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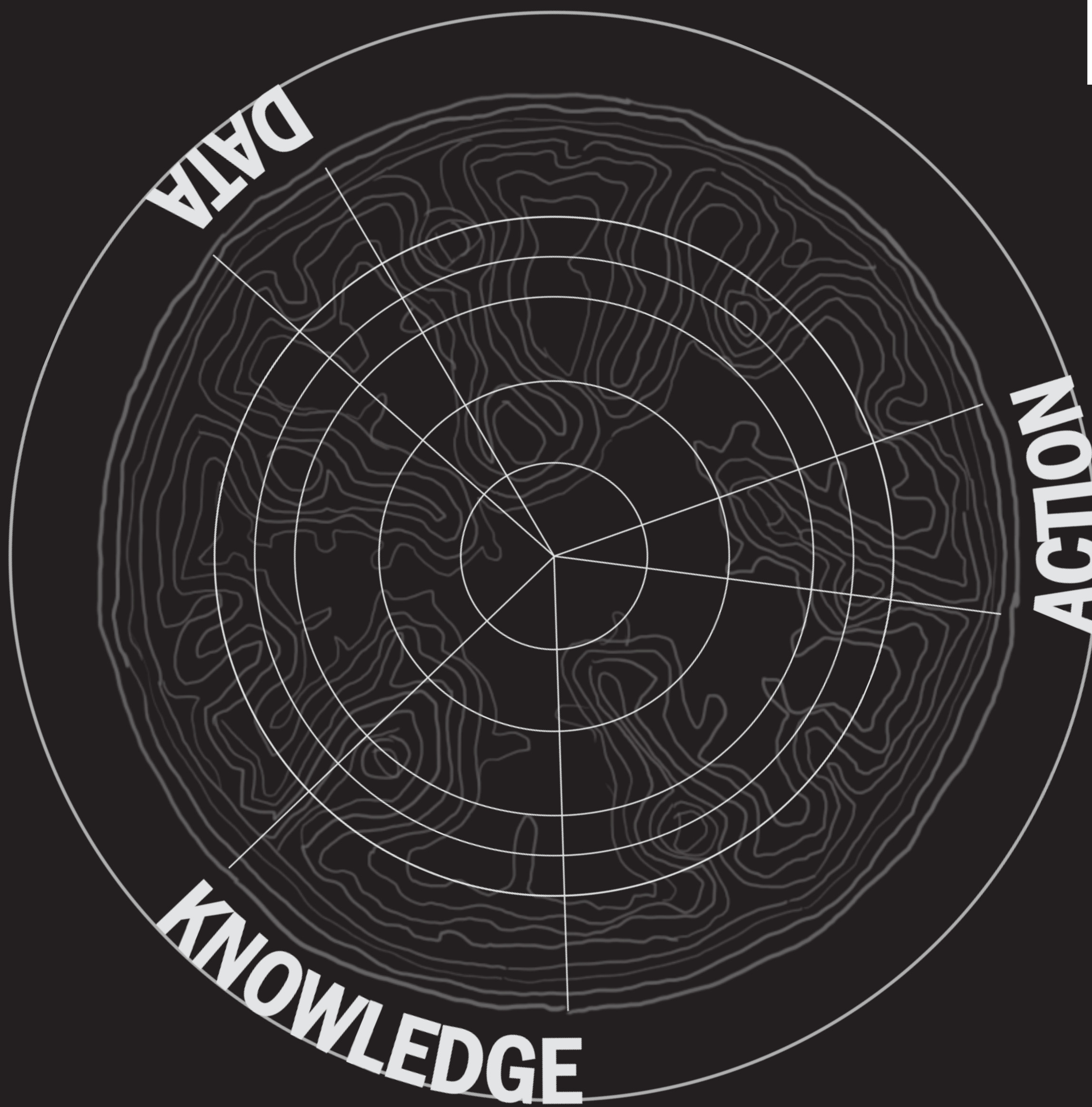

Circular Design Network

Data-Driven Circular Design

– A Guide Book

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ACADEMY OF FINLAND

Inspiration

Addressing urgent environmental concerns, such as climate change, biodiversity loss, water scarcity and marine plastics, requires rapid responses. We need novel solutions that are circular by design and have the potential to change our mode of operation more rapidly and systematically.

To understand and re-design our material cycles to be circular, we need data and systems understanding. Currently this data is scattered and siloed in many forms and formats, making its use difficult for individual decision makers.

The Circular Design Network project (2019 - 2022) was initiated to understand the practical data needs and gaps at the systems level, and to build a stakeholder network to develop data approaches for circularity. By building a network that comprises data users, providers and developers, we aim to develop new ways of collecting and validating data, along with new methods to process and refine it into system-level models of action.

This guide is meant as an open invitation to participate in building a circular economy based on shared data and knowledge. It also introduces central concepts, approaches and tools for data-enabled circular design, illustrating value creation from data to knowledge to action. These concepts are concretized through case examples in the battery, textile and food value chains.

We need a wide spectrum of multi-disciplinary competences and stakeholders to develop circular-by-design solutions. We hope this guide will serve as a source of information and inspiration for anyone interested in creating new value through data, contributing to a more sustainable future. You are needed to contribute!

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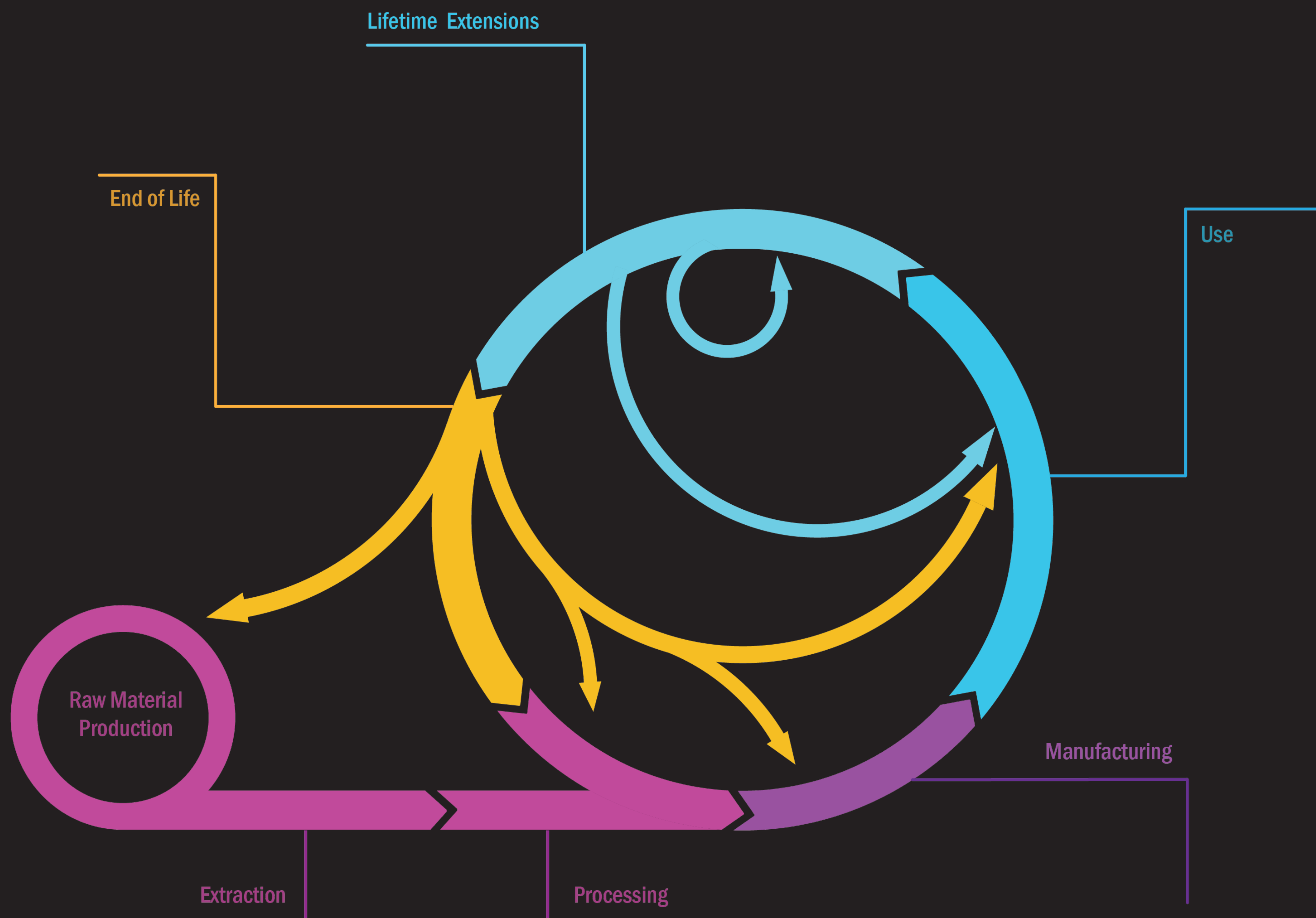
II: Circular Design

What Is It?



Circular Economy

The circular economy, vs. our current linear economy, is a techno-economic model that is cyclic, restorative and regenerative by intention and design. Products and materials are kept in use whenever possible, waste becomes raw material for new products and natural systems are supported.

Circular Design

Circular design is a design approach that aims to produce materials, products and operations that support the principles of the circular economy. By planning ahead and designing for circularity from the beginning, we can design out waste, extend use cycles and reduce the environmental burden.

The Circular Design Approach

According to Ellen MacArthur Foundation (2022), a pioneer of the circular economy, circular design applies and enables the three principles of the circular economy: design out waste and pollution; keep products and materials in use; and regenerate natural systems. These principles can be applied simultaneously at different levels.

The work towards circular design starts at understanding the product and value chain material flows, related sustainability impacts and value creation through the value chain. Even though we work from detailed information up towards the value chain view, our solutions should target the systemic benefits, instead of sub-optimization in one part of the value chain.

The elements of circular design include zero waste and clean designs, circular business models and partnerships, circular and regenerative material cycles, and circular strategies and policies. Ultimately, the implementation of all these elements requires data and data-sharing.

