PBL Netherlands Environmental Assessment Agency

MONITORING CIRCULARITY STRATEGIES

Principles for application by PBL

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Colophon

Monitoring circularity strategies. Principles for application by PBL

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1 Introduction

The current method of production and consumption with its extensive use of primary material resources is not only wasteful, but one of the most significant causes of climate change, biodiversity loss, and pollution of air, water, and soil (United Nations Environment Programme, 2024). Without policy changes, global use of raw materials is expected to double by 2060, which would only exacerbate the negative consequences for both people and the environment (IRP 2019; OECD 2019).

In order to combat these significant resource issues, a radical reduction and more efficient use of material resources is needed. In other words, this calls for a circular economy (CE). By committing to a more circular use of primary resources, materials, and products, material resource use can be significantly reduced, as well as the aforementioned negative environmental effects and supply risks. A radical reduction and more efficient use of materials is possible by making use of (a different combination of) different circularity strategies, also called R-strategies. These link into the production chain at varying places: extraction, production, use, and disposal. In this report, we distinguish four overarching circularity strategies (Konietzko et al. 2020; Hanemaaijer et al. 2021):

1. *Narrow the loop:* Use fewer raw materials by using fewer products (refuse), sharing products (rethink), or manufacturing them more efficiently (reduce).
2. *Slow the loop:* Longer and more intensive use of products and components through reuse and repair (repair and remanufacturing). This would slow down the demand for new raw materials.
3. *Close the loop:* Closing the loop by taking away leakages and undesirable materials, as well as recycling more materials. This way, only non-reusable waste is incinerated or landfilled and fewer new materials are needed for the use of secondary materials.
4. *Substitution* of finite material resources by sustainably produced, renewable material resources (such as bioresources), or alternative primary resources which exert less environmental pressure.

1.1 Role of the circularity ladder in monitoring

The Work Programme Monitoring and Evaluation Circular Economy (WP M&S CE, see https://www.pbl.nl/monitoring-circulaire-economie) publishes the Integral Circular Economy Report every two years (ICER; Hanemaaijer et al. 2021 and 2023). The goal of this report is to monitor the progress of the transition to a circular economy in the Netherlands and to evaluate Dutch policy for the circular economy. The circularity strategies play an important role in both the monitoring framework of the ICER as well as that of the WP M&S CE. A classification of circularity strategies helps structure insight into the varying ways in which businesses, governments, citizens, and other parties can be actively circular. A mix of these strategies is required in order to radically reduce the use of material resources. EU policy also makes use of circularity strategies (see Framework 1 below). The National Programme Circular Economy 2023-2030 (IenW et al. 2023) categorises the circularity of resource use: a reduction of material resource use; substitution of material resources; lifespan extension; and high-grade processing. To this end, goals are established and instruments are implemented for the input, use, output, and substitution of raw materials. The four strategies named above (*narrow the loop*, *slow the loop*, *close the loop*, and

substitution) directly link to this policy classification and are therefore relevant for monitoring material resource use.

In the ICER 2021 and 2023, such circularity strategies have also been deployed to help indicate the direction of the Dutch CE-transition. Which circularity strategies are implemented most by certain societal parties? Which opportunities, obstacles, and courses of action belong to which strategies? There is, for example, interest in circularity strategies concerning the development of new technologies, changes to laws and regulations, stimulation of circular behaviour, the deployment of new products and services on the market, the development of knowledge, and the development of alternative business and revenue models. Ultimately, a mix of all strategies will be crucial to fully realise a circular economy.

By monitoring activities associated with circularity strategies, we can gain important insight into the direction of the Dutch CE-transition. This helps clarify important subsequent steps that can be taken. The conceptual basis for monitoring circularity strategies, as an analytical framework, has been established by PBL in two reports by Potting et al. (2016 and 2018). In the report *Mapping the circular economy* (PBL 2019), this framework was applied to identify and classify circular businesses in the Netherlands. Subsequently, further research projects carried out by the WP M&S CE and the ICER 2021 and 2023 have used the framework to classify and analyse circular activities in practice. Examples of this are the research into circular businesses (Royal HaskoningDHV 2020, 2022a); research into the financial contribution from subsidies and legislation aimed at circular solutions (RVO 2020, 2021, 2022); and research into plans and action by (decentralised) governments and societal parties (Royal HaskoningDHV 2022b; RWS 2022). The principles for monitoring circularity strategies as laid out in this report have come forth from a collective search executed during these projects. Particularly the earlier research projects with Royal HaskoningDHV and RVO have refined and improved the principles as they are presented in this report.

Framework 1: Connection with EU *taxonomy for sustainable activities*
The European Commission has proposed a taxonomy which provides definitions for economic activities that can be considered sustainable. Definitions have been formulated for six sustainability themes, including the transition to a circular economy. The circularity strategies discussed in this report connect well to the definitions established in this taxonomy. The taxonomy declares: *"An economic activity can contribute substantially to the environmental objective of transitioning to a circular economy in several ways. It can, for example, increase the durability, reparability, upgradability, and reusability of products, or can reduce the use of resources through the design and choice of materials, facilitating repurposing, disassembly, and deconstruction in the buildings and construction sector, in particular to reduce the use of building materials and promote the reuse of building materials. It can also contribute substantially to the environmental objective of transitioning to a circular economy by developing 'product-as-a-service' business models and circular value chains, with the aim of keeping products, components, and materials at their highest utility and value for as long as possible. Any reduction in the content of hazardous substances in materials and products throughout the life cycle, including by replacing them with safer alternatives, should, as a minimum, be in accordance with Union law. An economic activity can also contribute substantially to the environmental objective of transitioning to a circular economy by reducing food waste in the production, processing, manufacturing, or distribution of food."* (link to the taxonomy)

1.2 Goal of this report

This report has been drawn up for two reasons. First of all, it aims to stimulate a uniform application of the circularity strategies as an analytical framework. Both within and outside of the Work Programme M&S CE, in the Netherlands and abroad, there is increased attention for the inventory of material resource streams or the inventory of circular activities according to the circularity strategies. There are diverse circularity ladders currently in circulation, sometimes with conflicting definitions. A consistent approach will make results mutually comparable and combinable and will also contribute to the continuous development of the analytical framework. As such, this report is primarily aimed at Dutch researchers who want to categorise aspects of a circular economy according to circularity strategies.

