D3.1: Decision-Making Framework interim report

« Design and validation of the decision-making framework including the umbrella document and the user interface in the knowledge hub »

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1. Task 3.1 overview

1.1 Description as in EoLO-HUBS proposal

Task 3.1 ‘Circular economy framework’ runs from Month 4 (April 2023) until Month 42 (June 2026), led by the University of Leeds (UK) and delivered with ECHT (Netherlands) and Mondragon University (Spain).

This task will co-produce a circular economy decision-making framework for wind farms’ end of use management in ca. seven regions across the EU and UK with a focus on turbine blades. Regions in the demonstration countries Spain and Germany / Netherlands plus UK, France, Denmark and Italy were initially selected. This research design will strengthen the validity of the results, enabling transferability and exploitation of the framework across regions.

Decision-making will likely vary in each region e.g. due to differences in policy and legal contexts, technological capabilities, market abilities and demand, finance and insurance, social pressure etc. Therefore, the circular economy strategies to be considered, and the processes and stakeholders involved, will likely vary across regions.

The decision-making framework will take the form of a flexible step-by-step guide, forming an umbrella for tools developed throughout EoLO-HUBS (Figure 1):

i) To articulate circular economy options/map best practices (WP1, WP2);
ii) To assess the quality of a component/material (WP2, WP4), sustainability costs and benefits (WP2), policy and regulation (T3.2), commercial viability (T3.3, T3.4);
iii) To engage relevant stakeholders in structured decision-making processes adapted to regional contexts (WP1).

The decision-making framework will be piloted and evaluated in the two demonstration regions within this project (WP5), after which the framework will be finalised and made publicly available for exploitation and dissemination (WP1, WP3).

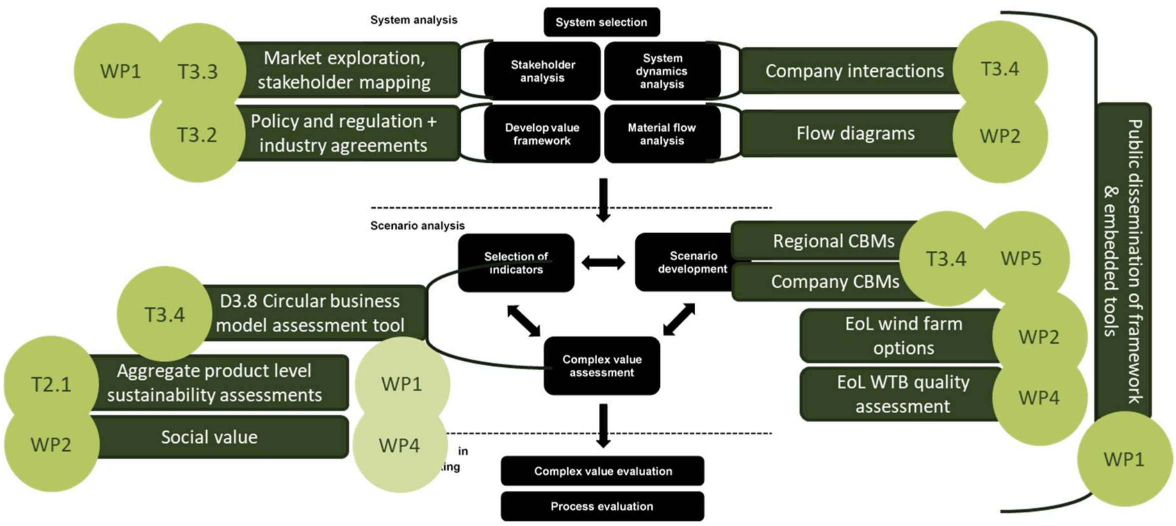

Figure 1: Relations between the draft circular economy decision making framework and tasks and work packages on EoLO-HUBS identified at the General Assembly in June 2023.

1.2 Task aims and objectives.

Task 3.1 will develop a proactive holistic framework to prepare and decide on sets of circular economy strategies for wind turbines in specific geographic and temporal contexts, with a view to optimise social, environmental, and economic values within a particular region over time.

Thereby this task contributes to the WP3 objective, to design novel circular business models for the sustainable exploitation of wind turbine recycling solutions now and in the future, supported by a context sensitive decision-making framework considering policy and market dynamics.

1.3 Deliverable 3.1

Task 3.1 will result in a report with the design and validation of the decision-making framework including an umbrella document. The framework will be implemented through a user interface in the knowledge hub (WP1). The report will be prepared in two stages – an interim report (D3.1, delivered herein) – and a final report (D3.6, currently planned for December 2025).

1.4 Benefits

The framework will help to future-proof the wind industry. Social, political and economic pressures to move beyond recycling are increasing. The EU's circular economy ambitions for 2030 place a high priority on waste prevention, reduced resource use and more repair, reuse and remanufacturing. The emergence of more diverse circular economy solutions that go beyond recycling, and the likely increasing stabilisation of the scale of some wind turbine designs, will strengthen the commercial case for more progressive circular economy solutions in contrast to just recycling. The decision-making framework will enable the proactive consideration of such strategies as they emerge over the coming years, and ensure that the wind industry does not miss out on new business opportunities in an increasingly circular economy.

Dynamic changes in the design, operation and end of use decisions of our current wind infrastructure will cause large fluctuations in the location, volume and quality of "waste" becoming available for recycling operations at the end-of-use of wind turbines. It is therefore important for both the demonstration projects and the exploitation of the up-scaled technologies to understand how increased circular economy performance throughout the wind lifecycle can reduce the quantities of materials use, while increasing the qualities of materials that become available to recycling operators and end-markets for the recyclate.

1.5 Impacts

The framework aims for the following impacts:

i) Make original contributions to the scientific knowledge base.
ii) Improve commercial and sustainability performance for our demonstration projects and in the industries that will exploit our results.
iii) Help to identify new business opportunities for companies in the wind industry and in affiliated industries such as consultancy, removal sector, construction and resources.
iv) Create more jobs through diverse and sustainable end of use strategies for wind infrastructure.
v) Substantially improve environmental performance, contributing to zero embodied carbon in the next generation of wind farms.

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2. Introduction

Natural resource extraction has roughly quadrupled in the past 50 years to more than 100 billion tonnes annually (World Bank 2022). Resource extraction and processing has exceeded the planet's carrying capacity, directly driving ca. 50% of carbon emissions and over 90% of impacts on water and biodiversity loss on land (International Resources Panel 2019). The benefits of an increased focus on recycling, seen by some as a pathway to a sustainable circular economy, would be cancelled out by the increase in virgin material use; the proportion of materials that is recycled decreased from 9.1% in 2018 to 7.2% in 2022 (Circle Economy 2023). Efforts to reduce the energy use associated with resource extraction to make so-called "green" products are often similarly outweighed by inexorable increases in resource consumption, especially mature sectors such as construction (Global Cement and Concrete Association 2023) and clothing (WRAP 2021). The environmental, social and economic costs and benefits of natural resource use are not equally distributed around the globe. Higher income countries consume 3-6 times more natural resources than lower income countries, yet the environmental impacts of extracting and processing these resources are largely felt in the latter (International Resources Panel 2019).

Sustainable development aims to meet the needs of current generations without compromising the ability to meet those of future generations. It aspires to the simultaneous improvement of environmental, social and economic outcomes for people and the planet. Aligning the production and consumption of resources with this aspiration requires a move away from an economy based on a linear "take-make-waste" mode of consumption towards a more "circular economy" in which products and resources are preserved at their highest-value state for as long as possible. Circular economy is now a critical component of the global sustainability agenda (UN 2015). Within the circular economy community there is a growing awareness of the importance of transformative whole system change. Scholars and practitioners now dismiss the reformative idea that increased mass recycling rates can achieve a sustainable outcome, as in the prevailing neoclassical economic model growth is firmly coupled with ever-increasing linear use of resources. Instead, a transformed circular society is now the aspiration. Substantially reduced average resource use per person in high income countries and greater global equality to increase fair access to resources in lower income countries is required to raise social well-being within environmental boundaries around the globe.

The implementation of circular economy embraces four main approaches, which must be combined if meaningful progress is to be made (Bocken, de Pauw et al. 2016, Velenturf, Archer et al. 2019)

- Narrowing resource flows to reduce the amounts of materials flowing into economies through strategies such as lean product design to minimise resource use and focussing on providing services rather than products through rental or sharing schemes;
- Slowing resource flows to extend the amount of time between the manufacturing and wasting of products with design strategies such as enhanced durability, modularity and repairability along with integrated end-of-life strategies for reuse, repair and remanufacturing;
- Closing resource flows to cycle materials back into the economy with strategies such as sustainable recycling and industrial symbiosis;
- Regenerating resource flows to return materials to natural biogeochemical processes when they cannot be kept in circulation within the economy in a sustainable manner.

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These strategies can help to minimise natural resource extraction (and thus associated emissions and pollution), maximise waste prevention and optimise the use of materials and products throughout their consecutive lifecycles.

The transition towards a circular economy requires collective efforts, as differing worldviews of stakeholders have to be brought together to agree on steps forward (Cramer 2020, Cramer 2020). Transformative changes strongly depend on coordinated action from diverse actors such as policy-makers, designers, manufacturers, retailers and the waste sector as well as society and consumer (Reike, Vermeulen et al. 2018, Velenturf and Purnell 2021). For example, transforming construction might require governments to set ambitious policy targets for the quality and relative quantities of new buildings and retrofitting existing building stocks, while also acting as an intelligent and exemplary client to the sector. Professional and building standards bodies have to translate such ambitions into the "new normal" for the construction industry. Consultants and architects (designers) and contractors (builders) must adapt practices and train staff to work in these new ways while having confidence that clients will adopt these new policies. Construction products suppliers have to change their offerings with e.g. more durable, modular and lower carbon components, and investors and customers have to be willing to finance and buy more "circular" buildings. Not one of these actors could transform construction on their own, and each could hold up transformative changes if they are not invested in developing the policies and practices that need to be in place for a sustainable circular economy. Transformative change must be inclusive of diverse perspectives and based on consensus.

Herein it will be argued that building consensus for action requires that actors co-produce plausible, value-driven sustainable circular future scenarios. For business, this could be achieved through the preparation of sets of circular business models for companies embedded in supply chains in a specific geographic context. The contribution to environmental, economic and social sustainability for each of these sets of circular business models should be assessed and constructively deliberated from the perspective of diverse stakeholders. The framework and tools for such approaches are in their infancy, but this should not prevent action. Rather their development should go hand in glove with building momentum for action by enabling better quality decisions that are appropriate for specific contexts to accelerate the transitions towards a circular economy.

Circular economy business models seek to primarily generate value ideally by means other than extracting primary resources and processing them into products to be sold and discarded. Quasi-circular business models also exist that seek to greatly reduce waste, emissions or social impacts, often by providing services that promote material efficiency or encourage recycling, that can be considered as part of the transition towards a circular economy. For example, the "air conditioning as a service" (acaas) model sells the customer a defined level of cooling for a given space, rather than selling or leasing an AC unit. This avoids over- or under-specification by unskilled clients, ensures systems are run at optimal efficiency by the skilled supplier, incentivises the supplier to preserve the life of the AC units used, and allows suppliers (rather than clients) to be responsible for and embrace upgrading, refurbishment, reuse and recycling. The net result is a reduction in the number of AC units "consumed" as they are kept at their highest value for as long as possible, in line with circular economy principles, while both the supplier and the client retain their profit margins. Understanding how such principles can be transferred to the wind sector will be a key aspect of this project.