Ellen MacArthur Foundation, 2022. What is circular economy? Accessed 9.11.2022. https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Systems Thinking

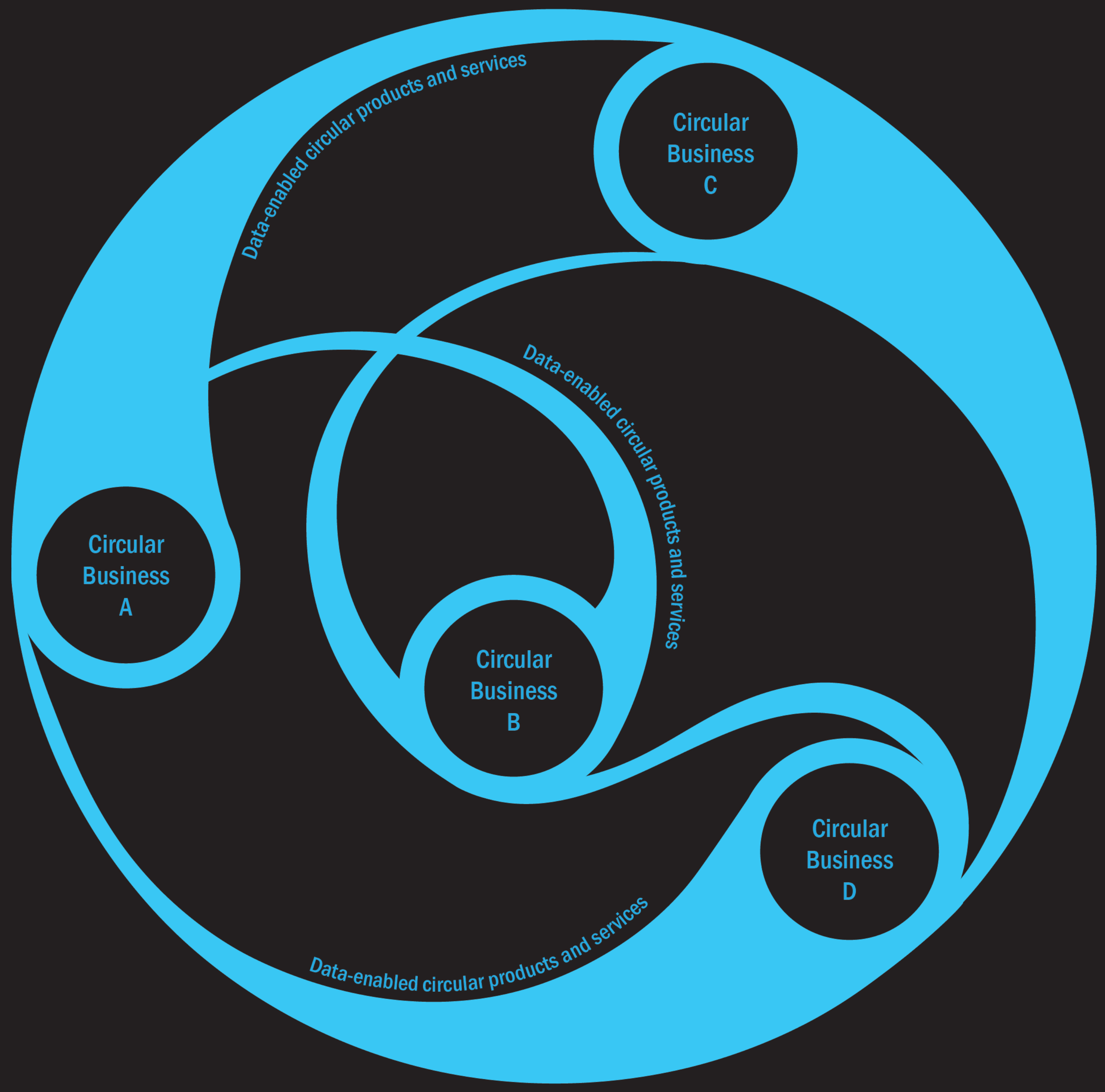
Systems thinking helps understand how different systems work and interact over time. One of its key features is the ability to represent and assess dynamic complexity.

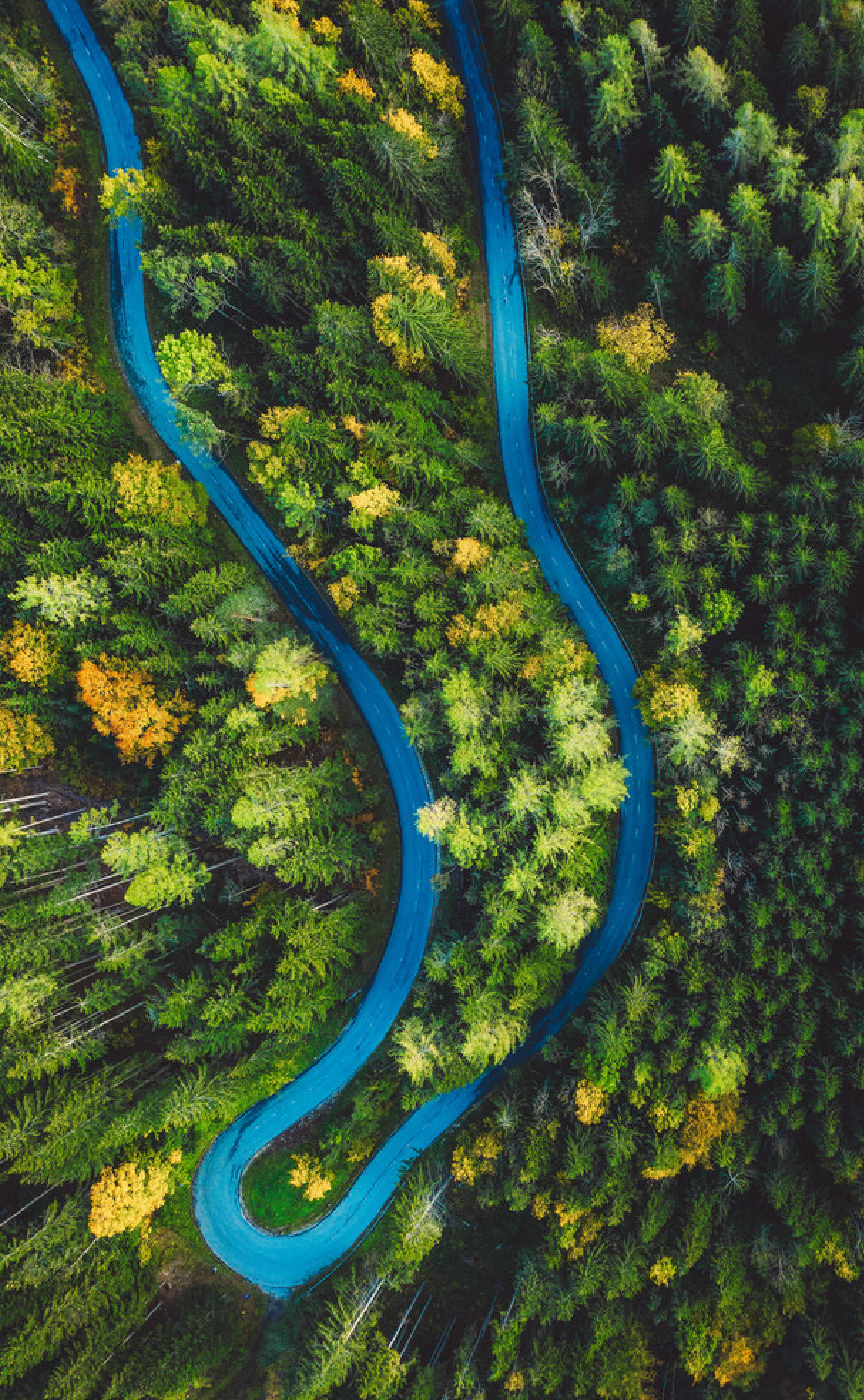
Systems thinking is a way of assessing the world. It is a methodological approach to understanding parts, entities, complex situations and their interactions. Instead of analysis, systems thinking focuses on synthesis, i.e., observing how different parts of a system interact to form the whole.

Systems thinking is important so that we can understand the wider system behavior such as feedback loops, cascading effects, inertia, tipping points, cause-effect chains and rebound effects. Including them in the design process we can design our solutions to be circular and sustainable.

Systems thinking in value chain design

Circular design can and should take place at different hierarchical levels: products, materials, business models and ecosystems. Data supports the circulation of products and materials and provides opportunities for implementing circular business models and operations.





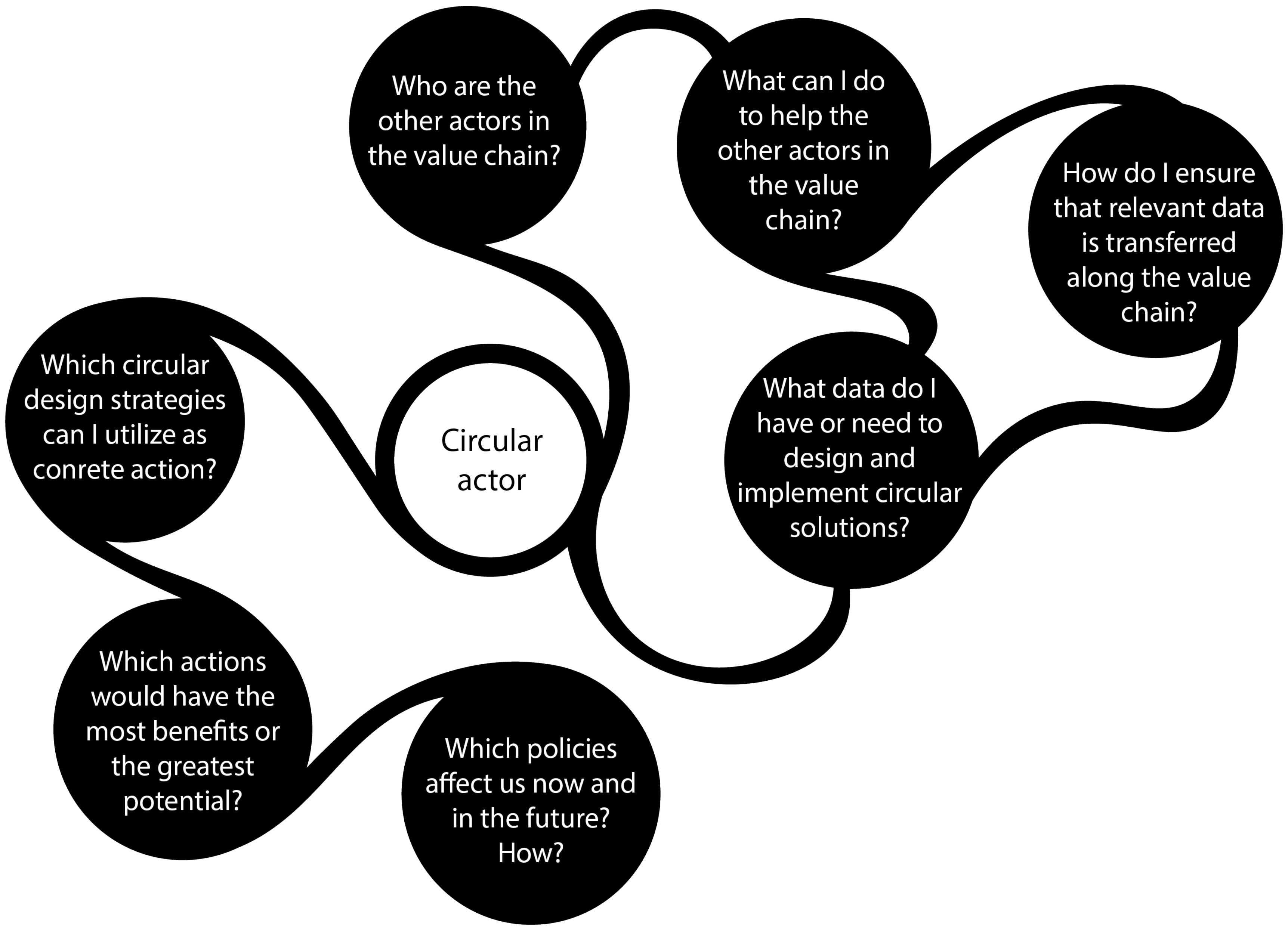
Systems Thinking in Value Chain Design

The circular economy is a collaborative effort by definition. The aim is to build operations and business that are designed as regenerative loops, maintaining the value of the resources through multiple lifecycles. We will need a holistic viewpoint, a bird's eye view of the possible impacts and opportunities of circularity, in order to seamlessly integrate multi-disciplinary competences and capabilities, ecosystems, and company clusters.