Secondly, this report compiles the experiences gained during the research projects of the past few years, as specified above. Much of the knowledge gained, especially concerning the application of circularity strategies as an analytical framework, has been outlined in various documents and background papers. A cohesive overview can be formulated by establishing the method in one single report, as we aim to do here. This report provides definition, but also describes which choices are made when applying the framework in earlier studies and the reasoning behind these choices. Overall, the principles described in this report are consistent with the application of the circularity ladder in the ICER 2021 and 2023, as well as with any background studies that have provided input for both ICER documents. Ultimately, the definitions and principles presented below in this report are not rigid; they can be updated as new insights are gained.

The English translation of this report is intended to inform international audiences about the Dutch analytical frameworks for the inventory of resource streams or circular activities. Hence, this report contributes to the international knowledge development concerning monitoring and analysis of CE-transitions.

1.3 Reading guide

Chapter 2 will start with a short overview of the definitions of the circularity strategies. This is followed by explanations of the different conceptual principles and backgrounds, which leads into an exploration of the different innovations in relation to the circularity strategies. Chapter 3 will then discuss the application of the Ladder of Circularity and the individual strategies in more detail. In order to properly generate this discussion, examples will be provided of activities and businesses that are illustrative of circularity strategies. These examples come from empirical research that lies at the foundation of this report. Finally, the different choices made when applying this analytical framework are explained, taking into consideration any borderline cases and other formatting and categorisation choices.

2 Principles and backgrounds of circularity strategies

2.1 The (R-)ladder with circularity strategies

In the existing body of literature, circularity strategies are often sorted in a so-called Ladder of Circularity ('R-Ladder') – named this way because every strategy starts with the letter 'R' – which can vary from three to ten 'steps'. Below, Table 1 illustrates the most elaborate Ladder of Circularity that PBL uses. The first column provides the four overarching circularity strategies already described in the introduction to this report (*narrow*, *slow*, *close*, and *substitution*). The second column shows the individual circularity strategies that belong to each category and, per strategy, a definition is presented in the third column. The rest of this chapter will then discuss the conceptual principles underlying this analytical framework.

Table 1
Overview and definitions of circularity strategies

Overarching strategy	Circularity strategy	Definition
Narrow	R0 Refuse	Making a product redundant by abandoning its function, or replacing that function with a radically different product
	R1 Rethink	Intensify product use by sharing products or manufacturing multi-functional products
	R2 Reduce	Manufacture products more efficiently, or make their use more efficient
Slow	R3 Reuse	Reuse of a product in the same function
	R4 Repair	Repair and maintenance of a product for use in its original function
	R5 Refurbish	Upgrade or modernise a product
	R6 Remanufacture	Using parts of a disposed product in a new product with the same function
	R7 Repurpose	Using a disposed product or its parts in a new product with a different function
Close	R8 Recycle	Processing and reuse of materials
	R9 Recover[a)]	Recover energy from materials

Overarching strategy	Circularity strategy	Definition
Substitution[b)]	*Substitution*	*Substitution of finite raw materials by sustainably produced, renewable raw materials (such as bioresources) or alternative primary resources with a lower environmental pressure*

a) Burning raw materials ensures they permanently disappear out of the loop, which does not connect well to the core message of a circular economy. From that point of view, the strategy of burning material resources should be avoided as much as possible. There are nonetheless still a lot of activities aimed at this and it is the expectation that it will remain relevant to follow these types of activities the coming years. Furthermore, this strategy has already been incorporated in the research projects over the last few years. This is why *recover*, for the time being, is still included as a circularity strategy.
b) There is no rule of thumb for *substitution* that would allocate it a logical place in the hierarchical table. Therefore, this strategy has been individually represented in Table 1 with an additional white space to separate it from the other strategies. This also explains why there is no corresponding R-number in the second column.

2.2 Explanation of the circular ladder

Product function is key
The circular ladder places product function at its core rather than the products themselves. In doing so, functions can potentially be replaced by radically different 'products', such as blankets instead of heat lamps to heat terraces, or streaming movies and music instead of buying physical CD's and DVD's (Potting et al. 2016). This includes strategies like the use of recycled material in the manufacture of plastic packaging and upgrading products. This is all part of the Ladder of Circularity. As such, different societal parties contribute to implementing circularity strategies, including designers, producers, manufacturers, retail, consumers, and governments.

Strategies higher up the ladder generate, as a rule of thumb, more significant resource savings
In the Ladder of Circularity, the circularity strategies are rendered in a hierarchical order. As a rule of thumb, we establish that the higher a circularity strategy is on the ladder, the more resource efficiency and resource savings the strategy in question generates and, hence, how much environmental benefit can be achieved. This idea is often connected to the concept of 'value retention' (see Framework 2, below).

This rule of thumb for resource and environmental benefit is not always applicable, however. This is due to, amongst other things, second-order effects. This includes people who increasingly use a shared car, even though they previously would have travelled by train. Additionally, not every strategy is employable for every single type of product, and, in practice, the effect of a strategy can work out differently. This would render the rule unapplicable, such as when the recycling of materials costs more energy than the production of new materials. It is therefore important, when applying and interpreting the Ladder of Circularity, to check whether any undesirable feedback or other exceptions are visible or probable in practice.