Circular economy approaches are not yet commonly and systematically used in the design, operation and end-of-use management of wind energy infrastructure (Velenturf 2021). Circular economy strategies for wind could be applied throughout the lifecycle of a wind turbine. The current focus is often on recycling of materials at and of life. However, ensuring that repair, reuse and remanufacturing of components happens in the operational stage – which in turn requires that the initial design of wind energy installations take into account all of these aspects – is equally important. Such strategies are essential for the sustainability of the wind industry, not only in the environmental sense but also from an economic point of view to meet demand and legislative mandates.

Consideration of circular economy strategies is already a legal requirement for all waste management in Europe (EU 2008). When a wind turbine is decommissioned, it is legally obligatory to consider – in order of preference – waste prevention, preparation for reuse of components, material recycling, energy recovery and disposal. When a wind turbine reaches the end of its life, it may become classed waste, at which point all its components and materials instantly lose monetary value. This can constrain their continued use and the ability to generate commercial benefits and avoid environmental costs. Therefore, both from a business and a sustainability point of view, a proactive end-of-life approach that goes beyond an assumption of waste and thus the waste hierarchy can be more advantageous, and potentially open up new business models for the wind industry.

Such an approach would involve the assessment of wind turbines and their constituent parts such as turbine blades, electrical components or foundation structures for their suitability to be used for longer (for the same, enhanced or different function, in the same or a different location) rather than an assumption that they have become waste. This would in turn inform decision making about the most suitable pathway for continued use or, indeed, the end of use management of an individual wind turbine part. It would also involve examining how best to design and operate wind energy infrastructure such that this alternative additional value can be preserved or even enhanced, maximising the benefits derived from the circular business model.

The decision making processes that choose the most suitable circular economy strategy at any given moment in time are complex. Circular economy strategies, both individually and combined, can carry different sustainability costs and benefits depending on the situation in a particular context (assessed in T3.4 and WP2). Existing decision-making frameworks for end-of-use strategies for wind infrastructure (e.g. (Jadali, Ioannou et al. 2021), Burges Salmon and Everoze 2020) have considerable weaknesses by either not considering decommissioning legislation, basic waste regulations such as the full extent of the waste hierarchy or the complete spectrum of circular economy strategies that can add considerable environmental, social and economic value. By extension, it is not currently possible to put forward detailed design heuristics and operational models that preserve future resource value.

A comprehensive review of circular business models in the wind industry revealed substantial gaps in viable, sustainable and circular business models (Mendoza, Gallego-Schmid et al. 2022). Business models for circular economy solutions in the wind industry are generally not considering whole system social, environmental and economic costs and benefits with and for stakeholders involved, meaning that such solutions may not operate in a manner that is conducive to a sustainable and circular economy. Unless this is addressed, eventually this may cause environmental damage, erode the wind industry's current "green" reputation, and increase costs and risks within the supply chain.

3. Methods

This section outlines the methods for the development of a framework and tools to coproduce integrated solutions and constructively deliberate up and downsides, as part of transition processes for a circular economy that will contribute to sustainable development, involving coordinated change at multiple system scales in order to coproduce viable circular business models for the wind industry.

3.1 Literature review

A draft framework will be developed based on extensive literature reviews. An outward exploration of the literature did not reveal the existence of a framework and/or complete set of tools required for the purposes of EoLO-HUBS. Hence, a series of literature reviews will aim to identify building blocks to inform the development of the framework and steps within it:

1. Participation processes for sustainability transitions towards a circular economy.
2. Multi-criteria decision making under uncertainty.
3. Frameworks and tools for circular business model innovation.
4. Participatory sustainability assessments in circular economy incl. Complex Value Optimisation for Resource Recovery.

Literature will be critically reviewed, after which any remaining gaps in the framework and tools will be filled using logical reasoning, theory and best practice experience.

3.2 Qualitative case studies

This framework will be piloted and developed further through a series of up to five case studies in regions in different countries in Europe, and then piloting it in EoLO-HUBS' demonstration regions (Table 1). Specific regions within the case study countries will be selected if required. Delivery of multiple case studies will strengthen the validity of results, offering a thorough insight into how the framework can be transferred and applied to diverse regions.

Table 1: Proposed case study countries for circular business model decision making framework.

Framework development	Framework pilots
United Kingdom	Spain
Denmark	Netherlands
France	Germany
Italy	
Poland	

Each of the framework development case studies will focus on the detailed specification of tools and guidelines for at least two steps within the framework while completing the other steps more superficially. By the end of the framework development case studies, the framework will have been fully developed in detail for the application of co-producing and deciding upon circular wind business models, ready to be piloted within the EoLO-HUBS demonstration regions.

3.3 Multi-level business model approach

Circular business models have to work for a company within the context of a region. The context will impact on the viability of circular business models in a particular location. For example, the viability of recycling solutions will depend on the industrial diversity, such as the presence of other industries that can supply the equipment and materials needed to operate the recycling solution and the presence of

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customers for the recyclates; it will depend on the availability of skilled people to design/build facilities and operate the recycling operations; it will depend on policies and regulations; etc. Moreover, the context is dynamic and can rapidly change over time. This will impact on the viability of business models and the level of risk for investment cases. Therefore, it will not suffice to just develop general business models for wind turbine blade recycling.

In this project, business models will be co-produced at two levels: business and regional (Figure 2). Business models for companies along the supply chain will be co-produced, in parallel with an overarching regional business model to assess the whole system social, environmental and economic costs and benefits.

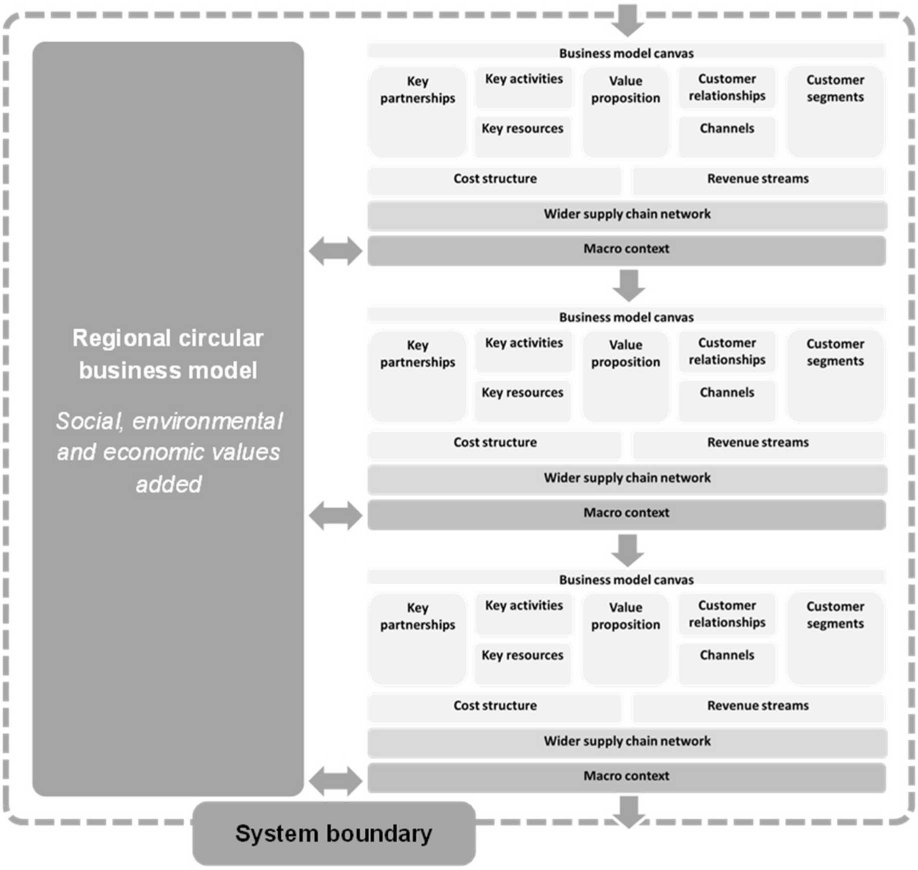

Figure 2: Concept of multi-level business models at company and regional levels.

For the company level circular business models, circular business model canvases will be used. Circular business model canvases integrate multi-dimensional value, i.e. social, environmental and economic value, from the whole system (regional) level and the supply chain into the core of the value propositions of individual companies.

Regional circular business models constitute a new concept that will be specified further within this research project.

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3.4 Circular wind scenarios

Within each case study, three or more sets of circular wind solutions will be articulated. These different sets represent diverse scenarios for circular wind "ecosystems". Each region will at least compare three scenarios, including:

1. **Business as usual:** for the manners in which wind turbines and blades are currently being managed at end of use.
2. **Wind turbine recycling:** such as the EoLO-HUBS wind turbine blade recycling and other recycling solutions for turbine blades and other wind turbine parts.
3. **Beyond recycling:** combination of recycling and solutions beyond recycling such as reuse, repurpose and remanufacture, to help future proof circular business models for wind.

At least half of the case studies will cover whole wind turbines, including the turbine blades and all other wind turbine parts. This will allow the circular business model development to cover integrated models that generate value from the recycling of whole turbines rather than from blades in isolation.

At least half of the case studies will include scenarios in which wind turbine blade recycling is combined with recycling of composite materials from other industries. This will allow for developing circular business models with multiple composite input streams.

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4. Review results

This section presents the results from a series of literature reviews to answer the question: What framework and tools can help to coproduce integrated solutions and constructively deliberate up and downsides, as part of transition processes for a circular economy that will contribute to sustainable development, involving coordinated change at multiple system scales in order to coproduce viable circular business models?

4.1 Participation processes for sustainability transitions towards a circular economy

Coordinated participatory and multi-level change is a core principle in circular economy transitions (Velenturf and Purnell 2021), aiming to "coordinate the development, integration and implementation of circular economy strategies and actions across societal actors – incl. government, industry, civic sector, consumers and academia – and across local to global scales, identifying key intervention points where the dedication of resources such as investment, policy change and expertise offers the most benefits for realising a circular economy.

Literature was derived from Scopus within the subject area of circular economy and sustainability, searching for publications on transition / transformation processes, frameworks, approaches or tools that involve companies. A total of 394 publications were found, of which 40 were selected after screening titles and abstracts. The rest was rejected because it fell outside of the subject area or did not cover participatory approaches. Here a narrative review of the shortlisted literature is presented to offer an overview of existing tools, frameworks and useful building blocks for the development of our framework.

4.1.1 Participation process management and action research

Dominko, Primc et al. (2023) introduce action-oriented research as "qualitative social research conducted by a group that includes researchers, representatives of companies (e.g. managers, designers, engineers), authorities, and communities that wish to improve their situation", aiming to link theory and practice by simultaneously solving problems and testing and generating knowledge through continuous interaction. They continue to argue that action-oriented research is a necessity to progress circular economy and sustainability. However, their systematic review on participatory action research in circular economy revealed only 22 publications on the subject, underlining the preoccupation of the academic circular economy community with theoretical concepts and technological solutions. Participatory action-oriented research is generally shaped by the following steps (Defoer, De Groote et al. 1998, Bacon, Mendez et al. 2005):

1. Form stakeholder group
2. Identify and analyse issues, solutions and opportunities for change.
3. Share, discuss and reflect on solutions ahead of implementation.
4. Evaluate the participation process, possibly followed by renewal of the process from step one.

