Deal policy changes this situation, as it sets mandatory sustainability reporting requirements that also include CE information and indicators. The two main instruments are the CSRD and the EU taxonomy.

The CSRD Directive replaces the Non-Financial Reporting Directive (NFRD), which has been in force since 2014, and is intended to provide stakeholders with information to assess a company's contribution to sustainability. It applies to all companies with the exception of micro-enterprises. The targets are set by the companies themselves. The content of the reporting is being developed through 12 European Sustainability Reporting Standards (ESRS), including the *ESRS E5 standard (resource use and circular economy)*[45] . This is part of the first set of standards to be applied from January 1, 2024. With regard to material flows, the standard stipulates that the absolute quantities of materials and waste must be specified together with their allocation to specific CE strategies. How this allocation takes place is not specified further, so that existing indicator systems can be used/adapted if necessary. In this respect, the effects of the CSRD can already be seen internationally in the above-mentioned organizations, which now support reporting in accordance with ESRS[46].

42 https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework
43 https://www.ellenmacarthurfoundation.org/circulytics-esrs
44 https://www.wbcsd.org/Programs/Circular-Economy/Metrics-Measurement/Resources/Circular-Transition-Indicators-v4.0-Metrics-for-business-by-business
45 https://www.efrag.org/Assets/Download?assetUrl=%2Fsites%2Fwebpublishing%2FSiteAssets%2F12%2520Draft%2520ESRS%2520E5%2520Resource%2520use%2520and%2520circular%2520economy.pdf
46 https://www.ellenmacarthurfoundation.org/circulytics-esrs; https://www.wbcsd.org/contentwbc/download/16815/238391/1

The second important instrument of the Green Deal is the taxonomy, which is geared towards the economic activities of companies and is intended to channel financial flows into sustainable investments. To this end, six environmental objectives are specified, including the transition to a circular economy. For each of these objectives, technical assessment criteria are laid down in a delegated act. For the area of the circular economy, the draft was submitted for comments in April 2023[47].

CSRD and the taxonomy are therefore likely to have a major impact on corporate reporting on CE issues in the coming years. In addition, the development of concrete specifications for the Digital Product Passport (UBA Resource Commission, 2017) for different sectors and products is likely to promote the provision of data on the entire life cycle of products, which could be used as a basis for the balancing of CE indicators.

3.6 CE indicators – Quo vadis?

Looking at the EU in particular, it is clear that there is currently great dynamism with regard to the development and implementation of CE indicators. A trend towards harmonization, which is brought about by the EU Monitoring Framework and the CSRD and taxonomy, overlaps with a trend towards further diversification, which is a result of the ongoing extensive development of sector- and material flow-specific requirements and indicators.

At the target level, it can be said that the target indicators to be used in any case for the evaluation of CE measures are derived from the key objectives of the CE itself: Climate protection, raw material availability and resource conservation. Each measure or strategy of a CE must therefore be examined to determine whether it makes a significant contribution to at least one of these key objectives. Other sustainable development objectives (e.g. in the area of natural resources) can be defined as described above as framework conditions that must be adhered to when pursuing these key objectives; however, the main aim here is to prevent deterioration in other areas. At the target level, the existing target indicators for the respective headline targets are therefore applicable in principle, for example the headline indicator of greenhouse gas emissions in CO_2-eq) for the climate protection headline target. This common headline indicator is also taken into account in the existing approaches for indicator systems at EU level. For the key objectives of raw material availability and resource conservation, however, there is as yet no general consensus on an indicator to be used in general. Furthermore, there is no general framework for prioritizing between several key objectives or target indicators, especially in the case of conflicting targets.

47 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13237-Sustainable-investment-EU-environmental-taxonomy_en

It should also be noted that even in the case of the climate protection key objective, there are no targets specifically defined for the CE. The only exception so far has been the German Climate Protection Act (Klimaschutzgesetz), which formulates sector targets for GHG reduction for the circular economy, although this only covers the traditional waste management industry on the basis of the international system of national inventories.

As described above, the level of operational indicators is characterized by a particularly large variety of proposals. The greatest challenge at present is to quantify the connection between operational indicators (and any target values set) and the achievement of CE objectives. A life-cycle-oriented approach is essential here, but there is still a considerable need for action on various aspects: on the one hand, there is a need for methodological development (for example when it comes to classifying the contributions of different actors to CE measures); on the other hand there is a need for the provisioning of valid and up-to-date data, especially for quantifying the target indicators.

In addition, it is particularly important that the need to review the contribution of operational indicators to the target level is strengthened both in the development of political concepts, strategies and measures and in the various areas of application. The integration of existing accounting methods and targeted screening tools for areas of application such as product design (UBA Resource Commission, 2024) should become a general component of corresponding organizational processes in the future.

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