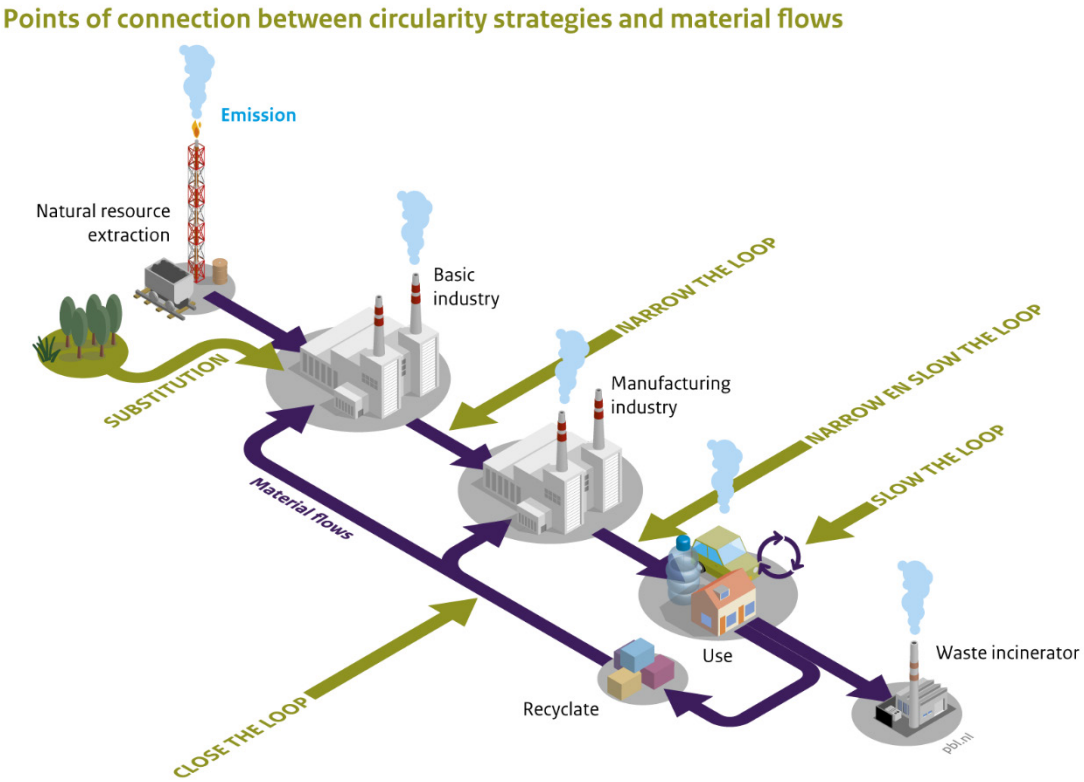
Framework 2: The concept of value retention
A key insight into the circular economy is the significance of the high-grade use of raw materials. Value retention of raw materials manifests itself in the different circularity strategies. The reuse, repair, upgrade, and recycling of products is particularly relevant, because these actions lead to a longer lifespan for products, parts, and raw materials in the economy. This way, more value is attributed to the same amount of raw materials, which increases the resource productivity or resource efficiency. Even though value retention is very important for a circular economy, the concept itself is not fully worked out yet. Up until now, there are no widely-supported indicators to operationalise value retention.

Another exception to the rule of thumb specified above is substitution, also sometimes called 'replace'. The term substitution is, in this report, exclusively used for:

1. The replacement of abiotic raw materials by bioresources, such as the substitution of concrete by wood in construction, or the substitution of oil by biomass in the manufacture of plastics.
2. The replacement of abiotic raw materials by other abiotic raw materials that are more commonly available and have a lower environmental impact. This also covers the substitution of substances of very high concern (SVHC; ZZS in Dutch) by safer alternatives.

For substitution, there is no particular criterion that would allocate this strategy its logical position in the hierarchical Ladder of Circularity – hence the singular representation of this strategy in Table 1 above. Substitution of abiotic raw materials does not lead by definition to a reduction in raw material use and/or a reduction in environmental effects, for example. It can, moreover, lead to a shift from fewer greenhouse gas emissions to more land- and water use and, so, to correlated effects on biodiversity (Hanemaaijer et al. 2023). As such, the production of biomass leads to relatively few greenhouse gas emissions in comparison to the extraction and production of metals and fossil fuels, but it still requires a lot of land use.

Every circularity strategy has its own points of connections
In essence, all circularity strategies contribute to a reduction in the use of primary raw materials. Only the points of connection differ, as Figure 1 demonstrates. Through *narrow the loop*, the total amount of raw materials/products are directly reduced. *Slow the loop* slows down the demand for new raw materials by extending the lifespan of products. Finally, both with the offer as well as with the implementation of secondary raw materials, the focus lies on *closing the loop*.



Source: PBL

Figure 1
Points of connection between circularity strategies and material flows

The circularity ladder can encompass entire product chains

The circularity ladder is not limited to one single product chain. It can happen that products, their parts, or the materials of which they are composed are no longer reusable in the same way. Alternatively, it can happen that reuse in a different application, outside of the original product chain, has more value than application in the original product. For example, the stalks of the tomato plant are of little to no use within agriculture itself, but they are excellent components for the production of paper, a method which Figure 2 illustrates. We explicitly want to make this point because there is often confusion around the widespread metaphors of 'the ladder' and 'closing the loop', which sometimes, wrongly, implies that circularity should only be considered within individual product chains. It is important to consider which choice in Figure 2 delivers the most in terms of a reduction in primary material resource use, reduction in waste production, and high-grade recycling. In practice it is, for example, also noticeable that different plastics in the waste stage in the Netherlands are not brought back to their original application but are used for other purposes. An example of this is the reuse of plastics in roadside signs on Dutch highways.