Action-research in circular economy generally focuses on procurement, food supply chains, citizen involvement in urban agriculture, energy generation, reuse and recycling (Petrescu, Petcou et al. 2016, Cramer 2020, Nogueira, Ashton et al. 2020, Dominko, Primc et al. 2023), waste management covering subjects such as composting, bio-related technologies, chemicals, heavy vehicles, textiles, and demolition (Kumble 2019, Becerra, Carenzo et al. 2020, Lag-Brotons, Velenturf et al. 2020, Saidani, Yannou et al. 2020, Christensen 2021, Dominko, Primc et al. 2023) and business model innovation in

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for example capital goods, furniture, electronic equipment, textile and clothing, medical devices, consumer durables, agriculture, product sharing, and water (Bocken, Schuit et al. 2018, Pieroni, McAloone et al. 2019, Dominko, Primc et al. 2023). More practical experience is needed about the manner in which companies create, capture and deliver value in a circular economy, calling for more research into circular business models within different geographic contexts. Circular business models may operate differently depending on the contextual conditions, such as policies and regulations. Research into circular business model innovation ought to include development of better tools, such as adapting the business model canvas to circular economy to cover a whole system perspective beyond single companies (Chen, Hung et al. 2020, Dominko, Primc et al. 2023). This will be assessed in more detail in Section 4.3.

Participation process management is more practice-oriented than participatory action research. It is relatively well-established for the management of space in its widest sense, for example for the purpose of water management and nature conservation. Participation process management is the practical embodiment of participatory governance, a known approach for managing transition processes for resolving complex environmental problems pertaining to multiple actors at multiple scales (Reed 2008). Through participation processes, individual concerns, perceptions and knowledge of actors become joined up through social debate, proposing increasingly coherent changes, linking concerns and solutions across multiple interests through social learning, leading to the construction of shared values, problem perceptions, and solution spaces that can function as “windows of change” for radical transitions towards a circular economy (Chapin, Kofinas et al. 2009, Everard, Reed et al. 2016). Stakeholders can be involved at varying stages of a participation process and at different levels, ranging from informing to listening, consulting, co-producing, co-deciding, or full autonomy (Arnstein 1969, Breman, Pleijte et al. 2008). Stakeholder engagement can be determined based on what is just and rightful, but there is also a pragmatic element, for example based on the “capital” that stakeholders can bring to the transition process such as information, finance, human resources, social connections, political power and market positions. Higher participation levels can increase efficiency, effectiveness and legitimacy of adaptation processes involving communities, and can help to generate more commitment to deliver societal changes. Participation could help to improve the quality of decisions through deliberation and collaboration to generate more viable, fair and inclusive options and solutions to choose from (Moallemi, Zare et al. 2023). Through practice, the following steps can help to devise a successful participation strategy by research programmes (Breman, Pleijte et al. 2008, Velenturf, Jopson et al. 2019):

1. Initial high-level clarification of the exact challenges that are to be solved, targets to be achieved, and for whom and why.
2. Evaluate resource availability for the participation process on a regular basis (funds, time, data, facilities, expertise etc) alongside changes to the understanding of the challenges at hand. Participation processes should only go ahead if they are feasible, otherwise it could risk deepening divisions between stakeholders and even reverse transition processes.
3. Context analysis using the “PESTEL” approach covering the political-economic system, markets, societal trends (e.g. public narrative, community perceptions, others aiming for change), technological potential for change, environment (e.g. climate change, biodiversity) and legislation.
4. Stakeholder analysis, and build up relations to get to know them, to gain insights into their perspectives, motivations, interests, concerns, wishes, relations, and learning and innovation behaviour with the aim to understand how they could be supported in the transition process.

5. Develop an understanding of the “space for change” and where there may be areas of overlapping perceptions that can function as a springboard for transformation.
6. Develop a public identity that is being communicated consistently.
7. Involve the research team in the coproduction of plans for engagement and impact, and identify how they need to be supported in the delivery of stakeholder engagement and activities that are likely to make a real difference in practice.

Lammi, Anttonen et al. (2019) argue that the application of transition theory perspectives in circular economy are still rare. A practical exploration of shaping transition processes for circularity in Finland highlighted the need for a “purposive transition with coordinated action, shared use of resources and shared creation of knowledge”. Such approach was developed in the EU-funded RETRACE project (Nohra, Pereno et al. 2020), enabling regional circular economy policy development for industrial change, reviewed more closely in the next section (Section 4.1.2).

4.1.2 Circular economy “ecosystem” change

Circular economy ecosystems can be understood as communities of diverse, interdependent yet independent actors who together generate a sustainable ecosystem outcome (Aarikka-Stenroos, Ritala et al. 2021, Harala, Alkki et al. 2023). Within circular economy, ecosystems have been specified as industrial, business and innovation ecosystems with differing focus and outcomes (Harala, Alkki et al. 2023). Industrial ecosystem actors are understood as sustainably producing industrial goods and services in synergy with each other through collaboration and resource use (Aarikka-Stenroos, Ritala et al. 2021). In a circular business ecosystem, companies realise a circular value proposition together. Within this context, innovation ecosystems have been specified as collectively generating value from innovations. Harala, Alkki et al. (2023) found that the three different types of circular economy ecosystems often co-exist in practice.

Circular economy ecosystem change can entail adaptation in the roles of actors such as diversification or expansion of roles, in interactions between actors such as communications, collaborations and means, and perceptions such as how resource value is understood, design thinking and attitude to change (Harala, Alkki et al. 2023). Circularity transitions require the redesign of industrial systems that consist of companies, and often companies are ascribed a leading role in this process in terms of encouraging and facilitating uptake of circular economy strategies throughout the industrial system, developing the enabling infrastructure and adapting their own companies and supply chains to realign with the changes within the system (de Lima, Seuring et al. 2022). Overall, this means that companies have to deal with a great deal of complexity and uncertainty (Turken, Cannataro et al. 2020), while making decisions that impact on their business operations, supply chain and customers. Decision making requires the proactive assessment of uncertainties (Linder and Williander 2017) in an attempt to control the situation and move with the evolving system around them.

Nohra, Pereno et al. (2020) present findings from the RETRACE project that developed a framework for policy design to enable circular business model innovation as part of regional circularity transitions, consisting of six steps:

1. Holistic diagnosis: combining desk and field research to investigate the given scenario from economic, social and environmental aspects, considering the flow of energy and materials. A three-step process was used to diagnose a region, understand needs and hidden possibilities:
    a. Regional framework: combining quantitative data from official databases such as Eurostat, to characterise a territory and its industries, and qualitative data such as from

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reports and interviews with local stakeholders; presenting results in infographics, diagrams, and maps to enable collaboration across diverse stakeholders and disciplines.

b. Analyse current policies: policy state-of-the-art covering waste management, energy and environment alongside smart specialisation as part of research and innovation strategy and development, to identify potential policy gaps hindering circular economy transitions.

c. Analyse main economic and industrial sectors: to find potential synergies at a whole system level between value chains or processes at (inter)regional scale.

d. Alongside of step a-c, exchange knowledge between the regions involved in RETRACE e.g. through best practice visits.

2. Definition of problems and levers for change: building on the holistic diagnosis, analyse connections and impacts to identify needs for and potential future scenarios. Challenges are levers for change from which the system can be defined and initiated.
3. Design new system: that aims to be zero emissions by optimising energy and material flows and by valorising wastes as resources.
4. Evaluate outcomes: assess environmental, economic and social benefits of the new production model.
5. Implement: the proposed system and estimate feasibility of new economic activities.
6. Analyse results and feedback: assess implemented system and ensure circular functioning.

The holistic diagnosis was spread out over two years delivery, alongside good practices selection (assuming this covers steps 2-4 above). The implementation of regional action plans took another two years and was generally not entirely completed within the duration of the project delivery.

RETRACE concluded that a much broader approach ought to be taken, with design as a decision-making tool in support of short, medium and long-term sustainable development for national and global value chains. The project found that the holistic diagnosis effectively identified policy gaps and potential opportunities for more supportive policies, develop capacity within regions and develop strategic thinking processes. However, regions still need more instruments for self-assessment of circularity strategies to support coordinated policy roadmaps. Moreover, RETRACE focused on the whole system level, while a combination with specific circularity examples in companies would have helped to generate more synergies for circular economy transitions.

4.1.3 Stakeholder-centric approaches

Stakeholder involvement lies at the heart of participation process management and participatory action research to enable circular economy transitions. In RETRACE, stakeholder involvement was essential for participatory policy action development, their effective implementation, monitoring and feedback from regional action plans, sharing of results and creating a background that was amenable to circular economy transitions (Nohra, Pereno et al. 2020). Stakeholder engagement was organised in three phases:

1. Stakeholders mapping and selection: map stakeholders with influence on circular economy transitions such as in public bodies, companies, research, education and civil society, specifying why stakeholders were important and what benefits they could gain from collaborating in the project i.e. analysing stakeholder interests.
2. Create regional stakeholder group: stakeholders committed to participate in regular meetings to discuss research and regional action plans.
3. Stakeholders involvement in research activities: in project activities such as inter-regional exchanges to explore transferability across territories and build capacity.

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Andrews, Newton et al. (2021) discuss the double diamond framework for design thinking, putting stakeholders and leadership at the core the process structure. In line with Nohra, Pereno et al. (2020), the double diamond approach follows the design principles of: 1) being people-centred, 2) communicating visually and inclusively, 3) collaborating and co-creating, and 4) going through multiple iterations. Stakeholders go through a process of discovery and definition, followed by development and delivery. The process design methods used include stages to explore (challenges, needs, opportunities), shape designs (prototypes, insights, visions) and build (ideas, plans, expertise) – similar to the basic elements of participatory action research, to understand a situation and the stakeholders involved, develop and implement solutions, and evaluate and iterate the process as required. While being a stakeholder-centric process, engagement is not continuous throughout the process; stakeholders are involved in different ways for specific reasons, and some more often than others.

Managing diversity of stakeholders involved in the transition process is critical to its success. Greater plurality may lead to more learning and, as a result, more change within the system. But too much diversity may also cause trade-offs. Diversity can be measured with the concept of proximity, including cognitive, social, organisational, institutional and geographic proximity (Boschma 2005). A degree of diversity is necessary to enable learning and change, but too much diversity can create barriers in stakeholder interactions and hence to enabling change.

Stakeholders involved in the transition process will often start from radically different stances on circular economy. Being part of circular economy transitions demands a new set of skills from people in companies. Santa-Maria, Vermeulen et al. (2022) present results on a great diversity of skills:

- Sensing and shaping opportunities and threats:
  - External sensitivity, e.g. being open for external expert support, identifying social and environmental opportunities and threats, and anticipating and responding to changes in regulation.
  - Adopting holistic perspectives, such as adopting a lifecycle perspective and a systemic perspective.
  - Knowledge creation, such as employing accumulated experience, know-how, and IP.
  - Use of sustainability-oriented instruments, such as implementing environmental management tools and guidance from sustainability frameworks.
- Seizing opportunities:
  - Delineating sustainable solutions and business models, such as ideating and developing value propositions with environmental and social impact, and generating business model architectures that can transform socio-technical systems.
  - Stakeholder engagement and collaboration, such as engaging strategic partners in collaboration and co-creation, and engaging an interdisciplinary team to participate in the innovation process.
  - Supporting sustainability and innovation culture, such as articulating a clear ambitious sustainability vision, developing a sustainability strategy and culture, educating workers in sustainability an empowering them to propose innovations.
- Reconfiguring resources and structures:
  - Co-specialisation of assets, such as prioritising strategic fit of resources and capabilities.
  - Organisational flexibility, such as implementing experiments / pilots to validate, learn and adapt quickly, build decentralised sustainability-oriented innovation teas and allow flexible organisational structures.