Circular actors

Transforming the value chain from linear to circular requires major changes to the current practices and actors in value chains. In designing a new product, business model or strategy for circularity, the actors have many questions to consider, ranging from potential partners and policies to data issues. Most importantly, the variety of different, attainable actions and their respective systemic benefits need to be considered when planning for the future.

Among others, consider these:



The Five Key Principles in Designing for the Circular Economy

Businesses can innovate towards a circular economy using five interrelated strategies: narrowing, slowing, closing, and building regenerative material-product loops, and informing the stakeholders in the value chain.

Before applying these principles it is important to understand the material and energy flows, the actors and the product and use cycles in the value chain.

Konietzko, J., Bocken, N., Hultink, E.J., 2020. A Tool to Analyze, Ideate and Develop Circular Innovation Ecosystems. Sustainability 12, 417.

Circular Design Strategies

Circular design strategies provide means for transition to circular products, value chains and operations.

This can be achieved by:

- using less materials by increasing material efficiency
- keeping materials, products and infrastructures longer in use by improving durability, repairability and resistance to corrosion, wear etc.
- keeping recycled and secondary materials in circulation by utilizing residues and waste as raw materials
- recycling materials more efficiently by selecting and developing recycling methods for each material or product at the design phase
- using renewable resources, such as bio-based materials and materials that can be sustainably produced or grown
- using non-toxic materials and decreasing their amount already in circulation, keeping track of toxic content throughout the lifetime of the materials
- using renewable energy to reduce emissions and waste generated through energy production
- digitalizing material and gaining benefits of data-driven circular solutions to minimize the negative effects of the material production, use and recycling

Circular Products and Materials

Circular design improves the circularity of materials and products. The combination of data analysis and science-based modelling supports circular design, and Design for X strategies, such as Design out Waste, Design for Repair, Design for Recycling and Safe and Sustainable by Design.

The utilization of data analysis and science-based understanding opens new business opportunities via new business models based on zero-waste strategies, using recycled raw materials, material lifetime extension, reuse, remanufacturing, and recycling.

II: The Role of Data in Circular Design

How to Move from Data to Solutions?

Data for Circularity

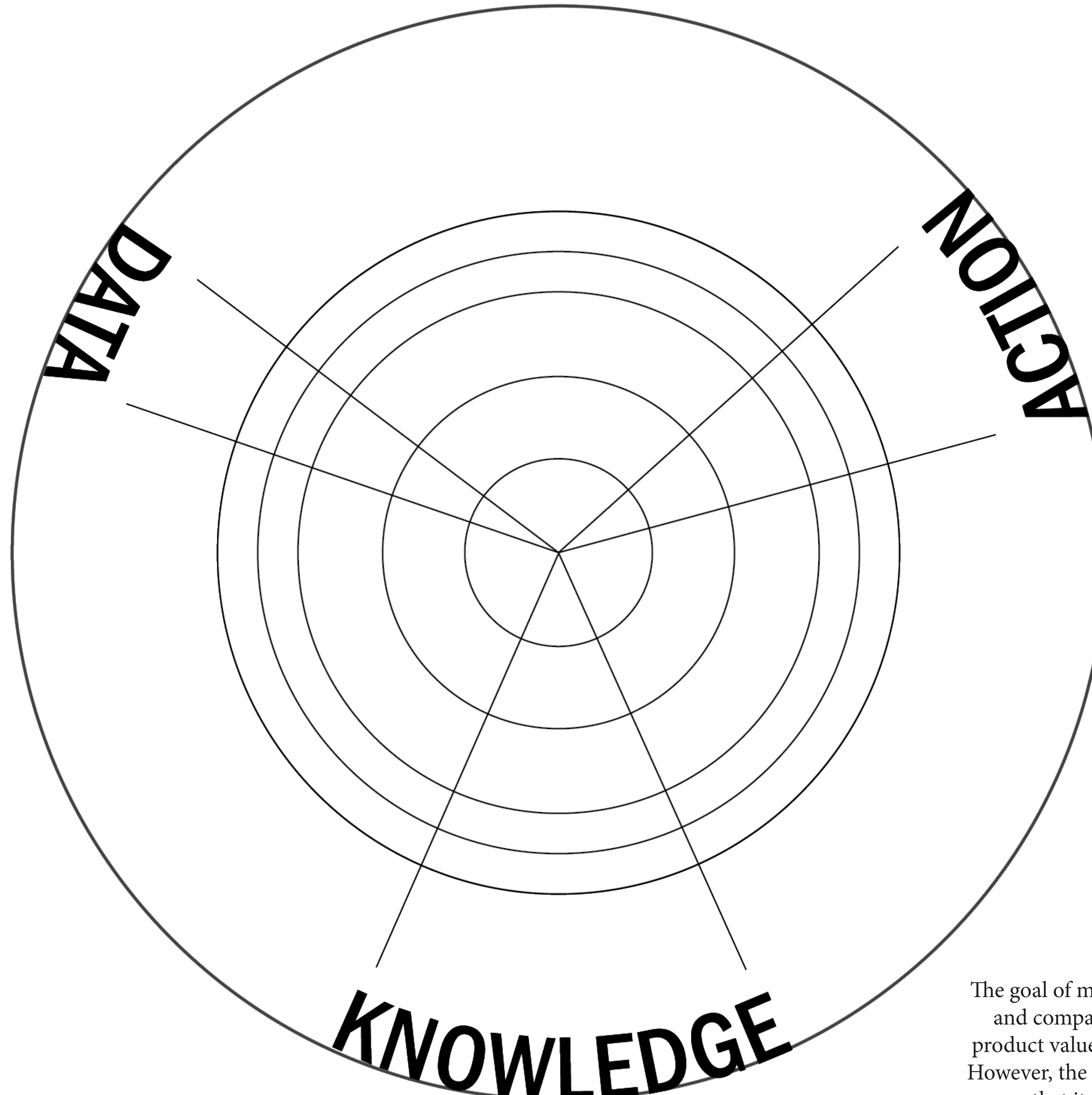
Accessible data is an important enabler of a circular economy and circular design. This transformation requires data and transparency throughout all stages of the value chain. Different circular strategies call for different data emphasizing both flexibility and interoperability of data sharing practices. Data can be shared as fully open, or the access can be restricted via agreements and different technologies to selected actors or within a specific ecosystem.

Circular economy can benefit from imlementation open ICT standards. For example, when data is published as Linked Data (W3C), the data is structured and interlinked together making them machine-readable. In this case, a data source serves as an Internet database and enables automatic linking of data for diverse data processing, such as for circular design processes.

Linked Open Data (LOD) is an uncomplicated way to make data available and free to use for anyone interested. Especially public actors, but also private ones are encouraged to publish their data as LOD.

However, businesses often consider their data to be business critical and confidential, and they will need a concrete incentive to share it. In addition, as there is typically a cost associated with making data available, they may be unwilling to provide it for free. To tackle this issue and facilitate the secure and sovereign data economy, the European Data Strategy stresses the creation of a digital single market for data, while the Gaia-X Federated Data Infrastructure implements the tools for fair and trustworthy data sharing. Gaia-X Data Spaces are built on standards and rules that allow participants to store their data at the source and share them based on standardized contracts, which is likely to promote emergent data-based circular business.

The European Green Deal introduces digital product passports (DPPs) as a central tool to improve the availability of product information, e.g. for repair, dismantling and end of life handling. DPPs are developed to empower both businesses and consumers. Battery passports are one of the pioneers creating a blueprint of a DPP to be adopted also for other products.



Data to Knowledge to Action

The goal of many actors, such as policy makers and companies, is to transform material and product value chains to more sustainable ones. However, the availability of data alone does not ensure that it is usable or used for this purpose. Raw data needs to be processed into relevant information and be put into context for use in educated decision-making, leading to the desired impacts. This is the concept of data-driven decision-making.

Data relevance depends on the stakeholder; a consumer may require different information than a supply chain actor, logistics company, service provider, waste management company or policymaker. This means that the data may need to be processed with different tools, into different formats, and validated to become relevant. With relevant data at our hands, we are able to compare our potential design choices.

However, the decision-maker should ensure that any societal and environmental tradeoffs are recognized and the potential rebound effects are factored in. The future outcomes of our desicions are never fully certain, but with analytical tools the risks and uncertainties can be made more transparent and mitigated.

The collection, storage and analysis of large data sets also come with a financial and environmental cost. Additionally, excessive data may complicate decision-making. In short, we should aim to collect and process only relevant data for meaningful uses.

Tools for Circular Design

Circular design tools include a wide range of ecodesign, innovation, Design-for-X, product-service-system and circular business model tools. The tools differ in their application, complexity, and data requirements, and can be used to support product development, integrate circularity into the product development process, and to prioritize product development options. Holistic circular design requires combining the different design perspectives and tools in the value chain.

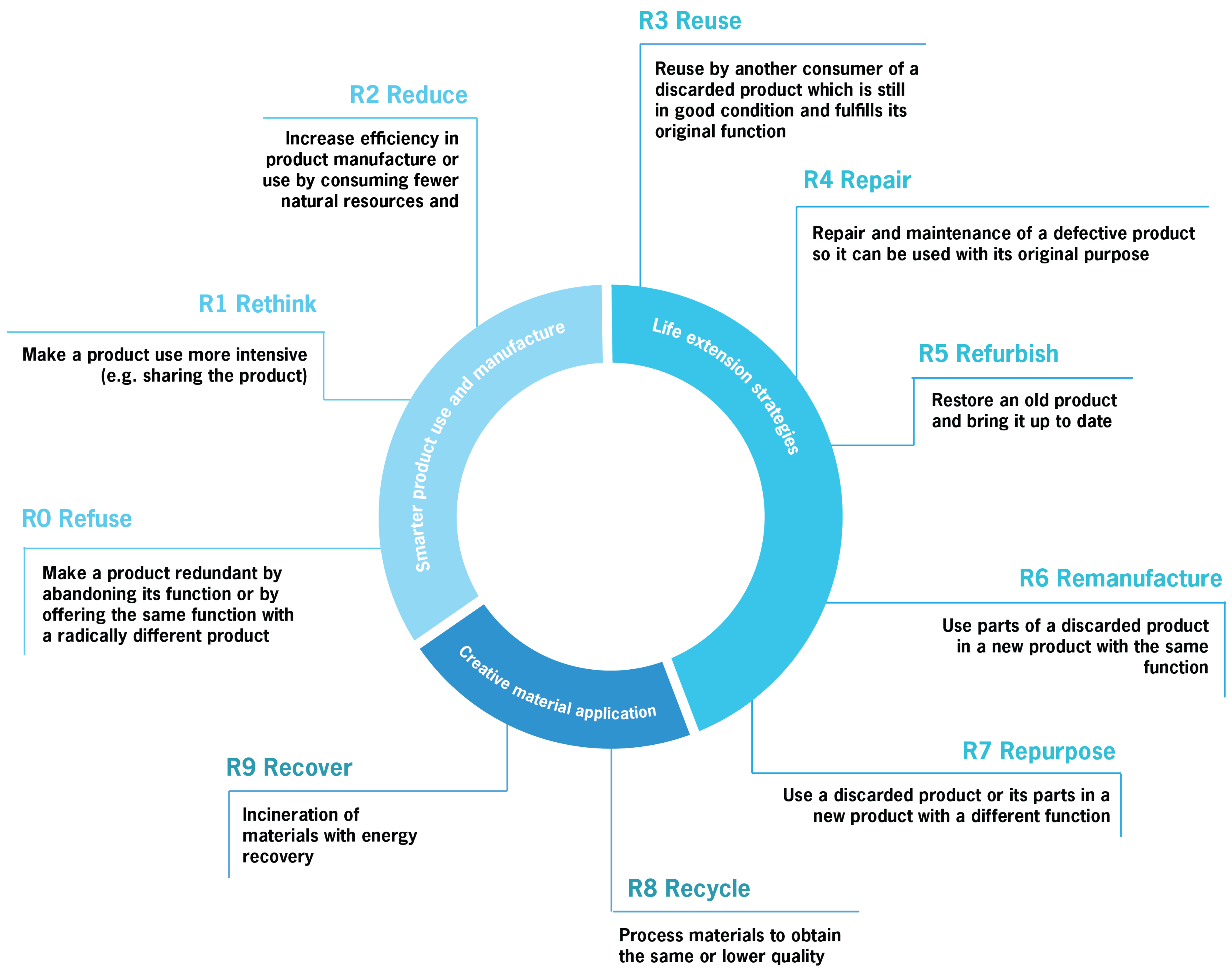
The level of accuracy and the demand for data and resources vary between the tools. Some tools are more suitable for design purposes, and some tools provide more accurate results for assessment purposes. Life cycle assessment tools have a higher demand for first-hand data, which may be hard to obtain in the design phase. Simplified life cycle methods are more suited to the design phase since they require less primary data and can be based on semi-qualitative analysis and empirical data, but their results are only indicative.