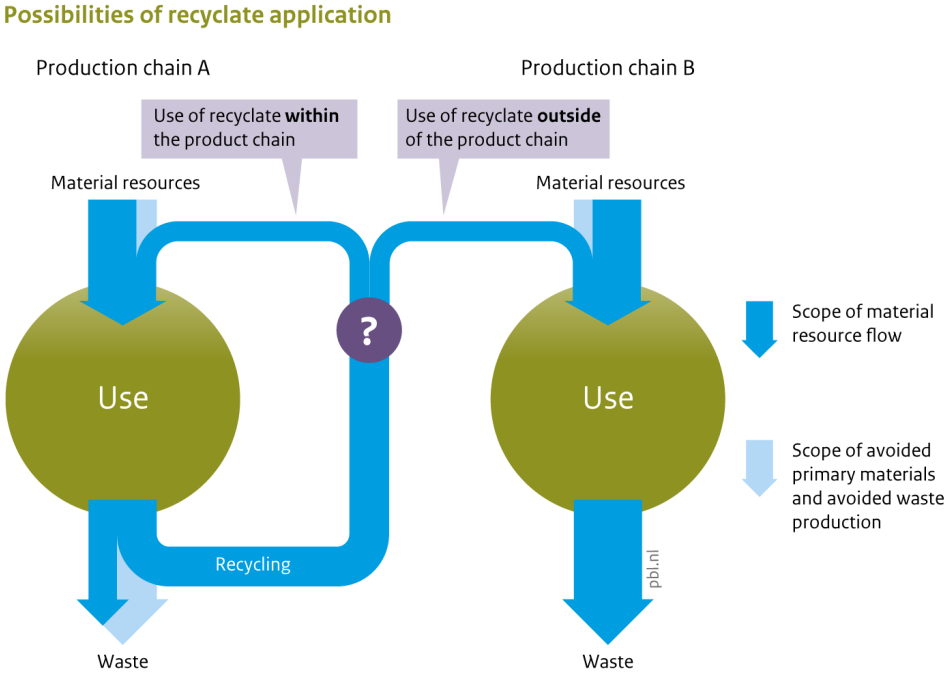


Figure 2
Possibilities of recyclate application

The circularity ladder is not an overview of all possible and necessary changes

A successful transition to a circular economy calls for all sorts of changes and strategies that do not have a place on the circularity ladder. There are strategies that are, in practice, considered additions to the Ladder of Circularity, such as, among others, re-supply (the reconsideration of existing supply channels), re-educate (distributing circular ideologies), re-organise (changing product chains), and remove (the capture of CO_2). There are also other relevant developments, including the sharing of knowledge, formulating goals, changing laws and regulations, and stimulating more circular behaviour. Even though these are all important processes in the transition to a circular economy, they do not fit into the Ladder of Circularity described above. As mentioned, the ladder provides an overview of circularity strategies which directly intervene with resource use for product functions. These strategies are then put in a hierarchical order in terms of expected resource benefit and, by extension, environmental benefit. The ladder is, therefore, not an exhaustive overview of all measures to accelerate the transition, nor is it a ranking of transition challenges.

2.3 Additional strategies to the ladder

There are three important topics that, in earlier research, have been analysed in connection with circularity strategies but are not in themselves individual steps on the Ladder of Circularity. These include: innovation in core technologies; innovation in product design (simply called design); and innovation in business models. These topics are particularly important from the point of view of producers and manufacturers who develop these innovations and implement them to then contribute to a renewal in circularity strategies.

Innovation in design, business models, and core technologies

Innovation is an essential part of circularity strategies. With new technologies, new product designs, or new business models, new circular products and services can be created that use fewer resources. These are essential developments for the transition to a circular economy but are not by themselves steps on the Ladder of Circularity. Innovations can take many shapes that are then connected to specific circularity strategies. Below, we discuss how the three types of innovations (design, business models, technologies) relate to the circularity strategies.

Design

An innovative product design can be aimed at the use of fewer materials (reduce), facilitating the replacement or upgrade of components through modular design (repair), or a reduction in glue to then improve recycling (recycle). There are many different terms that cover the concept of circular design, including redesign, design for reuse, design for repair, design for recycling, dematerialisation in design, design for disassembly, safe-by-design, modular design, and removal design. Perhaps the design for a product with a longer lifespan requires more materials in the short term, but then you have a product with parts that are more resistant to damage or wear and tear. To design a product that is repairable can ensure an extended lifespan, hence lowering the demand for new products. Designing a product to facilitate recycling aids with the processing of waste, but it does not mean a direct avoidance of using fewer primary resources. The effect of an innovative product design, then, is connected to the circularity strategy that enables the design in question in the first place. This is why design in and of itself does not constitute a step on the Ladder of Circularity.

Business models

The same type of reasoning persists for innovative business models. The term 'circular business models' is already in frequent use for the offer of a product-as-service, but is essentially a much broader term, covering all sorts of business models including models concerning raw material use, platform use, and lifespan extension (see, for example, this overview of circular business models by CIRCO, this knowledge map about circular business models by Het Groene Brein, or this quickscan of circular business models). This broader interpretation of the term also indicates that business models narrowly connect to various circularity strategies. The development of business model in question is important in order to decide which specific strategy it connects to. The product-as-service model can intensify product use (rethink) through short leases or shared use; the next user can directly utilise the product once the first one is finished. This model can also generate efficient use (reduce) if there is a pay-per-use component (e.g. paying per wash, or paying per kilometre consumed) so products are used sparingly. It can also encourage lifespan extension if the manufacturer offers maintenance and reparation. In other words, it cannot be estimated by definition which material resource benefit and environmental benefit is generated by a given circular business model (see also Remmerswaal et al. 2017). Circular business models are inextricably intertwined with the CE-transition, but they connect to different circularity strategies and do not, therefore, have their own step on the ladder.

Technology

The reasoning for both design and business models also holds true for innovative technologies. The eventual resource savings and environmental benefit of new technologies are dependent on what this technology actually looks like. Are we talking about new recycling technology? Technology that makes production more efficient? Technology which enables the use of safer or less polluting material resources in new applications? Or technology which enables a digital version of previously

physical products? In all these situations, the development of innovative technology connects to specific and different circularity strategies.

2.4 Circularity ladder for consumer behaviours

Not all producers and manufacturers utilise circularity strategies. Even the choices that consumers make with the purchase, use, or disposal of products and/or services have an influence on material resource use. Circular consumption concerns the way in which consumers acquire goods and services, use them, and then dispose of them in a way that contributes to the circularity strategies outlined in Table 1. By combining the stages of purchase, use, and disposal with the circularity strategies, a framework has been developed that demonstrates which possibilities consumers generally have to consume in a more circular fashion (Koch and Vringer 2023). Consumers can, for example, contribute to the recycling strategy by separating a used product into its parts for recycling, but also by buying products that are made of recycled materials, or products that recycle well. Table 2, below, shows a complete overview of this.