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- Trust building communication, such as having fact-based consistent and transparent external communication.
- Ecosystem orchestration, such as skills to integrate stakeholders and coordinate partners in the business ecosystem.
- Leadership and change management, such as implementing specific sustainable and circular KPIs.
- Governance, such as achieving incentive alignment and managing collective decision-making.
- Knowledge management, such as organisational learning and knowledge transfer.

Saari, Järnefelt et al. (2021) present an assessment tool for circular economy maturity levels, which could help to gauge the diversity in circular thinking within the business ecosystem. The maturity levels are:

1. Linearity: management meets legal requirements for waste management but is further monitored to avoid additional costs within a traditional make-take-dispose mind-set.
2. Industrial circularity piloting: pilot projects for resource sufficiency within company or through exchanges with external industrial actors.
3. Systemic material management: circularity uptake is extended to the whole company to identify and exploit all emerging opportunities internally, with systematic use of 'R-cycles' of industrial materials becoming the norm.
4. Circularity thinking: eco-design and circularity embedded in new products and services, with industrial materials cycled within the company as well as being part of external industrial symbioses.
5. Full circularity: full circularity of products, processes and operations that are environmentally, socially and economically sustainable has been achieved, by a broad understanding of value flows and co-created value circles in manufacturing networks.

The use of concepts of "value" and "values" is prolific within the circular economy literature. Value is key to circular business model innovation, to create a value proposition and understand how the value is created and delivered within circular supply chains. Here, value could be considered as the benefits compared to the costs (Stec and Zwolinski 2018). Stec and Zwolinski (2018) go on to argue that decision-making, however, is often driven by core values. Core values are principles deeply embedded in how people think, impacting on how information is processed and used in decisions. Despite their influence, core values are not generally part of circular economy tools for decision-making, although Zhang, Rio et al. (2013)'s framework for implementing sustainability in companies does include aspects of it at an organisational level.

4.2 Multi-criteria decision making under uncertainty.

Multi-criteria decision making (MCDM) under uncertainty is a well-established subject area for the preparation of future scenarios and their sustainability assessment. While it may be essential to involve multiple stakeholders in realising societal transitions that rely on actions by diverse people and organisations (e.g. (Cramer 2020), diverse stakeholders can be a source of uncertainty in decision-making due to the diversity in interests, behaviours, institutional settings and potentially conflicting objectives (e.g. (Boschma 2005, Reed, Graves et al. 2009). The effects of social and environmental changes can be a further source of uncertainty (Roelich and Giesekam 2019). Decision-making for long term strategies becomes more complex with incomplete data, changing and unpredictable situations, model uncertainty, uncertainty in criteria weighting, unknown outcomes, conflicting management, etc. (García-Segura, Penadés-Plà et al. 2018). Instead of the traditional paradigm of 'predicting and acting', decision making under uncertainty follows 'monitoring and adapting' with the aim to be flexible as the future evolves and knowledge is gained (Malekpour, Walker et al. 2020).

Literature on decision-making under uncertainty and sustainability was reviewed with the intention to derive insights from tools and frameworks in general and with a focus on participation of diverse stakeholders, and any lessons learned regarding stakeholder involvement. The subject area of MCDM is nearly three centuries old and there are no universal and comprehensive classifications of developed theories and approaches (Antucheviciene, Kala et al. 2015). The review here hence focuses on the critical discussion of a number of key challenges and building blocks that may serve valuable in the preparation of a framework for co-producing and assessing circular economy future solutions.

Moallemi, Zare et al. (2023) discuss coproduction as a synonym to participation processes, in which human and computational capabilities are combined. Coproduction processes can be characterised by their motivation (framing of problem / priorities / future, solving by analysing / evaluating options, and acting), setting (timing, actors involved, interaction), and impact (power, politics, thinking through change pathways) (Moallemi, Zare et al. 2023). Arguably a diversity of coproduction methods are being used in MCDM under uncertainty. Reviewing 50 cases of coproduction processes, four strategy groups were derived including innovation to test new methods for decision making, diversification to involve a wider range of stakeholders, collaboration to enhance social learning and inclusion, and transformation to implement changes (Moallemi, Zare et al. 2023). MCDMs tend to take a proactive thinking approach to give shape to desirable futures and coproduce adaptive pathways to realise such future scenarios (Kelly, Foley et al. 2022). An important question in such processes is the decision who gets to participate in the process, how and why. While many MCDMs regularly appear to take an exclusive approach that involves no or only a limited number of experts and decision-makers (see e.g. (Šomplák, Ferdan et al. 2013, Frangopol, Dong et al. 2019, Zhou, Li et al. 2023), the implementation of a sustainable circular economy depends on collective action and hence a more inclusive approach by involving a diverse range of stakeholders would be more appropriate (Velenturf and Purnell 2021, Kelly, Foley et al. 2022). Key steps at the start of a foresighting process with diverse stakeholders include an assessment of their values and specifying the problem at hand, followed later by desired futures and socioecological change processes (Antucheviciene, Kala et al. 2015, Kelly, Foley et al. 2022). The success of coproduction processes can be enhanced by investing in capacity building to increase future literacy among the stakeholders and allowing for time to build relations between stakeholders to develop a sense of trust to interact with each other (Kelly, Foley et al. 2022). This is important because including more diverse stakeholders can be a source of disagreement (Moallemi, Zare et al. 2023). While destructive disagreements ought to be avoided through process design, when disagreements do occur it is important to offer space for feedback and deliberation. When differences cannot be resolved, they could be parked for the time being to be revisited later in the process such during the decision-making when the MCDM results are available (Karunathilake, Hewage et al. 2019). In principle, a longer-term period with repeated interactions between stakeholders renders better results than short-term interactions such as one or a few workshops (Kelly, Foley et al. 2022).

Scenarios can be prepared in various ways. In foresighting studies that explore the medium to long-term future, scenarios can be based on the selection of two critical system variables that represent key uncertainties that have the potential to determine the majority of future developments of a given system (Pihlajamäki, Helle et al. 2020, Kelly, Foley et al. 2022). These variables tend to be external / exogenous variables that remain relatively stable over long periods of time (Chapin, Kofinas et al. 2009, Ives, Hickford et al. 2019). Critical variables can be derived from a contextual analysis to identify political, economic, social, technological, environmental and legal aspects that may impact on the development of a given system (Pihlajamäki, Helle et al. 2020). The two selected critical variables are used to specify four plausible future states using e.g. exploratory scenario storylines (Pihlajamäki, Helle et al. 2020), by preparing plausible narrative descriptions of the context that will shape the system (Witt and Klumpp 2021). Say, for example, that the critical variables are global political fragmentation and climate change, then the four future states could be a highly fragmented world under a low or high global temperature increase or political integration under the low or high global temperature changes. Critical variables may change, however, based on the state of a system over time. In such cases the specification of plausible system states at different moments with specific objectives for each period in transition pathways can help to ensure that the most appropriate critical variables are considered. Tools such as multiphase MCDMs could prove useful in such cases (such as MP PROMETHEE by Witt and Klumpp (2021)). The problem with this approach to foresighting is, however, that the state of social-ecological systems tends to be shaped by three to five critical variables, meaning that the scenarios are likely deficient from the outset. A second limitation is the presence of a strong directionality in the analysis, assuming impacts from the context on a system but not taking into account that system changes can feedback on the context. For example, the degree of decarbonisation of energy and resources systems influences the degree of climate change in the system context. Finally, these methods have tended to be expert focused and can be less inclusive in terms of stakeholder involvement.

There are alternative ways to understand scenarios. Many MCDM approaches specify alternatives first (e.g. (Holl and Pelz , Witt and Klumpp 2021). In circular economy transitions the alternatives could, for example, include business as usual, reduced average resource use per person, greater product sharing between users / consumers, and higher recycling rates. The alternatives could then be assessed against criteria with diverse weightings, resulting in scenarios consisting of different system results. Scenarios can also refer to decision-making scenarios that reflect the diverse stakeholder views now and in the future, comparing plausible scenarios that might emerge when diverse perspectives are followed through in the decision-making. In such cases it would be advisable to prepare guidelines to transparently handle conflicting stakeholder objectives in the decision-making, possible as part of a coproduced decision-making process. Here, stakeholder perspectives may only become truly integrated towards the end of the decision-making process, or indeed may never be integrated with decision-makers to follow the views of the one but another stakeholder. This forms a risk in terms of devising collective action because it means that some stakeholders who do need to act may end with limited motivation to do so, as their views are less reflected in the decided actions. It would therefore appear advisable to strive to integrate perspectives of stakeholders at an earlier stage in the coproduction process.

In transition processes, such as realising a circular economy and/or the energy transition, adaptive management is essential. Future contexts continuously evolve and, therefore, system scenarios that are being implemented collectively by diverse stakeholders have to be flexible. A likely outcome of a coproduction process is, hence, an adaptive management plan with an understanding of the change processes towards desired outcomes by the different stakeholders, alternatives / options in each stage of the transition process, path dependencies to understand how developments earlier in the transition process shape possibilities in later stages, the likely critical variables that come into play under different context conditions, and actions that can be taken to move from the current state to the next along a transition pathway (Witt and Klumpp 2021). Sensitivity analysis can be used to evaluate an optimum strategy's dependence on the model specifications and distributions, as part of the preparation of strategies that are robust even under uncertainties.

As argued above, the added value of MCDMs for the coproduction and assessment of circular economy solutions may not lay in the inclusion of diverse stakeholder perspectives, but rather in the integration of social, environmental, technical and economic criteria. One shortcoming could be that there may be a tension between the inclusion of diverse stakeholder perspectives, risking the generating of more variations / options than particular MCDMs can compute. Common issues in MCDM include challenges in pairwise comparison matrices in cases when there are too many options or criteria, normalisation challenges that impact on the results of the MCDM, challenges in the collection of data such as getting quantitative data, averaging methods to aggregate expert views, and dealing with judgements based on insufficient knowledge, and challenges with positive / negative ideal solutions (Mahmoudi, Deng et al. 2021). Common approaches to pairwise comparisons of options include analytical hierarchy processes (AHP), analytical network processes (ANP), linear programming technique for multi-dimensional analysis of performance (LINMAP), and performance ranking organisation method for enrichment solutions (PROMETHEE). Normalisation approaches include VIKOR, Complex Proportional Assessment (COPRAS), interactive and multi-attribute decision-making (TODIM), order preference by similarity to the ideal solution (TOPSIS) and qualitative TOPSIS (Q-TOPSIS), PROMETHEE, elimination and choice expressing the reality (ELECTRE), simple additive weighting (SAW), entropy, decision-making trial and evaluation (DEMATEL), and multi-attribute utility theory (MAUT) (Afsordegan, Sánchez et al. 2016, Karunathilake, Hewage et al. 2019, Mahmoudi, Deng et al. 2021). Many of these solutions depend on articulating positive / negative ideal solutions, but methods such as ordinal priority approach (OPA) and Grey OPA (OPA-G) can function without such specifications while taking into account multiple ranks for criteria if their value is uncertain (Mahmoudi, Deng et al. 2021). This could prove valuable in cases when experts are unsure about the values of criteria or if there are widely differing values allocated to criteria by diverse stakeholders. Real options approaches focus primarily on financial optimisation (Schachter and Mancarella 2016), and may therefore be less suitable for whole system optimisation considering sociocultural, governance, environmental, technical and economic variables (Iacovidou, Velis et al. 2017, Kelly, Foley et al. 2022). Some principles from real options theory may be helpful though, because it can increase flexibility in transition management by adjusting decisions based on future conditions and the ability to wait with decisions until some of the uncertainty has subsided. Values given to criteria can be "crisp" i.e. an absolute an certain fixed value, or "fuzzy" i.e. an approximation that uses an uncertainty factor, distinguishing triangular fuzzy i.e. a variable with a most likely point value or trapezoidal fuzzy i.e. a variable falling in a likely range (Karunathilake, Hewage et al. 2019). It is important to use the same method for determining uncertainty of the variables throughout the process in order to avoid analytical issues (Karunathilake, Hewage et al. 2019). Scenarios can be given shape by allocating different weighting schemes to the criteria, such as distinguishing pro-environmental or pro-economic sets of weightings (Karunathilake, Hewage et al. 2019).