The system dynamics tools are useful for evaluating interactions and trade offs at the system level. They are suitable for circular design, understanding the limitations in the level of detail in modeling outputs.

Due to the limitations of the current tools, there is a need for tool development to support circular design and decision making.

Useful tools:

Circular economy playbooks
Sustainable and eco-design guides
Circular business model canvases
Service design tools
Stakeholder mapping tools
Ecosystem development tools
System dynamics mapping
Sustainability assessment and LCA tools
Multi-criteria decision making tools
Checklists
Integrated design tools
Product and process design tools



After the source: Potting, J., Hekkert, M., Worrell, E., Hanemaaijer, A., 2017. Circular Economy: Measuring Innovation in the Product Chain. Policy Report 2544. PBL Netherlands Environmental Assessment Agency, The Hague.

Circularity of Materials and Products

R-Strategies

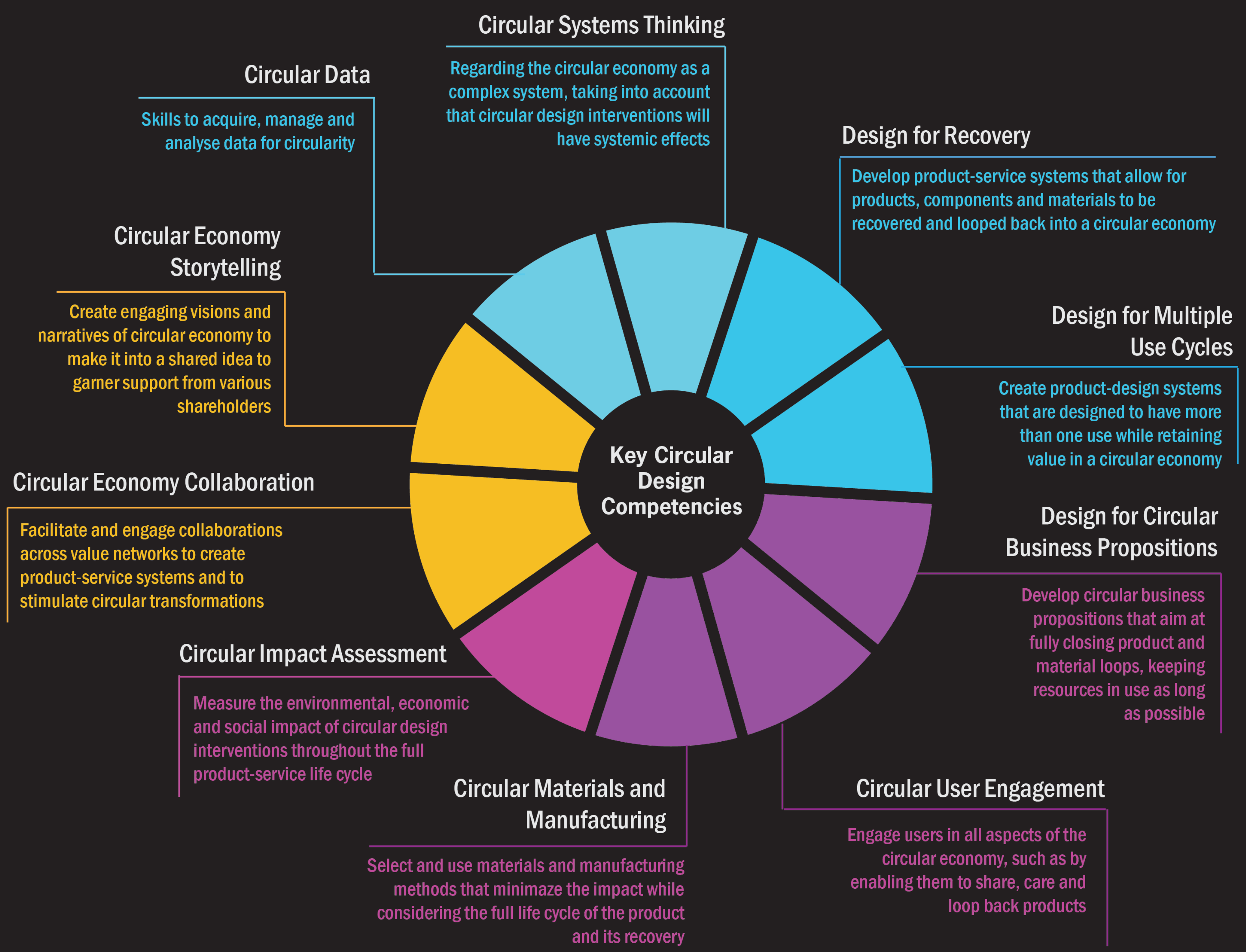
Circular strategies, often referred to as R-strategies, offer a framework to design circular materials, products, business models and value chains.

Interconnectivity of Competencies

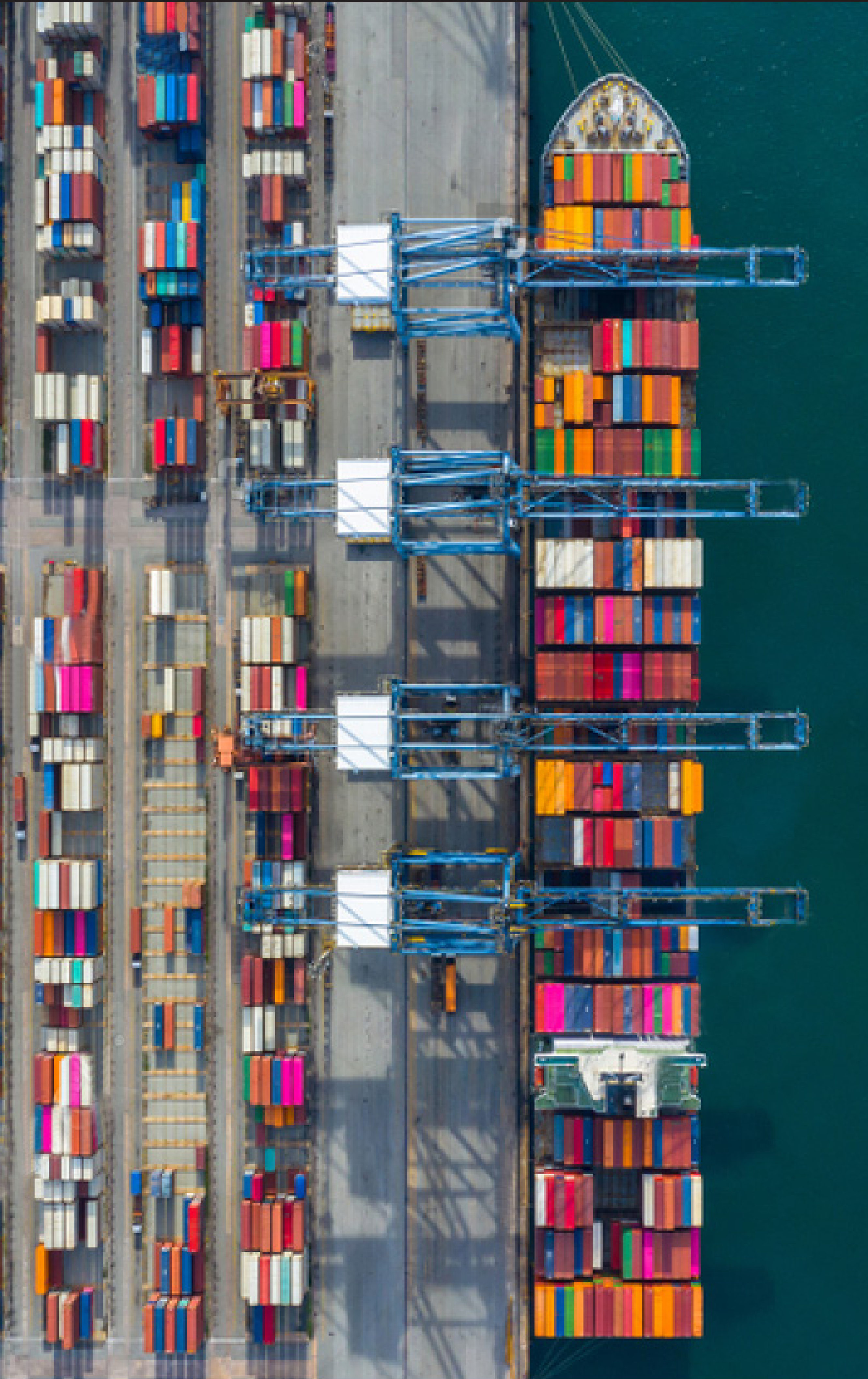
The circular economy requires cooperation and a set of versatile competencies to make sure that all important viewpoints are considered in designing the transformation.

Design for the circular economy combines traditional competencies in a transdisciplinary manner, such as behavioral sciences, engineering, environmental and business approaches. These competencies can complement each other in complex problem situations, as circular economy is.

No-one works in isolation but in interconnection with others. Using competencies proactively, i.e. in the design phases of products, policies, infrastructure, value chains and entire systems, it enables making informed decisions and strategy choices to benefit the business owner, the value chain, the environment, and society at large.



Modified after the following source: Sumter, D., de Koning, J., Bakker, C., and Balkenende, R., 2021. Key Competencies for Design in a Circular Economy: Exploring Gaps in Design Knowledge and Skills for a Circular Economy. Sustainability 2021, 13, 776.



II: Outlook to Three Value Chains

How to Design for Circular Cycles in Practice?