Table 2
Framework for circular consumption behaviour

R-strategies	Purchase stage	Use stage	Disposal stage
Refuse	Refusing a product or purchasing a digital alternative	-	-
Rethink	Purchasing a multifunctional product; borrowing, renting, leasing, or communally purchasing a product	Lending, leasing, or communal use of a product (e.g. carpooling)	-
Reduce	Purchasing a product that is made of fewer new resources or fewer resources have been used during the use stage (e.g. energy-efficient appliance)	Using a product in an efficient way (e.g. washing laundry on a low temperature, rarely driving a car)	-
Reuse	Purchasing a product that has a long lifespan, is second-hand, or can easily be reused	Using a product with care, keep it well-maintained, or use it to the end of its technical lifespan	Selling or giving away products to others for reuse
Repair	Purchasing a modular/reparable product	Repair the product, have the product repaired	Selling a broken product for reuse or for parts
Refurbish	Purchasing a refurbished or revised product	-	Selling or donating a product so it can be refurbished

R-strategies	Purchase stage	Use stage	Disposal stage
Repurpose	Purchasing a product that is made of an old product with a different function	-	Process the product or its parts into a product with a different function (e.g. making a bag from a damaged pair of trousers), or selling/donating the product so its parts can be reused for a product with a different function
Recycle	Purchasing a product that is made of recycled materials or which contains materials that can be recycled	-	Hand in a broken product in its separate parts for recycling
Substitution	Purchasing a product that is made of renewable materials, or materials with a lower environmental pressure, or that, during its production stage, uses renewable resources instead of fossil fuels (e.g. an electric instead of a petrol car)	-	-

3 Application of circularity strategies as analytical framework

Adding onto circularity strategies by providing examples

Table 1 contained a detailed overview of the various circularity strategies. Table 3 below supplements this by providing different Dutch examples per strategy. These examples are derived from earlier research done by PBL and research projects by the Work Programme M&S CE. As mentioned in the introduction to this report, these projects concerned categorising different topics in relation to circularity strategies, such as research into circular businesses (PBL 2019; Royal HaskoningDHV 2020, 2022a); research into the financial contribution from subsidise and legislation aimed at circular solutions (RVO 2020, 2021, 2022); and research into the plans and actions of (decentralised) governments and societal parties (Royal HaskoningDHV 2022b; RWS 2022). These projects, in other words, particularly concerned practical examples.

Table 3
Practical examples of circularity strategies

Overarching strategy	Circularity strategy	Definition	Example[1]
Narrow	R0 Refuse	Making a product redundant by abandoning its function, or replacing that function with a radically different product	Zero waste store (packaging-free); ban on plastic straws; digital receipts
	R1 Rethink	Intensify product use by sharing products or manufacturing multi-functional products	Shared bicycles; green deal car parts; mixed use/multifunctional buildings
	R2 Reduce	Manufacture products more efficiently, or make their use more efficient	Prefab construction; action plan against waste; self-healing concrete
Slow	R3 Reuse	Reuse of a product in the same function	Thrift store; obligation for retailers to offer second-hand products; offer a platform for second-hand sale

[1] These examples are derived from research projects where the circularity strategies have been applied by PBL or within the Work Programme Monitoring and Evaluation Circular Economy (PBL 2019; Royal HaskoningDHV 2020, 2022a, 2022b; RVO 2020, 2021, 2022; RWS 2022).

Overarching strategy	Circularity strategy	Definition	Example[2]
	R4 Repair	Repair and maintenance of a product for use in its original function	Bicycle repair shop; organising a repair café; demountable product design
	R5 Refurbish	Upgrade or modernise a product	Refurbish business; upgrading a laptop; modular product design which makes parts easier to replace
	R6 Remanufacture	Using parts of a disposed product in a new product with the same function	Produce new white goods from disposed ones; produce a new printer with disposed parts
	R7 Repurpose	Using a disposed product or its parts in a new product with a different function	Laundry basket made of old jeans; vintage furniture made of old wooden floor planks
Close	R8 Recycle	Processing and reuse of materials	Recycling concrete into concrete; applying recycled content in clothes; using packaging waste as raw material in roadside signs on highways
	R9 Recover	Recover energy from materials	Fermentation of bioplastic for biogas; burning construction waste with energy recovery
	Substitution	Substitution of finite raw materials by sustainably produced, renewable raw materials (such as bioresources) or alternative primary resources with a lower environmental pressure	Bioplastic packaging; mandatory percentage sustainable biomass in products; timber construction

[2] These examples are derived from research projects where the circularity strategies have been applied by PBL or within the Work Programme Monitoring and Evaluation Circular Economy (PBL 2019; Royal HaskoningDHV 2020, 2022a, 2022b; RVO 2020, 2021, 2022; RWS 2022).

3.1 Choices in applying circularity strategies

The definitions and examples in Table 3 above aid with the consistent use of the circularity strategies as an analytical framework. However, specific choices are required depending on the subject in question. Classifying businesses, for example, requires a different perspectives than classifying policy instruments, actions by societal parties, or academic publications. It is important to clearly define the chosen subject – businesses, actions, subsidies, or something else – to be able to consistently apply the circularity strategies as in Table 3 (see also Appendix 1, which maps out how circularity strategies can be fitted for the analysis of activities within the theme of biomass and food). Below, we lay out the most important choices and challenges when using circularity strategies as analytical framework.