In sum, the review on MCDMs under uncertainty suggests a number of framework steps to consider for the coproduction and assessment of circular economy solutions, alongside the obvious actual multi-criteria assessment of different options / scenarios, including problem definition, stakeholder analysis including values that they consider important, trust building between stakeholders, future literacy training, whole system analysis to derive critical variables and key uncertainties, formulating desirable futures possibly for multiple moments along a transition pathway, identification of change

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processes / pathways to realise futures, preparation of decision-making processes and scenarios and/or adaptive management plans.

4.3 Frameworks and tools for circular business model innovation

Business models "describe the rationale of how an organisation creates, delivers and captures value" (Osterwalder and Pigneur 2010). The circular business model canvas proposes nine building blocks including value propositions, key resources, activities and partnerships, customer segments, channels and relations, and cost structure and revenue streams (Osterwalder and Pigneur 2010). Sustainable business models are tailored towards creating and delivering a sustainable value proposition to customers and all other stakeholders, while capturing economic value as well as regenerating natural, social and economic capital beyond the boundaries of the organisation (Schaltegger, Lüdeke-Freund et al. 2016, Lüdeke-Freund, Carroux et al. 2018). Circular business models can be seen as a subset thereof, with the defining characteristic that they enable the narrowing (reducing volumes of materials in our economy), slowing (using products and components for longer), closing (materials recycling) and/or reintegrating (back into natural biogeochemical processes) of flows of products, components and materials, thereby helping to generate environmental, social and economic benefits within an increasingly sustainable circular economy (Bocken, de Pauw et al. 2016, Geissdoerfer 2019, Velenturf, Archer et al. 2019, Hernández-Chea, Jain et al. 2021).

Business model innovation involves changing one or more elements of the business model. Due to the holistic sustainability orientation and the inherently connected nature of circular business models throughout supply chains, innovation processes generally involve the participation of stakeholders from within and outside an organisation. As such, on the one hand, circular business model innovation could offer pathways for the transformation of entire economies, given their ability to connect multiple actors in different parts of production and consumption systems, involving technical and non-technological innovation (Gorissen, Vrancken et al. 2016, Hernández-Chea, Jain et al. 2021, Ibarra and Mendoza 2023). On the other hand, circular business model innovation is subject to wider circular economy transitions that involve systemic innovations that can change whole business ecosystems (Bocken, Boons et al. 2019, Castro, Trevisan et al. 2022, Mendoza, Gallego-Schmid et al. 2022). Business ecosystems can be understood as value-oriented multi-stakeholder networks including actors within a company, their shareholders, their value chain and consumers, and wider "value network stakeholders" which can be directly or indirectly related to a company's business model e.g. competitors, local communities, government bodies, research and development institutes, and organisations representing societal and environmental interests (Bertassini, Zanon et al. 2021).

Circular business model innovation research has been rapidly developing, with approaches and tools emerging such as configurators (e.g. (Lüdeke-Freund, Gold et al. 2019), innovation patterns (e.g. (Pieroni, McAloone et al. 2021), process models (e.g. (Geissdoerfer, Savaget et al. 2017) and frameworks (e.g. (Joyce and Paquin 2016, Mendoza, Sharmina et al. 2017). Ibarra and Mendoza (2023) reviewed tools that focus on circular business model innovation as part of whole system change. Their systematic literature review covered articles on: Circular economy and sustainability; Business model innovation; Tools; and Ecosystem-related keywords. The review covered 13 tools and frameworks of which the contents were analysed based on their purpose (e.g. innovation stage and approach), characteristics (e.g. complexity, form, data use) and approach to circularity and sustainability (lifecycle stage, sustainability impact).

Ibarra and Mendoza (2023) found that existing whole system tools for circular business model innovation rely primarily on qualitative data. They are limited in quantitative approaches to assess interdependencies between circular business models in the supply chain and their impacts. Systems thinking regarding unintended consequences such as rebound effects is limited. Some tools take a value chain perspective covering steps from material acquisition to end of life; visually engaging formats such as cards and games; or guidelines for step-by-step processes or (conceptual) frameworks to follow in innovation processes. Some tools are based on the generic business model canvas from Osterwalder and Pigneur (2010), such as Nußholz (2018) who developed a form placing the nine business model canvas building blocks in the first column, with several further columns to add contents for business models active at the different steps of a product lifecycle. Antikainen and Valkokari (2016) put the business model canvas into a multi-level perspective, taking the original canvas as the micro-level and adding the meso-level consisting of trends and drivers and stakeholder involvement in the business ecosystem, the macro-level consisting of the sustainability requirements and benefits, and sustainability and circularity assessment at the micro, meso and macro-levels.

Various process tools are variations on three steps, sometimes split out into more detailed steps, broadly covering the generating of system understanding, ideation of new business models, and piloting them, often followed by evaluation and iteration of parts of the process (e.g. (Bocken, Strupeit et al. 2019, Santa-Maria, Vermeulen et al. 2022) – this is similar to the basic steps in participatory action research cycles. Santa-Maria, Vermeulen et al. (2022) propose a circular sprint process starting with preparations (problem framing, background research) followed by a 3-day workshop with seven stages: 1) Inspire (circular economy introduction, vision co-creation); 2) Understand (context scan, value chain mapping, customer profile); 3) Define (how might we...?); 4) Ideate (helped by circular business patterns, simplified business model canvas); 5) Decide (sustainability scan); 6) Prototype (value exchange mapping, circular business model canvas); 7) Test (assumptions mapping, test cards, next steps). Bocken, Boons et al. (2019) take a business ecosystem approach, starting from the current/ideas for a business model, followed by analysing dependencies (e.g. on other companies, infrastructure, resources, etc.) and characterising relations between business models (e.g. neutral, competitive, symbiotic, mutualistic), designing business model ecosystems to increase positive value, and finishing with a new/evolved business model for a company. Aminoff, Valkokari et al. (2016) present a dynamic co-creation network approach for multi-dimensional value to ensure that circular business models will be restorative / regenerative. They propose a framework consisting of 1) Defining a preliminary value proposition of the circular co-creation network; 2) Identifying actors that are needed to deliver the value proposition and analysing their perspectives on drivers and barriers; and 3) Value hunting to identify customers and the value for them as well as values that have been missed or destroyed. The circular value co-creation network is meant to consist of the core business value network covering all direct value chain actors, stakeholders such as local community, regulators and investors, and representatives for societal and environmental interests. Aminoff, Valkokari et al. (2016) point out that value network approaches tend to be focused on existing supplier-customer interactions, which could hold back transformative innovation potential, while co-creation networks are more focused on new business opportunities. Nevertheless, Hansen and Revellio (2020) propose a typology of circular value creation architectures, revolving around the idea that there is an actor in the supply chain who will take on the role of central coordinator, with the choice of four supply chain coordination strategies: 1) Vertical integration (fully integrated circular solution between supply chain actors); 2) Network (supply chain actors team up for circular solutions e.g. through strategic partnerships); 3) Outsourcing (e.g. arm's length contract with independent circular solutions provider); 4) Laissez-faire (no initiative or direct relation with potential circular solution provider). In most tools, system boundaries are poorly defined (Ibarra and Mendoza 2023). As Bocken, Boons et al. (2019)

argue, the decision on where system boundaries are drawn can impact substantially on the perceived sustainability potential and decisions made regarding potential circular business models. Hence it could be recommended to include a step in the innovation process to discuss where the system boundaries ought to be and reach consensus about impacts / key indicators of interest among the stakeholders within them (Boons and Lüdeke-Freund 2013).

Very few circular business model innovation tools have been truly coproduced with practitioners, even fewer are thoroughly tested in practice while guidance on how to use the tool is often missing (Bocken, Strupeit et al. 2019, Ibarra and Mendoza 2023). Moreover, tools for circular business model innovation generally do not offer explicit linkages to tie business model innovation to broader strategic circular economy transition processes (with the notable exception of (Hernández-Chea, Jain et al. 2021) though could be made amenable to it (e.g. (Aminoff, Valkokari et al. 2016, Antikainen and Valkokari 2016). A number of valuable building blocks could be extracted from the circular business model innovation literature to help compile a more comprehensive approach as part of longer-term and wider ranging circularity transitions:

- Incorporate steps to understand the whole system, coproduce ideas for new circular business models and relations between business models, experiment/pilot the circular business models, likely followed by reiteration(s) of preceding steps (e.g. (Mentink 2014, Bocken, Boons et al. 2019, Santa-Maria, Vermeulen et al. 2022).
- Prepare for strategic, tactical and operational actions at different system and time-scales, taking a strategic approach towards circular economy transitions and circular business model innovation by covering long, medium and short-term plans at the macro (whole system context), meso (network) and micro (business) level (Aminoff, Valkokari et al. 2016, Antikainen and Valkokari 2016, Hernández-Chea, Jain et al. 2021).
- Build co-creation networks with a shared long-term purpose (Aminoff, Valkokari et al. 2016), based on a stakeholder analysis, including coordinator(s) / core innovation team, supply chain network members, and directly and indirectly related stakeholders (Mentink 2014, Aminoff, Valkokari et al. 2016).
- Analyse stakeholders including their values, perspectives, positions, needs and interests, capabilities and role in delivering a possible shared value proposition (Mentink 2014, Aminoff, Valkokari et al. 2016, Averina, Frishammar et al. 2022).
- Educate and inspire stakeholders about circular economy and circular business models (Santa-Maria, Vermeulen et al. 2022).
- Prepare whole system / network value proposition based on a shared vision and long-term sustainable business opportunities (Aminoff, Valkokari et al. 2016, Hernández-Chea, Jain et al. 2021).
- Analyse the current supply chain and business models including dependencies on other products, value chains and infrastructure (Bocken, Boons et al. 2019).
- Analyse the system context including changes in the business environment and ecosystem level trends and drivers, taking a dual perspective on directions of impacts i.e. how the context shapes business models and vice versa (Mentink 2014, Antikainen and Valkokari 2016, Bocken, Boons et al. 2019, Santa-Maria, Vermeulen et al. 2022).
- Explore system boundaries, for example based on sustainability impacts / key indicators (Bocken, Boons et al. 2019).
- Carry out a baseline sustainability assessment before co-producing new circular business models, including analyses of ecosystem alignment e.g. values captured, destroyed and missed

and for whom, and value opportunities for major stakeholder groups such as environment, society, customers, network actors (Aminoff, Valkokari et al. 2016, Bocken, Boons et al. 2019) and value capture viability (Averina, Frishammar et al. 2022).