Three cases: Value chains of batteries, textiles and food-carbon cycles

A value chain view offers a relevant level of study for impactful circular design to avoid sub-optimization in some parts of the value chain. We will provide examples of how to use the R-strategies in three different value chains.

We selected three key value chains for our study, namely consumer textiles, batteries and the carbon in food cycles. Our aim was to to understand the material and related data flows along with data-based future opportunities in the value chains. The selected value chains represent different types of commodities in our society and are in the focus of the European Green Deal. For practical reasons, we concentrated on the stakeholders and material flows in Finland.

EU’s Circular Economy Key Value Chains

The Circular Economy Action Plan (CEAP) is one of the cornerstones of the European Green Deal, aiming at achieving climate neutrality by 2050. Design aspects are one of the main product policy themes in the CEAP. Through ecodesign, the Commission aims to promote the durability, reusability, maintainability, repairability, resource efficiency, and environmental efficiency of products.

CEAP highlights sustainability through key value chains that require urgent, comprehensive and coordinated actions. These will form an integral part of the sustainable product policy framework.

The new circular economy key value chains:

Electronics and ICT

Batteries and vehicles

Packaging

Plastics

Textiles

Construction and buildings

Food, water and nutrients

The Circular Economy Action Plan (CEAP), 2020. Accessed 9.11.2022. https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

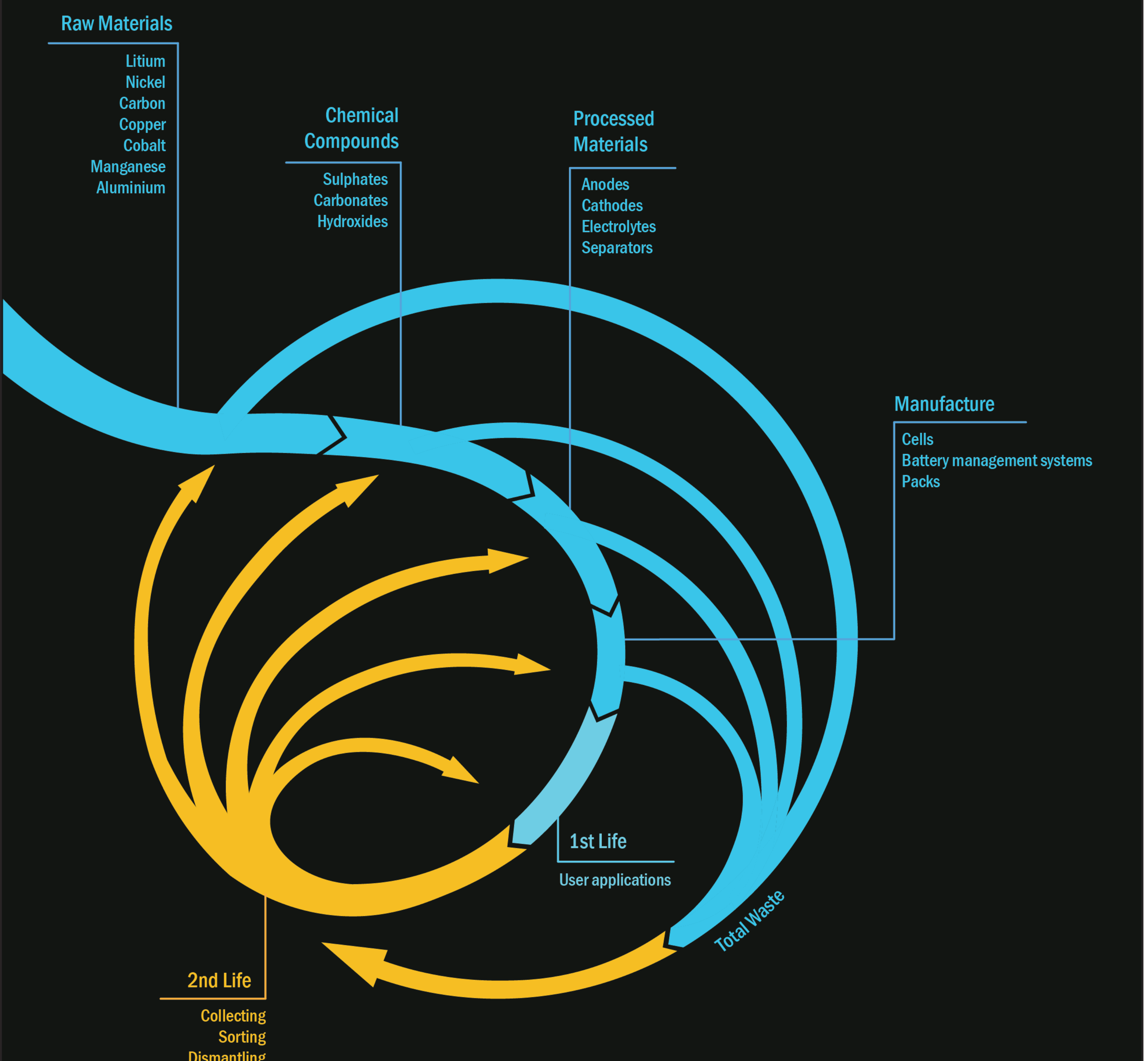
Value Chain I: Batteries

Drivers for Circular Batteries

Important sustainability drivers in the batteries value chain include the electrification of society, conversion to renewable energy, raw materials sufficiency, and preserving natural resource deposits. The ever-growing need for energy storage requires sustainable solutions that rely on circular principles instead of linear consumerism. Therefore, the aim towards a low carbon society has high demands on the battery industry.

The battery value chain is rapidly growing and taking shape according to growth potential expectations. The current raw materials are not circulating effectively, which has been acknowledged. The EU battery directive proposal is taking lifecycle thinking and data use to the next level towards the circular economy. The recycling percentages of materials are supposed to rise significantly, and by 2030 a battery is expected to have a minimum content of recycled materials instead of virgin raw materials only. Rules on recycled content and measures to improve the collection and recycling rates of all batteries will ensure the recovery of valuable materials and provide guidance to consumers, e.g., addressing non-rechargeable batteries with a view to progressively phasing out their use where alternatives exist.

Additionally, a digital battery passport is proposed - one of the most important drivers of circular battery economy.



Designing Circular Batteries

The battery value chain starts with raw material production. It includes several battery mineral ores (e.g., nickel, cobalt, copper, lithium, graphite, manganese, aluminium), with the future addition of alternative materials in the making, such as salts and plastics.

Through mineral processing, the desired minerals are liberated from the residue phases. Consequently, the main material flows generated by the raw material extraction phase are mineral concentrate (the product) and residue flows (mine tailings). The concentrates are processed into battery chemicals (metal salts such as nickel sulphate, cobalt sulphate, and lithium hydroxide). Battery chemicals are used as raw materials for precursor cathode-active material (pCAM) processing and further for cathode-active material (CAM) production.

As the next step in the value chain, battery cells are manufactured from the battery materials (cathode materials, anode materials, electrolyte, and separator). The finished battery cells are then transported to battery pack manufacturers for battery pack assembly and battery management systems integrations.

After production, the use of the battery starts. Digital monitoring of state-of-health and knowledge-driven predictions of remaining useful life can optimize the use of batteries and extend the useful lifetime.

At the end of the first life, there is a possibility for second-life applications and recycling. Through recycling, the battery materials can be returned into the cycle.

Battery passports are under development. What kind of data is relevant? What kind of data is required by actors throughout the value chain?

The R-Strategies in the Battery Value Chains

The R-strategies can help in designing and developing circular battery value chains.

The current aim is to refuse (R0) and eliminate waste with holistic process and product designs. There may also be competitive technologies to substitute batteries with other power storage options.

Companies are rethinking (R1) their products and supply chains to provide traceability and to develop data-driven business opportunities and products. These opportunities can be based on data and battery passports, new battery chemistries, or a recycled material base, for example.

The battery industry has acknowledged the limited mineral resources and is aiming to reduce (R2) the use of new materials, as well as the production costs, through recycling.

Batteries can be reused (R3) for other purposes than their original use and converted to 2nd life applications.

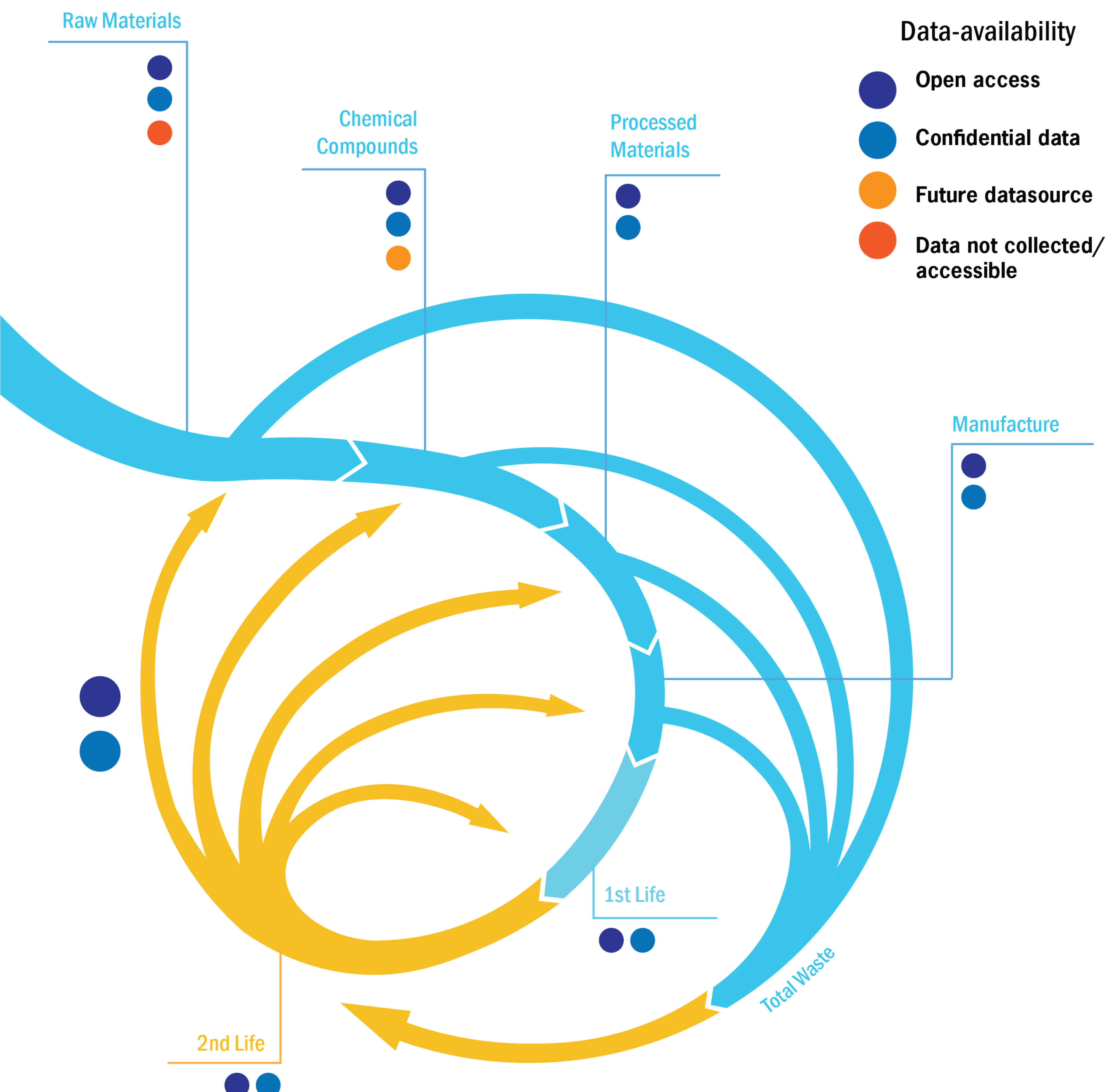
Current battery production is shifting towards rechargeable and repairable (R4) products that can be maintained, which will result in a longer life span of the product.