Refuse

This strategy covers the refusal of products or delivering the function in question with a radically different product. Refusing products often occurs in actions and instruments (e.g. a ban on plastic straws), but less so with businesses. A zero-waste store (packaging-free) makes refusing packaging possible, for example. But there are still too few businesses that have a business model aimed at refusing products. Moreover, the refusal of a product often leads to a different product delivering the same function (e.g. replacing plastic straws with paper straws). Delivering the same function with a radically different product also falls within this strategy, but requires empirical control to estimate if this really leads to effective resource savings. Establishing whether a radically different product leads to resource savings or environmental benefit is not always simply and can be very time-consuming. A helpful control question is whether the alternative product that now delivers said function, actively replaces a (more polluting) product or whether it becomes an alternative product. A simple example would be the deployment of blankets instead of terrace heating; is it a replacement, or can it also act as an additional product? If the latter, this is not a question of refuse. Digitalisation – offering a digital instead of a physical product, such as streaming services for music and films instead of CD's and DVD's, or e-books instead of physical books – is often considered a replacement when fewer raw materials are consumed, and can thus be labelled as refuse.

Rethink

Even though the definition of this strategy strictly concerns intensive product use, rethink, in practice, often causes confusion as it calls up different associations. This strategy is often translated as 'thinking differently', which can lead to a wide variety of things including circular design, new business models, or the application of biofuels being represented as forms of rethink. A quick webcrawl on the term 'rethink' actually delivers an extremely diverse set of businesses and initiatives that seldom really concern more intensive product use – instead ranging from deploying recyclate, to the use of innovative technology, to the changing of old habits. Ultimately, a more intensive use of a product entails that, with the same or decreased amount of product, more function is delivered. This is possible, for example, with multifunctional products. Instead of an oven and a microwave, a microwave oven can offer both functions in one. Moreover, resources are saved because only one instead of two products is manufactured. Sharing products is also a way of intensifying product use. Instead of 10 people all individually purchasing a car, one shared car can provide the same amount of function.

Reduce

The core of the reduce-strategy is efficiency. By making products more efficient, less resources are used up to produce the same amount of product. Every manufacturing business can take measures to produce more efficiently. This is a meaningful strategy because a business can produce more with fewer resources and, hence, save costs. Within its broadest interpretation, virtually all improvements on the field of efficiency in traditional production processes fall within the category of reduce. This is not, however, always helpful in analyses. Innovative circular products that yield significant resource efficiency are mostly identifiable on a case-by-case basis. For incremental improvements in production processes, it becomes significantly more difficult. Where possible, it helps to empirically establish whether the efficiency improvement can also lead to a reduction in resource use. In other words, whether the same output is produced with less input (so not whether the same input yields more output). When classifying business activities, this information is not always readily available. That is why, in earlier research, the choice was made to only incorporate radical improvements of products or business processes in this circularity strategy. It is advisable to adjust this choice to the goal of the analysis. If it concerns classifying policy actions, it is often possible to make a distinction between traditional efficiency and this particular circularity strategy.

Reuse, repair, refurbish, remanufacture, repurpose

For the strategies that fall within *slow the loop*, hardly any difficult choices present themselves. With reuse, we have chosen to let reuse by the same user fall within this category, while the earlier definition by Potting et al. (2016) only concerned the reuse of a product by someone else. It is, however, often difficult to collect sufficient data in practice, for example concerning business activities, that would even allow a solid, good distinction to be drawn between reuse, refurbish, remanufacture, and repurpose. In practice it is not always possible to make a distinction between strategies such as repair, refurbish, remanufacture, and repurpose. In these cases, we choose to use the label lifespan extension (slow the loop) as a general indication.

Recycle

Even though this strategy is located 'at the bottom' of the Ladder of Circularity, it is equally important as the others for the success of a circular economy. Recycle denotes both the offer of secondary materials as well as the actual deployment of secondary materials in production processes. In practice, there is discussion about this. The argument that is made often is that the deployment of secondary materials indicates that fewer primary resources are needed, and therefore recycle is a strategy that needs to be higher on the ladder. However, all circularity strategies essentially contribute to a reduction in primary resource use, as explained in Chapter 2 (see Figure 1). The point of contact of recycling is, however, the waste stage at the end of a product chain. To even implement secondary materials, first waste flows need to appear. Before they can appear, the other circularity strategies will already have played their role. This is why both the activities concerning the offer of recyclate as well as its deployment fall under the strategy of *recycle* (*close the loop*). However, it can be useful for analyses to make the distinction between offering and implementing recyclate, independent of the goal of the analysis. Another relevant distinction is between low-grade and high-grade recycling. This distinction is not, however, made on the Ladder of Circularity itself and is highly dependent on context.

Recover

Burning resources means they permanently disappear from the loop. This, naturally, does not connect well with the core message of a circular economy concerning the conservation of resources and closing the loop. That is why, in practice, it is sometimes advocated that this strategy not be included as a circularity strategy. Simultaneously, there are waste flows where winning back energy through burning is one of the few useful and possible options. In our analyses, we do incorporate recover as a circularity strategy, precisely to gain insight into how much attention goes to burning in comparison to other strategies.

Substitution

It is important to compare the concepts of substitution and recycling, particularly for a consistent use of the substitution-strategy within an analysis. If abiotic raw materials are replaced by biotic residual flows, for example, is this recycling or substitution? Following the analytical framework, and for consistency, this would be recycling. The biotic residual flows used have appeared as by-product or waste in a (different) production chain. Replacing or substituting primary with secondary resources (i.e. recycled materials) is not substitution, as it is part of the recycling-strategy. In the case of substitution by bioresources that have actively been produced for application as material, then we could speak of substitution. In practice, however, it is not always possible to determine whether the bioresources that are being applied in a circular product are actually residual flows or primary bioresources. In that case, it is wise to be explicit about which choice is being made and to be consistent.

3.2 Other choices when applying this analytical framework

Innovations in design, business models, and technology can be categorised

The three types of innovation – design, business model, and technology – can hook onto all circularity strategies. In analyses it is, nonetheless, often desirable or even necessary to make these innovative developments explicitly visible as their own category. Within the analytical framework, this is still possible and, indeed, is often applied by the Work Programme M&S CE. Businesses or projects are, for example, first categorised into circularity strategies and then into one of the types of innovation. Within the CE-transition, it is this connection in particular that is interesting to gain more insight into.