- Ideate circular business models with adapted versions of the business model canvas (Osterwalder and Pigneur 2010) adding a multi-level perspective to include the business ecosystem and wider sustainability context (Antikainen and Valkokari 2016), possibly coproducing initial ideas first with a simplified list of questions (who, what, how and why) and more detailed ideas later in the process (Mentink 2014, Santa-Maria, Vermeulen et al. 2022).
- Analyse dependencies and alignment in proposed new circular business model ecosystems (Hansen and Revellio 2020) linking back to the shared value proposition, including the values to partners and stakeholders (Antikainen and Valkokari 2016) that are created, destroyed and possibly missed (Bocken, Boons et al. 2019), internal and external barriers to implementation and plans to overcome them (Mentink 2014), and carry out SWOT and sustainability scans (Santa-Maria, Vermeulen et al. 2022).
- Experiment / pilot – (Bocken, Boons et al. 2019).
- Integrate evaluation moments for sustainability and circularity at regular moments throughout the innovation process (Antikainen and Valkokari 2016).

4.4 Participatory sustainability assessments in circular economy

The previous sections highlighted the importance of sustainability assessments of proposed circular economy solutions such as new circular business models. Based on the earlier reviews, such sustainability assessments for circularity would ideally be able to:

1. Involve stakeholders:
   - Throughout the supply chain and the wider system.
   - Throughout the process from start to end.
   - Enable discussion with results that are easily accessible and to interpret.
   - Distinguish values to diverse stakeholders and demonstrate the perspectives of diverse stakeholders.
2. Compare diverse circular economy strategies and solutions.
3. Take a whole system approach:
   - Incorporate social, environmental, technical and economic values.
   - Cover all lifecycle stages of materials, components and products.
   - Include multiple system scales for micro, meso and macro levels.
   - Assess diverse timescales for short, medium and long-term.
   - Consider results under varying system boundaries.
   - Combine qualitative and quantitative data and indicators.
   - Assess positive and negative values.
4. Reiterate assessments:
   - Delivered in stages with high level assessment first and adding detail to assessment of (some of the) solutions later.
   - Regularly revisit the assessment throughout the coproduction and longer transition process.

Within circular economy, sustainability assessments involving stakeholders have gained interest since 2017, in applications such as waste management/ recovery, packaging, construction, information and communication, product design, biorefinery, automotive and photovoltaics (see e.g. (Iacovidou, Velis et al. 2017, Niero and Hauschild 2017, Zijp, Waaijers-Van Der Loop et al. 2017, Ddiba, Ekener et al.

2022). In decision making it is important to include stakeholders throughout the life cycle/ supply chain (Lindgreen, Salomone et al. 2020, van Bruggen, Zonneveld et al. 2022) as engaging different stakeholder perspectives could enable to identify the best strategic choice for sustainable circularity (Zijp, Waaijers-Van Der Loop et al. 2017). In other words, the expertise of different stakeholders enables to critically evaluate available options, collaborate, and generate creative solutions.

Lindgreen, Salomone et al. (2020) reviewed assessment approaches, tools, and methods for the assessment of circular economy solutions at the micro level i.e. for products and individual companies. In their search for assessments focused on implementation, they found some studies that took a participatory approach by involving end-users but concluded that the link between academic research and practical circular economy implementations ought to be strengthened with further transdisciplinary research. While there are some practical examples published (Nadal, Pons et al. 2018, Sala Benites, Osmond et al. 2023), they are primarily focused on the involvement of experts rather than including a wider diversity of stakeholders that may be affected by or influence circular economy implementation.

Nadal, Pons et al. (2018) used the Integrated Value Model for Sustainability Assessment for a sustainability analysis on locating rooftop gardens on schools. The analysis was embedded in a four-stage process consisting of checks if the basic – mostly technical – conditions were met for rooftop gardens (preselection criteria), followed by shortlisting locations based on technical characteristics and stakeholder interests (selection of necessities), which were followed by the sustainability and sensitivity analysis. In this approach, economic and social assumptions were made without stakeholder input, with further technical and social criteria collected through interviews and site visits, and qualitative and quantitative requirements, criteria and indicators being prepared through expert presentations and discussion. This approach embeds analytical hierarchy approaches and is deterministic, resulting in the “objective” recommendation of a solution to the end-users.

Conversely, Sala Benites, Osmond et al. (2023) also considered analytical hierarchy approaches but chose a Delphi approach instead because it allows for the inclusion of a much broader range of criteria. This approach too, however, involved only recognised global experts in the area of built environment and circular economy rather than including a more diverse range of stakeholders. It may be possible to adapt the approach accordingly though.

Ddiba, Ekener et al. (2022) – building on a review (Iso 2006, Sala, Ciuffo et al. 2015, Arushanyan, Ekener et al. 2017, Iacovidou, Millward-Hopkins et al. 2017, Wang, Maier et al. 2018) – proposed a sustainability assessment framework consisting of five steps:

1. Generating scenarios (with experts or broader participants) and setting the context
2. Scoping of the sustainability assessment covering e.g. the focus, level of detail, system boundaries based on the technical system etc.
3. Inventory analysis i.e. information and data gathering including on contextual factors.
4. Assessment including interrelations, risk assessment, assessment of opportunities for each sustainability aspect and integration of results across sustainability aspects.
5. Interpretation and reporting to stakeholders, taking place throughout the process through reflection and discussion.

Zijp, Posthuma et al. (2016) characterised wicked problems by their multi-dimensional and subjective aspects that require adaptive management. Wicked problems can be recognised when encountering challenges to specify and agree on the problem context by stakeholders who can understand problems

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in multiple ways including time and space variations, limited clarity on rules for multi-dimensional assessments, multiple possible optima and trade-offs, absence of clear right or wrong solutions, there are no objective success measures and assessments are value-driven, there are often strong moral, political and professional dimensions to the problem, and problem solving requires iteration and learning between stakeholders. Circular economy transitions could hence clearly be characterised as wicked problems. Zijp, Posthuma et al. (2016) continue to propose three general coping strategies to deal with wicked problems:

1) Authoritative strategy to resolve a problem with a selection of (expert) people, which makes the process less complex but risks missing important perspectives on problems and solutions.
2) Competitive strategy to invite contrasting solutions and let the best one win, which can include a wide range of alternatives but, conversely, also discourage knowledge sharing.
3) Collaborative strategy to involve all stakeholders to identify the most supported solution, leading to broadly supported solutions though making the process more complex.

van Bruggen, Zonneveld et al. (2022) argue that circular economy has so far taken a more competitive approach focused on the differences between stakeholders and their contested solutions, and propose an approach to collaborative reach shared solutions through discussion and learning to bring perspectives together. The Solution-focused Sustainability Assessment framework is a qualitative systematic approach in the context of sustainability transitions, covering six steps brough together with continuous communications (Zijp, Posthuma et al. 2016, van Bruggen, Zonneveld et al. 2022):

1) Pre-assessment
    a. Exploratory non-exhaustive literature review on barriers and solutions e.g. categorised by stakeholders encountering the barriers, with the purpose of the review being to enable that start of stakeholder interactions.
    b. Stakeholder analysis, based on the literature review and snowballing.
    c. Exploratory interviews with a select group of stakeholders
2) Develop solutions
    a. Focus groups for discussion to further identify and prioritise barriers using sticky-dots exercises, and develop solutions with a solutions-canvas.
    b. Questionnaire to further specify the focus group results and invite input from a wider group of stakeholders.
    c. Expert reflection on solutions to check reliability and validity of results.
3) Set the rules for quantification and choice of solutions.
4) Quantify the sustainability metrics of solutions.
5) Evaluate sustainability metrics and choose solution.
6) Evaluate against sustainable development criteria.

van Bruggen, Zonneveld et al. (2022) specify two steps within the Solution-focused Sustainability Assessment framework that was initiated by Zijp, Posthuma et al. (2016). They add a chain approach to involve stakeholders along the supply chain in order to invite diverse perspectives on the scientific and practical aspects of problems and solutions in sustainability transitions in specific priority sectors or parts thereof.

4.4.1 Complex Value Optimisation for Resource Recovery framework

The development of the Complex Value Optimisation for Resource Recovery framework (Iacovidou, Millward-Hopkins et al. 2017, Millward-Hopkins, Busch et al. 2018) was driven by a need to properly characterise visible and hidden positive and negative changes in the social, environmental, economic, and technical domains of value – i.e. benefits and impacts respectively – caused by interventions in resource flow systems of materials, components and products (MCPs). The method was intended to support both policy-making processes and the development of new business models by highlighting potential unintended consequences and problem-shifting and identifying where value is being lost or discarded in a system. At its heart is a circular economy concept that systems should be designed to prevent the technical properties of MCPs being dissipated into waste.

Despite being developed in the context of recovering resources from waste, it specifically avoids an 'end-of-pipe' approach and embraces a whole-systems perspective. It stresses the need to consider multiple domains of value in a single assessment, particularly when interventions are guided by mono-dimensional heuristics such as "zero-waste" or closed-loop recycling (where a focus only on eliminating physical resource leakage could increase energy or water consumption) or resource efficiency (where rebound effects caused by reduced costs or prices can actually increase resource consumption; the Jevons Paradox).

It attempts to synthesise a number of established methods of analysing resource flow systems in order to achieve this. The principles of mass flow analysis (MFA) are used to outline the physical system in terms of the flow of key resources. The attachment of values to these flows follows the principle of life-cycle assessment (LCA) but expands on LCA in three key aspects. First, it moves beyond LCA's singular focus on environmental value, instructing the modeller to use at least one metric from the economic and social domains as well as the environmental domain, and to also track the technical quality of resources as they flow through the system. Secondly, it does not prescribe the metrics that should be used, but expects the modeller, in consultation with stakeholders, to select from a wide range of metrics those that best address the problem or intervention under consideration and justify this choice. Thirdly, it insists on complete transparency, with all embodied values and assumptions expected to be made explicit to the user of the results (rather than remaining hidden in proprietary software as is often the case for published LCA analysis), and the variability and uncertainty both in source data and system boundaries to also be published.

It also draws on cost-benefit analysis (CBA) in the sense interventions are assigned benefits and impacts, but insists that these are not 'collapsed' onto a single domain of value (i.e. via monetisation as in traditional CBA) but kept separate to allow trade-offs between e.g. financial costs and social benefits to be explored. This requires an understanding of the political dynamics of the system being studied. The "systems of provision" (sop) approach, rooted in the study of political economy, is used as guidance in this regard as a more practical and appropriate approach than standard neo-classical economics.

The steps in a CVORR analysis after the selection of the resource flow system to study are as follows. A conceptual model of the system is designed by considering the mass flows, processes and points where complex value changes occur (e.g. addition of economic value, degradation of technical properties, or environmental impacts). This sets initial system boundaries and hence foreground and background systems. The political system i.e. the money flows, actors involved and power relationships are overlaid onto this using a sop analysis, which will further inform the system boundaries (i.e. what must be included in the foreground system, and what can be considered background). Secondly, a set of metrics for measuring changes in complex value specific to the system under study are selected to provide necessary, but not excessive coverage. These choices must be justified by the user, with the only precondition that one metric must be selected from each domain of value (economic, environmental, social and technical) (Iacovidou, Velis et al. 2017). These may be quantitative or qualitative. Thirdly, scenarios of change are developed i.e. potential interventions in the system intended to increase value (e.g. reduce environmental impact, improve social conditions, retain technical properties). These interventions may change the technical or political relationships between various parts of the system, or require particular agents to act, and thus may affect the system boundaries and metrics required, so this step is performed iteratively with the previous two steps until a reasonably stable model design is reached. The complex value assessment – i.e. how value changes as a result of proposed interventions – can then be performed. These changes are then evaluated, particularly with regard to 'trade-offs' in value both within and across domains (e.g. if environmental value is created at the expense of economic cost, who wins and loses?). The system design is also reevaluated, particularly with regard to whether the boundaries are sufficiently robust. The system model may then be refined, and the process repeated as many times as necessary.