Refurbishing (R5) used products has become an option as new, more effective technologies and modular structures have been developed.

As aging and wearing rates of components in a product may be varied, their partial reuse enables remanufacturing (R6) of the product.

Repurposing (R7) certain components enables their use for new products and application in other value chains.

Legislation has set targets for recycling (R8) batteries and battery materials to increase the supply security of critical raw materials.



Data from the Battery Value Chain

Most data is collected in the core business areas of the companies. Companies and research organizations working with the production, use and recycling of batteries collect data about production processes, materials, and battery characteristics. This data is often collected systematically and continuously. Product and production data is gathered to ensure product quality and to enable traceability, and for evaluation of production efficiency and safety. However, detailed information about side streams or residues is commonly collected only upon demand. Despite the general trend towards digitalization and data sharing, there are organizational and technical barriers to sharing data. Additionally, data availability and data practices vary, which may restrict mineral business development.

Transparency, traceability, and openness are important aspects in the value chain. For example, how the battery materials are produced and whether the production is ethical. The data about lifecycle helps maximizing product lifespan as well as reuse and recycling potential. Comprehensive data on batteries and their use has led to the idea of a battery passport. Especially for the larger battery products, this digital product and usage history document would cover their entire life span. This would include sustainability and transparency requirements for batteries taking into account, for instance, the carbon footprint of battery manufacturing, ethical sourcing of raw materials, security of supply, and facilitating reuse, repurposing, and recycling.

Value Chain II: Textiles

Drivers for Circular Textiles

Resource-intensive value chains and high-volume markets place textiles in the fourth highest -pressure category for the use of primary raw materials and water, and fifth for greenhouse gas emissions (EEA, 2019). Besides the sector's considerable climate change impacts and water and fossil resource consumption, other environmental concerns related to textiles involve the release of microplastics, environmental and health risks caused by hazardous chemicals and pesticides, waste generation and loss of biodiversity. The high production volumes mainly caused by the industry's fast fashion business models and short product life spans further aggravate these environmental concerns.

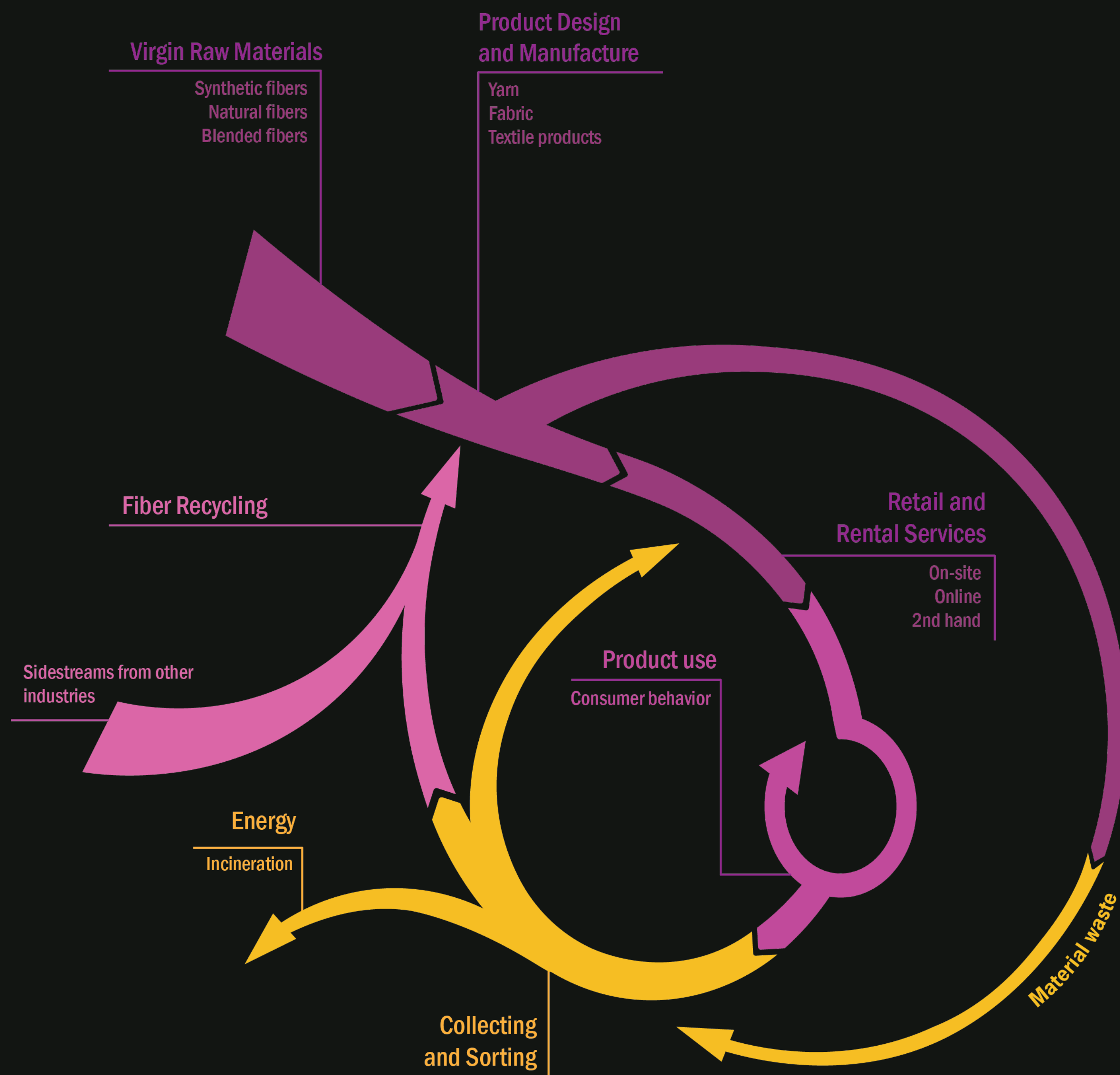
The textile value chains still operate predominantly in a linear way and only 12% of textiles are recycled – mostly downcycled into lower value products such as insulation material or wiping cloths and less than 1% are recycled into new textiles (Ellen McArthur Foundation, 2017). Due to their vast environmental impacts as well as their considerable circularity potential, textiles have been identified as a priority group for implementing novel circular practices covering the whole life cycle of the product (European Comission, 2020).

The application of circularity strategies to textiles is needed not only to cover the collection of textile waste and recycling, but also to include production and consumption patterns to favor environmentally sound raw materials, facilitate longer lifetimes, utilize production processes that generate less waste and fewer emissions, and phase out hazardous chemicals.

EEA (European Environment Agency). 2019. Textiles in Europe's circular economy. Briefing no. 10/2019.

Ellen MacArthur Foundation, 2017. A new textiles economy: Redesigning fashion's future.

EC (European Commission). 2020. Circular economy action plan: for a cleaner and more competitive Europe. Publications Office of the European Union.



Designing Circular Textiles

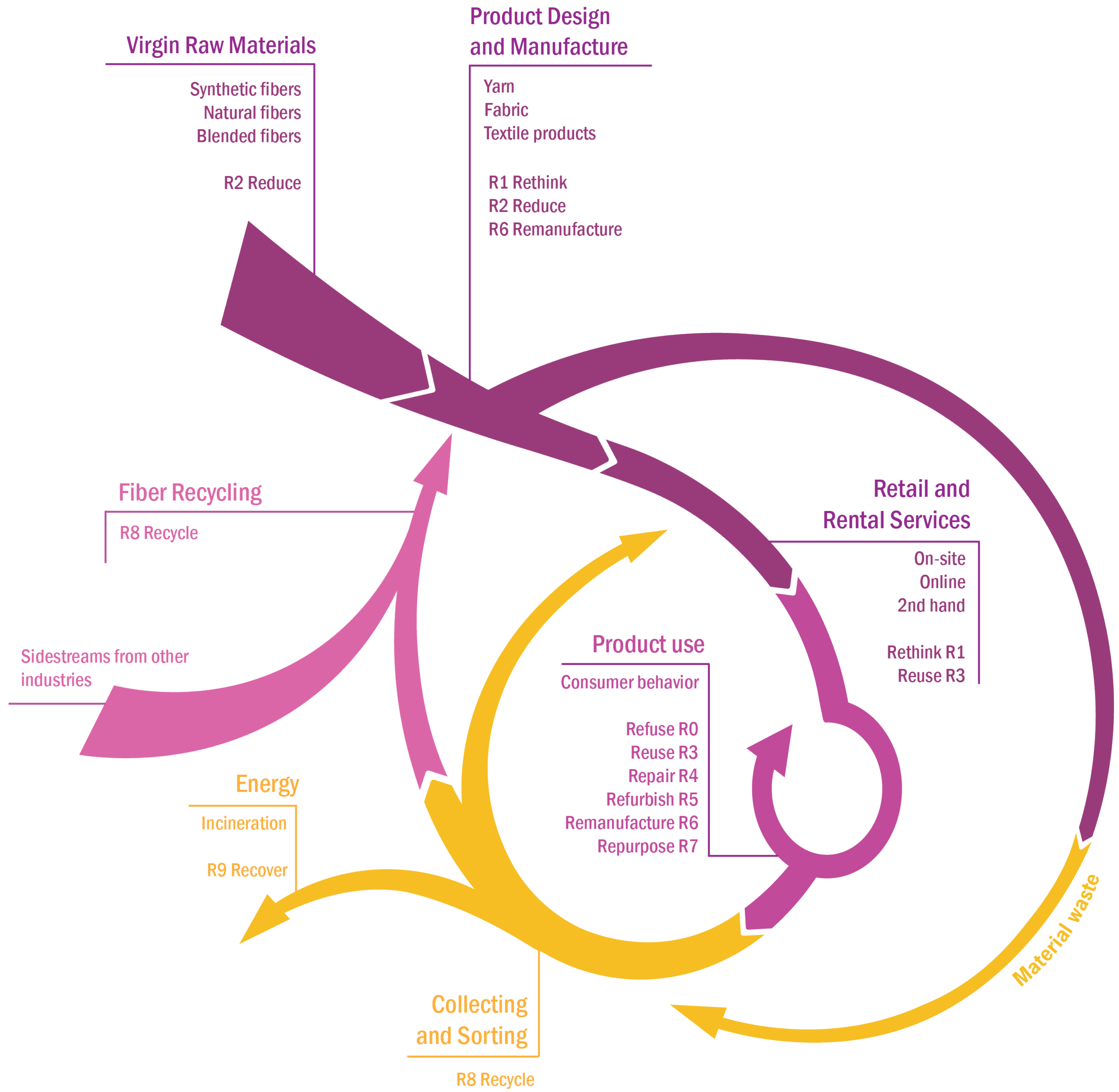
The traditional linear textile value chain starts with producing or extracting virgin raw materials for natural or synthetic fibers and processing them into yarn and eventually fabric. The fabric is finished and fashioned into a textile product. It is often only used by the initial buyer after which it is disposed of by landfilling or incinerating.