The extent of innovation is dependent on context

Another challenge when classifying innovative circularity strategies is the question whether we can call something innovative. Innovation is mostly defined as something new or something that has been (substantially) improved. But ‘new’ and ‘improved’ are dependent on both context as well as time. For example, it is customary nowadays to be subscribed to a streaming service rather than owning physical CD’s or DVD’s. Yet a subscription for a bicycle or a washing machine is relatively new for consumers and hence an innovative business model in this context. To make a consistent estimation of innovation, knowledge of the context is paramount, as well as a clarification of the alternative; in relation to what exactly can we call something innovative? A comparable challenge occurs when trying to determine the extent of the circularity of a business (see Framework 3, below).

Framework 3: The extent of circularity in businesses
Recycling businesses and thrift stores are often seen as clear-cut examples of circular businesses. These types of businesses are easy to find in existing statistics by using the so-called Standard Industrial Classification codes (SBI-codes). In earlier research with Royal HaskoningDHV and CBS, we have analysed the list of SBI-codes using circularity strategies in order to determine which business sectors can be designated as circular. For example: the SBI-code 47793 covers the business sector of shops dealing in second-hand goods (excluding clothes). This sector is directly connected to the reuse-strategy. Appendix 2 provides an overview of the SBI-codes which are connected to circularity strategies. In other words, the primary business activity in this business sector is indeed a circular activity.

There are, however, also businesses in other SBI-codes that apply circularity strategies, as pilot, project, or other additional business activity. If these are, for example, manufacturing businesses, they will not fall within the selected SBI-codes. Previously we have used various additional search actions to find businesses regardless, such as manually combining existing overviews or webcrawls (see PBL 2019; Royal HaskoningDHV 2020, 2022a). A consistent and continuous challenge is whether we can make a more precise measurement for the extent to which a business is circular. Currently it is a binary score (i.e. circular or not circular), while a continual score would be much more nuanced (i.e. what percentage is circular, found, for example, on the basis of profit from traditional and circular products).

Allocating one or more R-strategies
Circular businesses rarely apply only one singular circularity strategy. A business that has designed a circular product that requires fewer resources for its production (reduce), can also design this product to be repairable (repair). It can even use recycled materials in the production process to begin with (recycle). This also counts for actions, subsidies, and other related topics. Depending on the goal of the research project, we use two approaches in this type of classification:

1. Is a summative overview per circularity strategy necessary (without double-counting)? Then the highest circularity strategy that is applied is allocated. In the example named above, this business would be allocated the reduce-strategy.
2. Is a summative overview not necessary and are double-counts between the circularity strategies allowed? Then all relevant strategies are allocated. In the example above, this business would be allocated reduce, repair, and recycle.

Circular, but not specific enough for a circularity strategy
Actions aimed at taking away obstructive legislation for circular businesses, setting up a roadmap for circular fabric, or implementing a subsidy for circular chain projects; piece by piece, these are logical activities to ascribe to a circular economy. Simultaneously, it is not possible to classify them all under one specific circularity strategy. In these cases, we use a 'general' or 'other' label. They are clear actions that could have an effect on the circularity strategies and are therefore also relevant to consider when doing research, but they are not specific enough to be allocated a strategy.

In other words, in practice it is not always possible to make a distinction between strategies such as repair, refurbish, remanufacture, and repurpose. In these cases, we choose to use the label lifespan extension (*slow the loop*) as a general indication.

Circularity strategies are not always possible

Even though the circularity strategies in Table 3 are all broadly applicable, not every strategy is possible for every party and/or within each product group. Some products, for example, are consumed by definition, like petrol or food. This makes recycling the complete product impossible. Businesses can, moreover, be limited in their circular trading options because of their place in the product chain (see also Figure 1). A business can, for example, offer white goods made by a manufacturing company via product-as-a-service, but it will not have any influence on the original product design. Hence, the circularity strategies from Table 3 are not always applicable for all parties and for all types of products. This is important to keep in mind when interpreting analysis results. If a certain strategy does not occur often in practice, it can be because of these impossibilities.

Customisation remains necessary, seek consistency in choices

There will always be borderline cases which require specific choices, depending on the topic in question. We have encountered this in our own experiences with applying circularity strategies on topics such as businesses, action plans, academic publications, and subsidy funds. Following the principles of this report will make it possible, however, to start from a substantiated, general basis. When encountering borderline cases it is important to stay sharp on the 'goodwill-factor' (i.e. "my intuition says I should place this activity higher on the ladder") and precisely follow a systematic and, most of all, consistent approach. This ultimately contributes to the further development of the analytical framework.

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Appendices

Appendix 1: Circularity ladder for biomass and food

This appendix shows how the circularity ladder can be adjusted for activities within the theme of biomass and food. This adjustment is necessary for this particular topic, since it relates to specific circularity strategies that do not have their own, explicit place on the Ladder of Circularity. Furthermore, the strategies within *slow the loop* are usually, in turn, not applicable to biomass or food (Rood et al. 2016). A simple example to illustrate this point is that of the tomato: once eaten or decayed, it is no longer repairable. The circularity strategies for biomass and food are as follows:

- *Optimal use of natural resources* (e.g. soil, water, and biodiversity). An example of such an activity is food production on roofs. Such a form of urban agriculture decreases the pressure on farmland (to some extent). Another example is sustainable soil management, which avoids further soil degradation.
- *Producing products for an optimal diet*. This includes the production of food products that can replace or substitute products which exert a high environmental pressure. Crucial here is that the word 'optimal' is reasoned from the perspective of resource use and environmental impact, not from a health perspective. Producing products for an optimal diet comprises strategies for the production of vegetable proteins as a substitution for animal proteins. Meat substitutes, such as mushrooms or algae, make more efficient use of material resources.
- *Reducing food waste*. This is done by restaurants which, for example, work with food that would otherwise be discarded (e.g. Instock). Consider also initiatives that convert 'saved vegetables and fruit' into soups and sauces (e.g. Kromkommer and the Verspillingsfabriek in the Netherlands). 'Saved vegetables and fruit' are those which, due to external qualitative demands, cannot be sold via the standard channels.
- *Use of residual flows for various applications*. We distinguish four recycle-strategies in order of importance in the application of the residual flow (in other words, a cascading of the ladder by Moerman). These are:
    - Use of residual flows for food and cattle feed,
    - Use of residual flows for materials,
    - Use of residual flows to produce fertiliser,
    - Use of residual flows as compost.
- *Use of residual flows for energy*. This includes fermenters and pellet stoves that convert (predominantly) biotic residual flows into energy.