The Complex Value Optimisation for Resource Recovery framework has been piloted and evaluated, adapting it to be delivered in ten steps over three stages (Figure 3):

1. System analysis, with five iterative steps: a) System selection; b) System dynamics analysis; c) Material flow analysis; d) Develop value framework; e) Stakeholder analysis;
2. Scenario analysis, with three iterative steps: f) Scenario development; g) Indicator selection; h) Complex value assessment;
3. Embed in decision-making, with two steps: i) Complex value evaluation, possibly with feedback to stage 2; j) Process evaluation.

4.5 Overview of key characteristics

Table 2 offers an overview of key characteristics and building blocks of frameworks for sustainable circular economy transitions including decision-making, business model innovation and sustainability assessment. The aspects have been categorised into "Secretariat" for building blocks to organise an administrative head quarter for the process management, "Whole process design" to identify major building blocks within which "Process steps" can be embedded, and "Stakeholder" to classify actions directly related to stakeholder involvement. These aspects will be analysed and synthesised further into a framework in Section 5.

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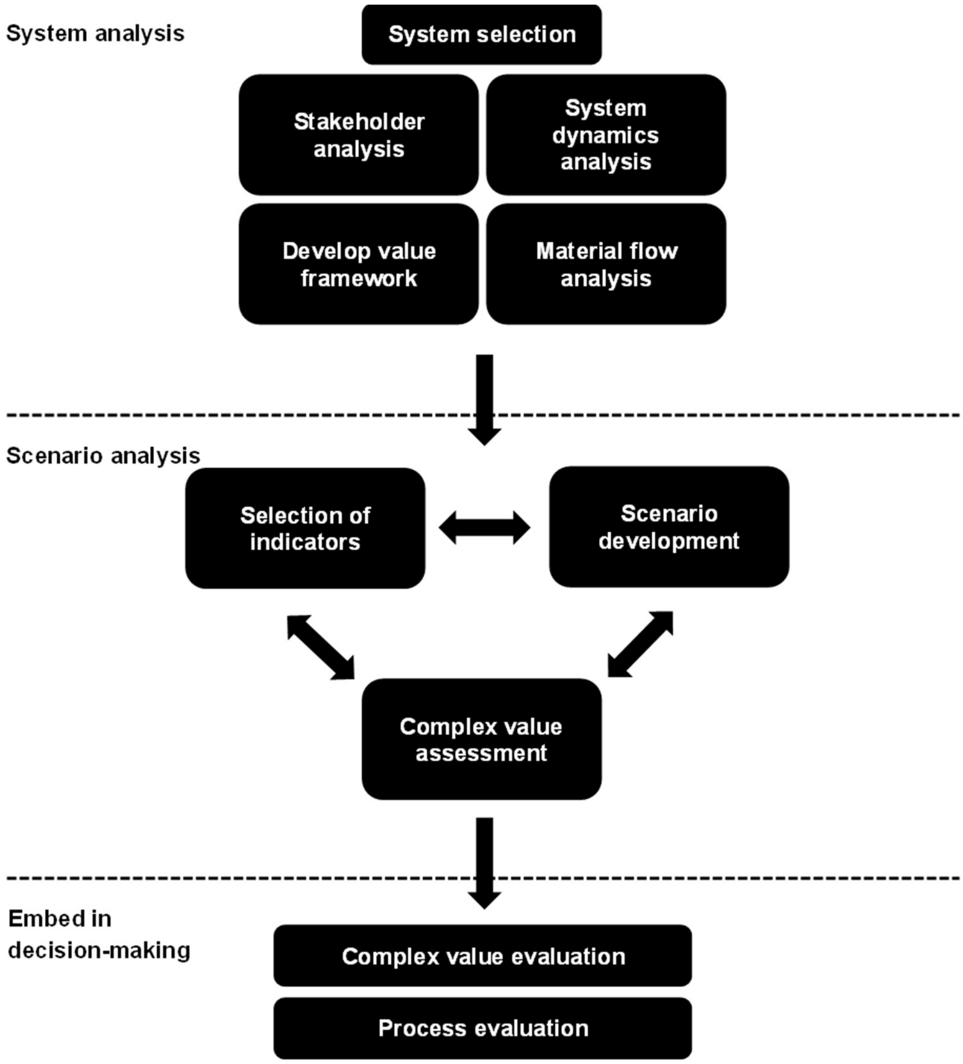

Figure 3: Updated complex value optimisation for resource recovery framework.

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Table 2: Overview of building blocks derived from literature reviews in Sections 4.1-4.4 [coded for alignment into one framework in Section 5].

4.1 Participation processes for sustainability transitions towards a circular economy	**4.2 Multi-criteria decision making under uncertainty**	**4.3 Frameworks and tools for circular business model innovation**	**4.4 Participatory sustainability assessments in circular economy**
[Overall process design] Multi-system level. [Stakeholder] Multi-actor. [Process step] Multi-geographic scale. Participation action research cycle: [Stakeholder] 1) Form stakeholder group; [Process step] 2) Identify and analyse issues, solutions and opportunities for change; [Process step] 3) Share, discuss and reflect on solutions ahead of implementation; [Evaluate] 4) Evaluate the participation process, possibly followed by renewal of the process from step one. Participation process management applied in research: [Secretariat] 1) Clarify challenges and targets, and for whom and why. [Secretariat] 2) Evaluate resource availability for the participation process, and feasibility / likelihood to effectively address challenges.	[Process step] Actual MCDA. [Overall process design] Monitor and adapt. Foresighting: [Process step] Stakeholder values; problem specification; desired futures; socio-ecological change process. [Stakeholder] Future literacy. [Stakeholder] Stakeholder relations / trust to interact. [Stakeholder] Space for feedback / deliberation for disagreements. [Stakeholder] Multiple interactions over time. [Process step] Selection of two critical system variables linked to key uncertainties, often exogenous variables that are stable over longer period e.g. found with PESTEL. [Process step] Specify 4 plausible future states based on two critical variables, narrative descriptions of context of system. NB variables can shift over time along multiple stages of transition process. [Process step] Multiple transition phases.	[Process step] [a] Incorporate steps to understand the whole system, coproduce ideas for new circular business models and relations between business models, experiment/pilot the circular business models, likely followed by reiteration(s) of preceding steps. [Process step] [b] Prepare for strategic, tactical and operational actions at different system and time-scales, taking a strategic approach towards circular economy transitions and circular business model innovation by covering long, medium and short-term plans at the macro (whole system context), meso (network) and micro (business) level. [Stakeholder] [c] Build co-creation networks with a shared long-term purpose, based on a stakeholder analysis, including coordinator(s) / core innovation team, supply chain network members, and directly and indirectly related stakeholders. [Process step] [d] Analyse stakeholders including their values, perspectives, positions, needs and interests, capabilities and role in	[Evaluate] The actual SA together with stakeholders. CVORR: [Process step] [1] System analysis, with five iterative steps: a) System selection; b) System dynamics analysis; c) Material flow analysis; d) Develop value framework; e) Stakeholder analysis; [Process step] [2] Scenario analysis, with three iterative steps: f) Scenario development; g) Indicator selection; h) Complex value assessment; [Process step] [3] Embed in decision-making, with two steps: i) Complex value evaluation, possibly with feedback to stage 2; j) Process evaluation. Ddiba: [Process step] 1 Generating scenarios (with experts or broader participants) and setting the context [Evaluate] 2 Scoping of the sustainability assessment covering e.g. the focus, level of detail, system boundaries based on the technical system etc.

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[Process step] 3) Context analysis using PESTEL. / Analyse context conditions. [Stakeholder] 4) Stakeholder analysis and build up relations: perspectives, motivations, interests, concerns, wishes, relations, and learning and innovation behaviour. And also: circular economy maturity; skills in circular economy transitions / CBMs. Map and select stakeholders, why important and benefits to them; create regional stakeholder group; involve stakeholders in research and knowledge exchange. Proximity concept. Core values. [Process step] 5) Space for change, overlapping perceptions. [Secretariat] 6) Public identity. [Secretariat] 7) Involve the research team. RETRACE: [Process step] Holistic diagnosis: SEE aspects; material and energy flows; characterise region with quantitative and qualitative data, visual presentation results; policy gap analysis; economic and industrial sectors for synergies in value chains within / outside region; knowledge exchange across regions. [Process step] Future scenarios and levers for change to resolve challenges.	[Process step] Alternatively, specify alternatives at start process, assess with criteria using weightings, outcomes are system scenarios. [Process step] Decision-making process guidelines / agreement. [Stakeholder] Guidelines for dealing with conflict during decision-making; but aim to avoid by integration / alignment earlier in process. [Process step] Adaptive management plan: Change processes for desired outcomes; Alternatives / options in each stage of transition process; Path dependencies – how early choices impact later on; Critical variables under different context conditions; Actions to move to next transition stage; Possibly sensitivity analysis.	delivering a possible shared value proposition. [Stakeholder] [e] Educate and inspire stakeholders about circular economy and circular business models. [Process step] [f] Prepare whole system / network value proposition based on a shared vision and long-term sustainable business opportunities. [Process step] [g] Analyse the current supply chain and business models including dependencies on other products, value chains and infrastructure. [Process step] [h] Analyse the system context including changes in the business environment and ecosystem level trends and drivers, taking a dual perspective on directions of impacts i.e. how the context shapes business models and vice versa. [Process step] [i] Explore system boundaries, for example based on sustainability impacts / key indicators. [Evaluate] [j] Carry out a baseline sustainability assessment before co-producing new circular business models, including analyses of ecosystem alignment e.g. values captured, destroyed and missed and for whom, and value opportunities for major stakeholder groups such as environment, society, customers, network actors and value capture viability.	[Evaluate] 3 Inventory analysis i.e. information and data gathering including on contextual factors [Evaluate] 4 Assessment including interrelations, risk assessment, assessment of opportunities for each sustainability aspect and integration of results across sustainability aspects [Stakeholder] 5 Interpretation and reporting to stakeholders, taking place throughout the process through reflection and discussion Solution-focused Sustainability Assessment framework: [Stakeholder] 1 Pre-assessment: Exploratory literature review on barriers and solutions to help start stakeholder interactions; Stakeholder analysis with literature; Exploratory interviews with a select group of stakeholders. [Stakeholder] 2 Develop solutions: Focus groups to identify and prioritise barriers, and develop solutions; Questionnaire to further specify the focus group results and invite wider input; Expert reflection on solutions to check reliability and validity of results. [Stakeholder] 3 Set the rules for quantification and choice of solutions. [Evaluate] 4 Quantify the sustainability metrics of solutions. [Evaluate] 5 Evaluate sustainability metrics and choose solution.