From a design perspective, the circularity of textile products can be increased throughout the life cycle, considering both material and product circularity. In the product design phase, the products can be designed for long use, extended use, repair and recycling (see den Hollander et al., 2017). In the context of textiles, designers can help prevent a product from becoming obsolete, which in practice means, that they can design the products for emotional durability and according to slow fashion trends, instead of fast ones. It is also important to design products with high physical durability and products that are easily maintainable or repairable.

From the viewpoint of the material circularity, it is crucial that in the selection of materials, recycled or repurposed materials are prioritized and particularly, that the textile product is designed for recycling, i.e. using monomaterials or otherwise easily recyclable materials in order to be able to retain as much value of the material as possible. Design choices are not necessarily restricted to the product design phase; further down the value chain, for example reuse and sharing can be promoted by designing rental, 2nd hand and repair services. Various processing stages, such as the manufacturing or recycling processes can also be re-designed for higher efficiency, thus reducing the amount of resources consumed.

den Hollander, M., Bakker, C., Hultink, E. 2017. Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms. Journal of Industrial Ecology 21(3), 517-525.

R-Strategies in the Textile Value Chain



The R-Strategies in the Textile Value Chain:

Refusing (R0) to buy unnecessary products or making products redundant

Rethinking (R1) textile products, e.g. by sharing, to make their use more efficient

Reducing (R2) resource consumption, e.g. via more efficient manufacturing processes, reducing loss from unsold or returned products, and promoting washing only as needed in the use phase

Reusing (R3) a used but intact product by another consumer, e.g. by simply handing over or through second hand services

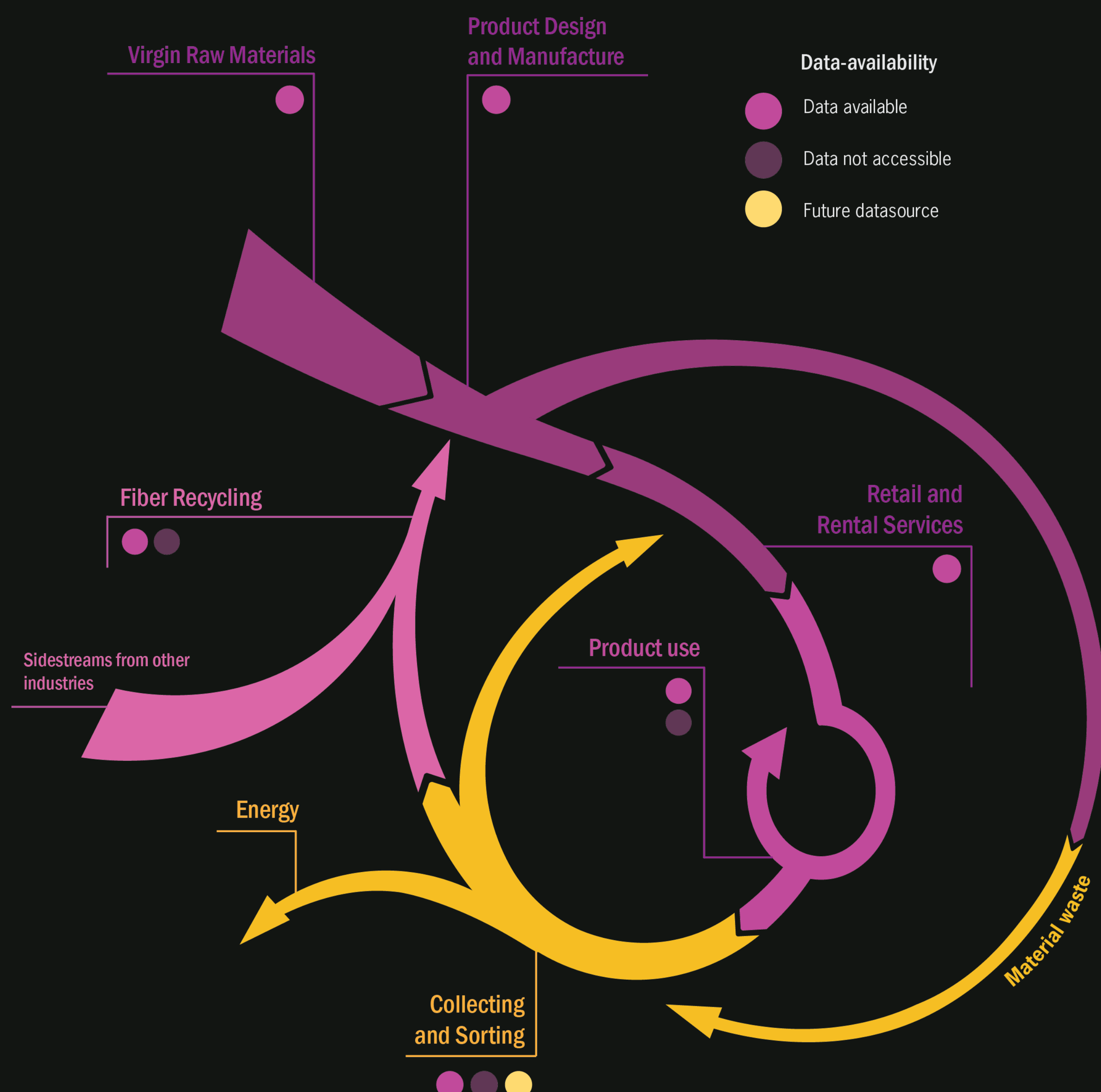
Repairing (R4) defective textile products to enable longer use

Remanufacturing (R6) new items from discarded textile products, e.g. by dying or patchwork

Repurposing (R7) a non-textile product such as plastic, to produce textiles, or using a discarded textile item in a different function

Recycling (R8) textile waste material to be used to manufacture new textiles or other products

Recovering (R9) energy from textile waste by incineration; the last resort



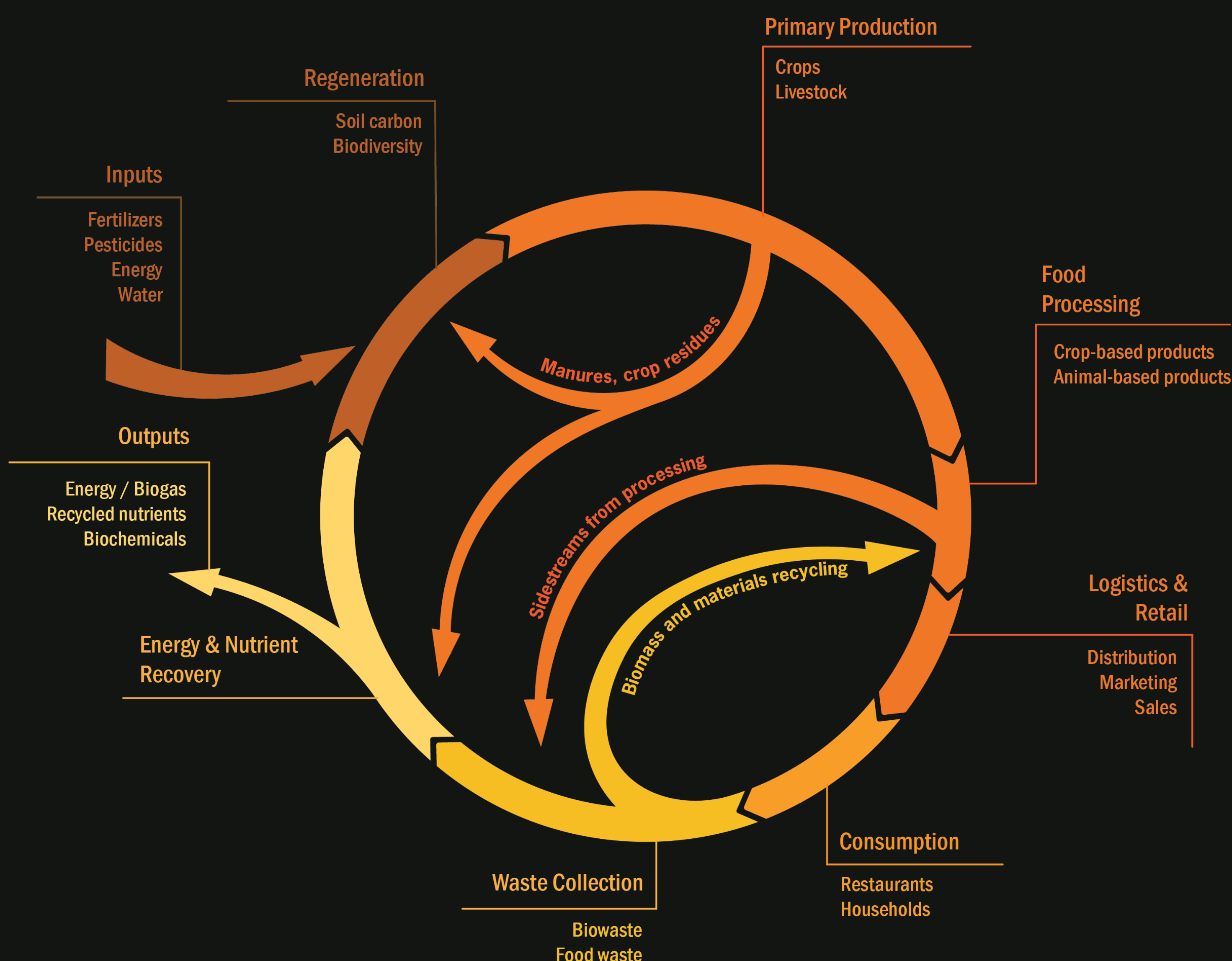
Data from the Textile Value Chain

Data covering the entire textile value chain is needed to design more circular and sustainable textile products, and for informed decision-making. This data may contain information on processes and consumption as well as general statistics on material flows. Company-specific process data comprises energy and raw material use (natural and synthetic materials), chemical use for dyeing and finishing treatments, emissions to water, transport distances and material contents of the finished product.

Due to complex and global value chains and business sensitivity issues, data is often unavailable to actors further along the value chain. Data quality may not be sufficient due to poor traceability, timeliness or accuracy. Data is needed from the raw material providers, from the processing and manufacturing phases, and also from the recycling processes. Business sensitive data sets and process data on recycling are often unavailable, or data maybe inaccurate due to use of developing technologies.

Consumer-related user data, such as life cycle lengths, reuse, repairs and other use phase behaviors, are usually not collected or available as especially private consumers do not track their consumption habits, nor do they make it publicly available. General statistics on material flows are high-level data sets, with low granularity, that are gathered by public offices and statistics authorities. Combining this data enables informed decision-making, and including environmental and social considerations. The challenge is not only gathering good quality data, but also how to provide access to it throughout the value chain. In the future, specific tools such as digital product passports or block chain applications may support transfer of data as well as its transparency and traceability.