These circularity strategies exist as a rule of thumb in order of the expected environmental benefit of activities. Careful soil management avoids soil degradation and ensures an as high as possible benefit in the long term. Producing products for an optimal diet lowers the environmental impact, because as few as possible biotic resources are needed (e.g. fewer cattle feed). The total environmental benefit is, however, the outcome of the entire food system and not just the result of individual initiatives. This means that even the activities at the bottom of the hierarchical ladder remain crucial. For an optimal use of soil, for example, you need compost. There will always be

residual flows – or, even better, streams alongside those for human consumption – because, at least in the near future, not the whole plant is consumed.

Appendix 2: Connecting a selection of SBI-codes to circularity strategies

This classification is also included in Royal HaskoningDHV 2022a.

SBI	Description	Circularity strategy
3311	Repair of fabricated metal products	Repair
33121	Repair and maintenance of machinery for general use and machine parts (no tools)	Repair
33122	Repair and maintenance of pneumatic and electric tools and machine tools	Repair
33123	Repair and maintenance of machinery for specific industries	Repair
3313	Repair of electronic and optical equipment	Repair
3314	Repair of electrical equipment	Repair
3315	Repair and maintenance of ships and boats	Repair
3316	Repair and maintenance of airplanes	Repair
3317	Repair and maintenance of other transport equipment	Repair
3319	Repair of other equipment	Repair
3700	Sewerage	Recycle
3811	Collection of non-hazardous waste	Recycle
3812	Collection of hazardous waste	Recycle
3821	Treatment of non-hazardous waste	Recycle
3822	Treatment of hazardous waste	Recycle
3831	Dismantling of ships, white goods, computers, etc.	Recycle
3832	Recovery of sorted materials	Recycle
3900	Remediation activities and other waste management	Recycle
4311	Demolition	Recycle
45112	Sale and repair of passenger cars and light motor vehicles (no import of new cars)	Repair
45192	Sale and repair of heavy commercial vehicles	Repair
45193	Sale and repair of trailers and semi-trailers (no caravans)	Repair

SBI	Description	Circularity strategy
45194	Sale and repair of caravans	Repair
45201	Sale and installation of motor vehicle parts	Repair
45202	Tyre centres	Repair
45203	Repair of specific motor vehicle parts	Repair
45204	Bodywork repair	Repair
45205	Other specialised repair; washing and towing of motor vehicles	Repair
45311	Wholesale and commission trade of motor vehicle parts and accessories	Repair
45312	Wholesale and commission trade of tyres	Repair
4532	Retail trade of motor vehicle parts and accessories	Repair
45401	Wholesale and commission trade of motorcycles and related parts	Repair
45402	Retail trade and repair of motorcycles and related parts	Repair
46771	Wholesale of reusable parts of motor vehicles	Recycle
46772	Wholesale of iron and steel waste and non-ferrous metal waste	Recycle
46779	Wholesale of other waste and scrap	Recycle
47544	Shops selling parts of electrical household appliances	Repair
47792	Shops selling second-hand clothing	Reuse
47793	Shops selling second-hand goods (no clothing)	Reuse
47892	Retail sale of second-hand goods via markets	Reuse
77111	Renting of passenger cars and light motor vehicles (no operational lease)	Repair
77112	Operational leasing of passenger cars and light motor vehicles	Repair
7712	Renting of trucks, buses, and motor homes	Rethink
7721	Renting of recreational and sports goods	Rethink
7722	Renting of video tapes and disks	Rethink
77291	Renting of magazines	Reuse
77292	Renting of clothing and household goods	Repair

SBI	Description	Circularity strategy
77299	Renting of other consumer goods n.e.c.	Repair
7731	Renting and leasing of agricultural machinery and equipment	Rethink
7732	Renting and leasing of construction machinery	Rethink
7733	Renting and leasing of computers and office machinery	Repair
7734	Renting and leasing of ships	Repair
7735	Renting and leasing of airplanes	Repair
77391	Renting of vending and slot machines	Repair
77399	Renting and leasing of other machinery and equipment and of other goods (no vending and slot machines)	Rethink
91011	Public libraries	Rethink
9511	Repair of computers and peripheral equipment	Repair
9512	Repair of communication equipment	Repair
9521	Repair of consumer electronics (no computers)	Repair
9522	Repair of electrical household equipment	Repair
9523	Repair of footwear and leather goods	Repair
9524	Repair and upholstering of furniture	Repair
9525	Repair of watches, clocks, and jewellery	Repair
9529	Repair of other consumer goods	Repair
96011	Laundries and renting of linens	Repair
96012	Dry cleaning and dyeing	Repair

Certain business activities surrounding renting and leasing have here been allocated the classification of 'rethink', even though other renting and leasing activities have been allocated to 'repair'. The difference here lies in control and an expert estimation on the basis of the following two questions:

Control question 1: does renting mean the product is not purchased? In other words, is the renting/leasing a substitution/real, viable alternative for new purchases or not?
Control question 2: is it a short rent or a long-term rent/lease?
For short rents that avoid new purchases, 'rethink' is allocated, because there is a (potential) intensification of product use. In other cases, 'repair' is allocated, because there is a (potential) decrease in intensification of product use, but there remains the incentive of lifespan extension. Renting/leasing the product to more users would provide the manufacturer with the incentive to provide the product with a long lifespan. The estimations here have been made conservatively. See also Royal HaskoningDHV for a more elaborate explanation.