Value Chain III: The Food System



Sustainable Food Production

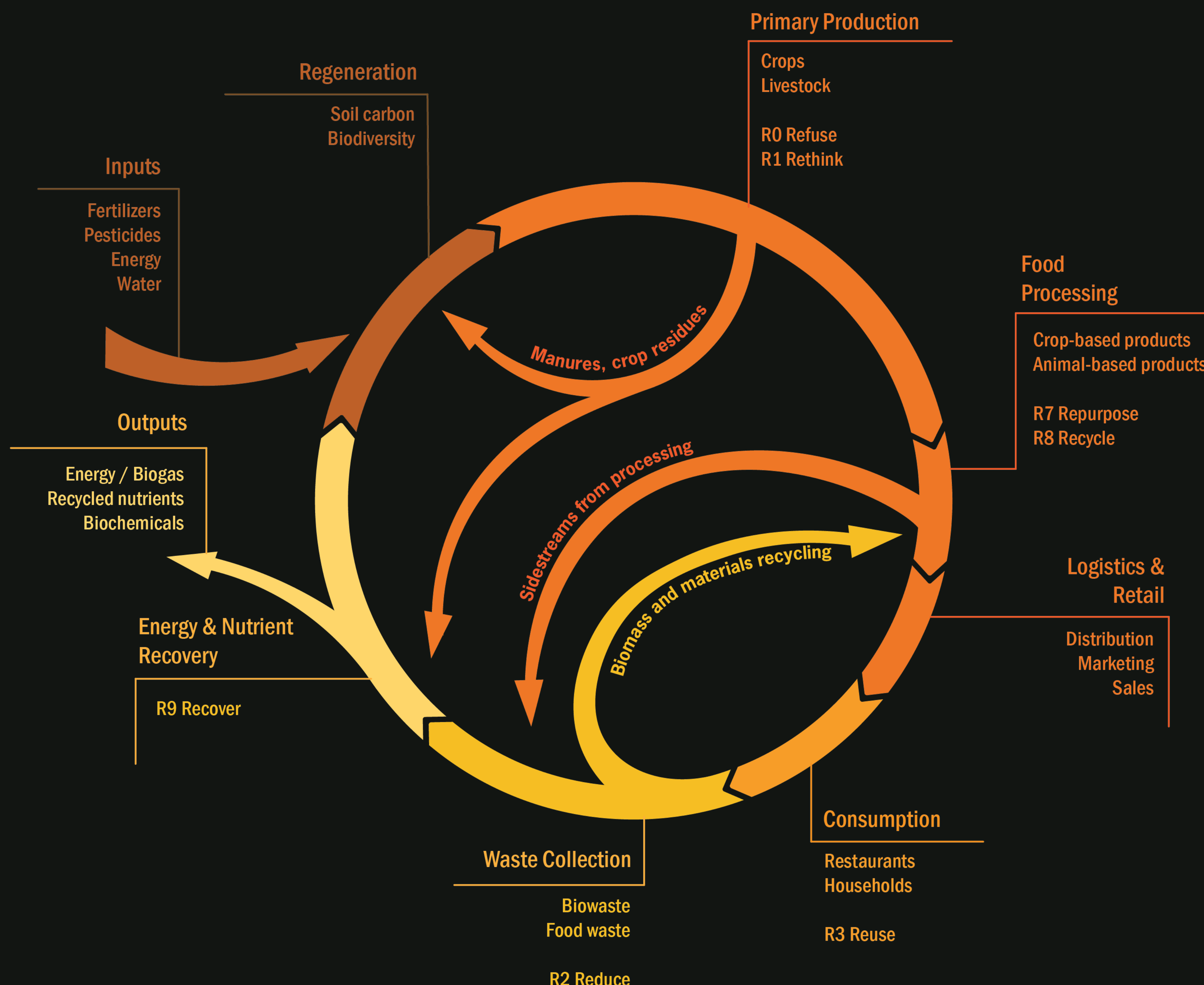
Sustainable food production follows the principals of resource efficiency, regenerative farming, waste hierarchy and cascading use of residues.

Resource efficiency starts with the premeditated use of inputs. When the fertilizer use is optimized, it also reduces the risk of nutrient run-off. Biological pesticides are used instead of chemical pesticides to minimize the harmful effects on biodiversity while renewable energy is used to mitigate climate change.

In regenerative agriculture the soil carbon content is at least maintained but preferably increased. Manure is used for fertilizing either as such or as a digestate from biogas production. Additionally, fiber sludge from the pulp and paper industry can be used as a soil amendment to increase the soil organic matter content.

The aim of the waste hierarchy is to get the highest possible value from residues and to generate the minimum amount of waste. Good examples of value-added use for side-streams from food processing are the use of spent grain from breweries either as feed or even as food when used for baking granola bars.

Finally, the separate collection of biowaste provides high quality raw material for biogas, recycled fertilizer and biochemical production. Biogas can be used as such for heat and power production (CHP) or upgraded to biomethane for traffic fuel or industrial use. In addition to agriculture, recycled nutrients (N, P) can be used in biological wastewater treatment in pulp and paper industry or in production of chipboards.



The R-Strategies in the Food System

Refusing (R0) to use a certain land area for food production has a direct effect on food availability. At the same time, it raises the question of what else will be grown on the same land area, and what will happen to that biomass.

Rethinking (R1) the species of plants and animals grown on farms, and the raw materials used for food and feed, impact the routes of carbon cycling in the system.

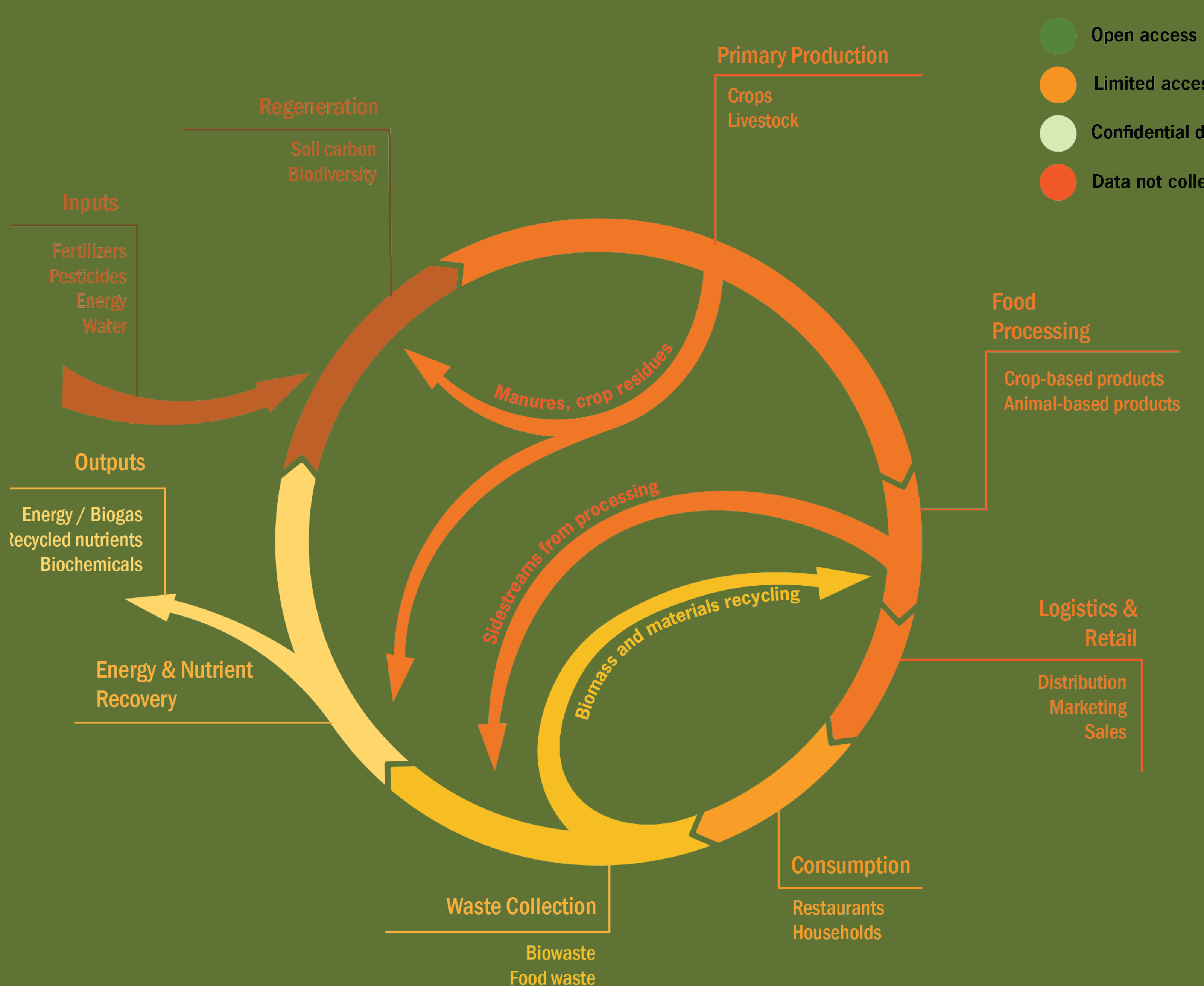
Reducing (R2) the consumption of food may not serve a purpose. Instead, the focus should be on reducing food waste.

Reuse (R3) of food as leftovers is an option in households, and to some extent in restaurants and catering. Additionally, the circulation and reuse of packaging materials can be considered.

Repurposing (R7) food leftovers can be done in many cases, e.g. in the case of using old bread in brewing beer.

Food waste can also be used as a raw material for new products through recycling (R8), e.g. when oat hulls are used to produce xylitol.

Finally, energy and nutrients can be recovered (R9) from biomass, e.g. when manure is used as biogas raw material.



Data from the Food Value Chain

Food value chains are well documented from farm to fork and back to farms. In primary production, field or animal specific data is recorded about used inputs and gained yields to optimize production, ensure safety, soil and animal health as well as to monitor governmental subsidy schemas. The data is mainly private and hosted by external private or governmental services. The data can be shared and utilized for business or research purposes but tools for safe and trusted data sharing are presently limited. Only a few datasets are shared as open data by public actors, such as field border lines and cultivated crop types.

Industrial actors in the value chains from food processing, logistics, retail to recycling also collect data from their processes, raw material, products, sales and customer activities. Large companies collect and store data using ERP systems (Enterprise Resource Planning) from which the data can be shared for business or reporting purposes. Small enterprises, however, are comparable to primary producers regarding data management and their ability to share and utilize data.

The actors of circular design in food value chains, especially small enterprises and start-ups will benefit from the coming EU-wide legislation and data space concepts for controlled, transparent and trusted data sharing within ecosystems. The aim is to establish data flows within and between sectors as well as countries with increased provision of data management tools. The development will enable trusted, flexible and cost-efficient data sharing within circular ecosystems and thus, efficient business.

The level of detail and quality of data varies in food value chains from one enterprise to another. The data can be manually entered or created automatically by proximate or remote sensor networks in machinery and the environment. This sets challenges for ecosystem-wide data-driven processes.

From Data to Action

Holistic circular design supports building sustainable value chains and optimizing the operations over the life cycle of the product. Data provides the essential basis for understanding business, sustainability and technology viewpoints and interactions, as well as for building holistic circular solutions. Data is also a vehicle to build additional value or even to enable circular solutions.

We encourage the stakeholders to connect with value chain partners and to build circular economy via circular design and novel data approaches. The authors hope that this guide will serve as a first step towards data-enabled circular design.

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