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[Process step] Design new circular economy system. [Evaluate] Evaluate outcomes. [Process step] Implement / estimate feasibility. [Evaluate] Analyse results for circular economy functioning, feedback. [Process step] Inspiring examples from companies. [Overall process design] Stakeholder-centric. [Stakeholder] Communicate visually and inclusively. Design thinking double diamond: [Overall process design] Discover, Define, Develop, Deliver. [Process step] Explore needs, opportunities, challenges; Shape design (visions, insights, prototype); Build (ideas, expertise, plans). [Stakeholder] Diverse stakeholder involvement at different levels and times. [Process step] Aligning CBMs. [Process step] Proactive assessment of uncertainties. [Process step] Decision-making.		[Process step] [k] Ideate circular business models with adapted versions of the business model canvas adding a multi-level perspective to include the business ecosystem and wider sustainability context, possibly coproducing initial ideas first with a simplified list of questions (who, what, how and why) and more detailed ideas later in the process. [Process step] [l] Analyse dependencies and alignment in proposed new circular business model ecosystems linking back to the shared value proposition, including the values to partners and stakeholders that are created, destroyed and possibly missed, internal and external barriers to implementation and plans to overcome them, and carry out SWOT and sustainability scans. [Process step] [m] Experiment / pilot. [Evaluate] [n] Integrate evaluation moments for sustainability and circularity at regular moments throughout the innovation process.	[Evaluate] 6 Evaluate against sustainable development criteria. [Stakeholder] Involve stakeholders along the supply chain. [Process step] Practical aspects of problems and solutions in sustainability transitions in (parts of) specific priority sectors.

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5. Draft decision-making framework

This section presents the draft framework, written from the perspective of a process facilitator. The presented proactive holistic framework aims to support the preparation and decision-making about sets of circular economy strategies for wind turbines in specific geographic and temporal contexts, with a view to optimise social, environmental and economic values within a particular region over time.

Sections 6 and 7 will present results from two pilots on parts of the framework. Additional ideas about the user interface (to be realised in the knowledge hub in WP1) will be shared in Section 8. Links to other EoLO-HUBS tools and frameworks and next steps will be specified in Section 9.

5.1 Overall framework design

The framework forms the basis for a longer-term circular economy transition process, in this case for the wind industry and affiliated companies and stakeholders. The process is proposed to be managed by a facilitation team, forming the process management secretariat for a region. The framework puts stakeholder involvement at the heart of the process, managing stakeholder interactions through three iterative steps as circular economies within regions evolve over time, going through system exploration, development of whole system solutions, and the preparation and delivery of actions to implement circular solutions. The process is guided by regular ex-ante and ex-post evaluation actions (Figure 4).

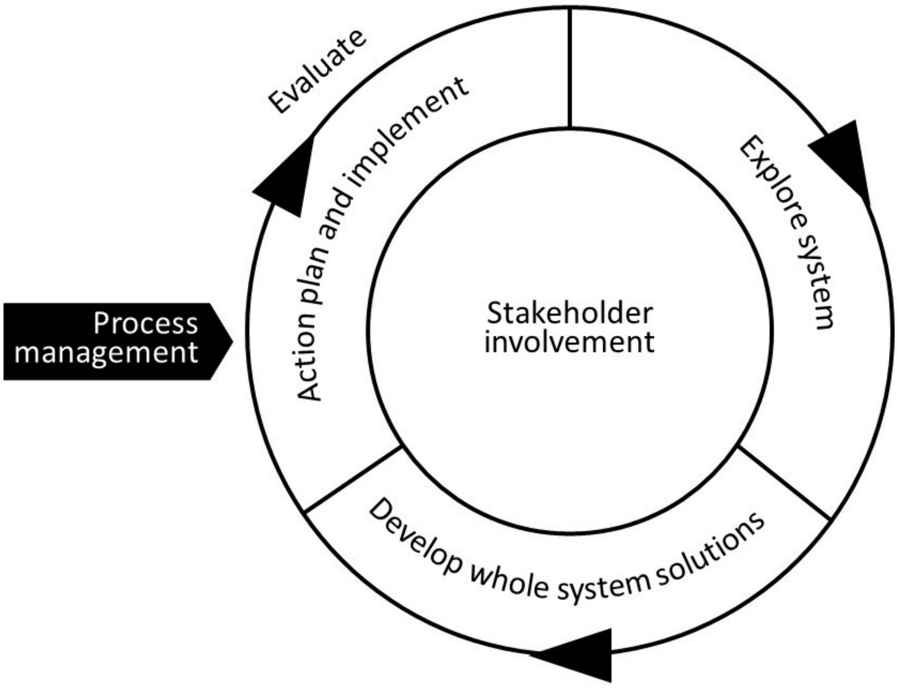

Figure 4: Draft proactive holistic framework for the preparation and decision-making of sets of circular economy strategies for wind turbines in specific geographic and temporal contexts, with a view to optimise social, environmental and economic values within a particular region over time.

The framework takes an evolutionary perspective, putting actions to co-produce new circular wind business models and their subsequent supply chains into a longer-term perspective of multiple circular economy transition phases (Figure 5). EoLO-HUBS supports the start of this circular economy transition with a focus on the wind industry – in some cases connecting to other circularity transition initiatives

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that are already underway in a region – and, within the timescale of the project, will be able to prepare actions for a first transition phase through our series of case studies. At the end of each case study, however, the project will need to handover the process management to another facilitation team, to proceed the regional transition processes towards an increasingly circular wind industry.

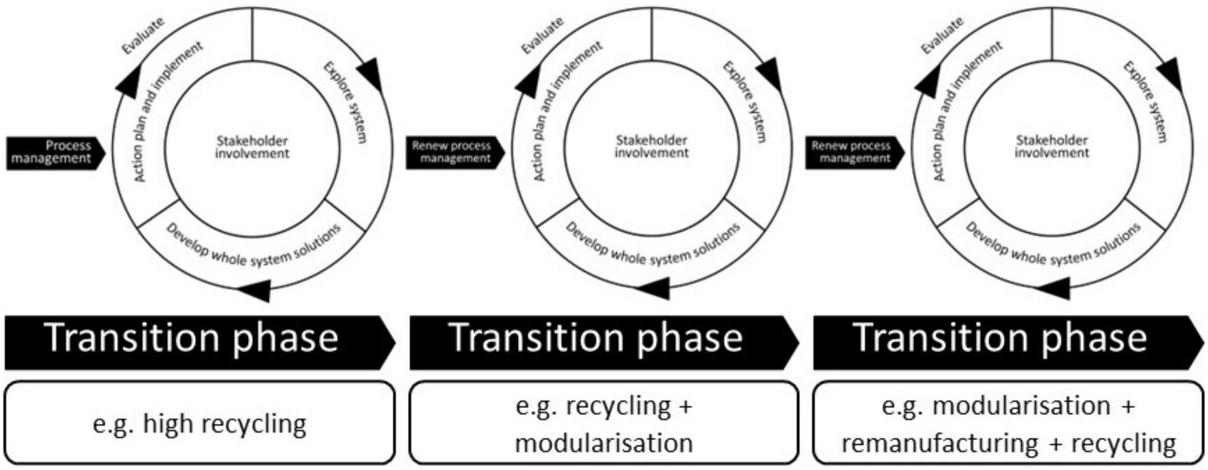

Figure 5: The framework is meant to be used in iterative processes to prepare and deliver on multiple subsequent transition phases for an increasingly circular economy for wind. Each phase prepares detailed plans for the current phase, alongside high-level plans for future phases to manage path dependencies to create long-term synergies while avoiding negative trade-offs.

5.2 Process management secretariat

The aim of this stage is to set up a regional process management "office" (which could be virtual) with a team for research and engagement within a selected region. The review suggests the following actions:

1. Prepare a team to facilitate the participation process including a lead facilitator and research and innovation team members.
2. Initial process exploration to specify main challenges to resolve and/or targets to achieve, and for whom and why.
3. Initial introduction with key initial stakeholders.
4. Feasibility check to confirm if resources to deliver process are likely sufficient for addressing the challenges in a meaningful way.
5. Develop a public identity for the participation process / community.

Missing from review results and to be added: Continuity planning for when initial resources end, plan for more resources or other team members e.g. local companies / government bodies to take over the process management for the next transition phase(s).

5.3 Stakeholder involvement

The process is set up in a stakeholder-centric manner, with steps to be taken alongside phase 1-3 below and connected to evaluation at regular intervals:

1. Identify stakeholders and develop a co-creation network.
2. Coproduce a shared long-term purpose for the co-creation network, in the case of EoLO-HUBS within the conceptual space of delivering a circular economy for wind.

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3. Stakeholder analysis and selection of participation level for stakeholders within the network.
4. Circularity skills and maturity assessment.
5. Prepare, maintain and deliver knowledge exchange and circularity transitions literacy hub.
6. Analyse core values (organisational and/or personal).
7. Build relations and trust in interactions with a schedule of regular meetings including space to resolve differences throughout the process.
8. Visual and inclusive communications.
9. Broad input on drivers and barriers for change and possible solutions, with regular expert evaluation.
10. Share, discuss and reflect upon solutions and actions.
11. Analyse the costs, benefits, capabilities and role of stakeholders in delivering a possible shared value proposition and associated circular business models.
12. Evaluate participation process.

Missing from review results and to be added: Specification of possible stakeholder groups, e.g. whole system experts, supply chain network, and forum; Detailed outline of timeline / planning with the types of stakeholder engagement actions such as interviews, focus groups, workshops, etc.

5.4 Phase 1: Explore system.

The aim of this step is to understand the regional industrial system and how it could be changed, with the following actions:

1. Challenges / problem specification.
2. Identify solution directions / (formal) targets such as set out in (regional) economic strategy.
3. Set and review system boundaries.
4. Map material and energy flows; identify potential opportunities for greater circularity.
5. Analyse current wind supply chain and business models including dependencies on other products, value chains and infrastructure.
6. Desk review for initial (incomplete) drivers and barriers, as basis for initial stakeholder interactions.
7. Context analysis using PESTEL to analyse current state, trends, drivers and barriers in political, environmental, social, technical, economic and legal domains; including interactions between aspects and between aspects and business models in the mapped supply chains (action 5).
8. Prioritise drivers and barriers across system levels to select levers for change.
9. Identify inspiring examples of companies adopting circular practices, from within and outside the region.

Missing from review results and to be added: Multi-level assessment analysing and connecting macro, meso and micro system levels (covered in Section 5.7 Evaluate).

5.5 Phase 2: Develop whole system solutions.

The aim of this step is to coproduce solutions for whole system change including innovative circular business models:

1. Building on the context analysis from phase 1, identify two critical system variables per transition phase, and specify plausible narrative context scenarios for the whole system.
2. Specify possible future visions for the regional circular economy within the context scenarios (building on previous step).

3. Articulate shared whole system / network value proposition based on a collective vision for the regional circular economy and long-term sustainable business opportunities.
4. Specify circular business models and relations between them to deliver on the shared value proposition, within future regional circular economy visions (building on previous steps). Use tools such as adapted versions of the business model canvas adding a multi-level perspective to include the business ecosystem and wider sustainability context, possibly coproducing initial ideas first with a simplified list of questions (who, what, how and why) to consider a multitude of options, before detailing prioritised circular business model options.
5. Research and development to build up expertise (feeding into stakeholders' knowledge hub).

Missing from review results and to be added: Tools for actions 1-4, while some tools are available, they arguably require further development for ease of use with broader stakeholder inclusion.

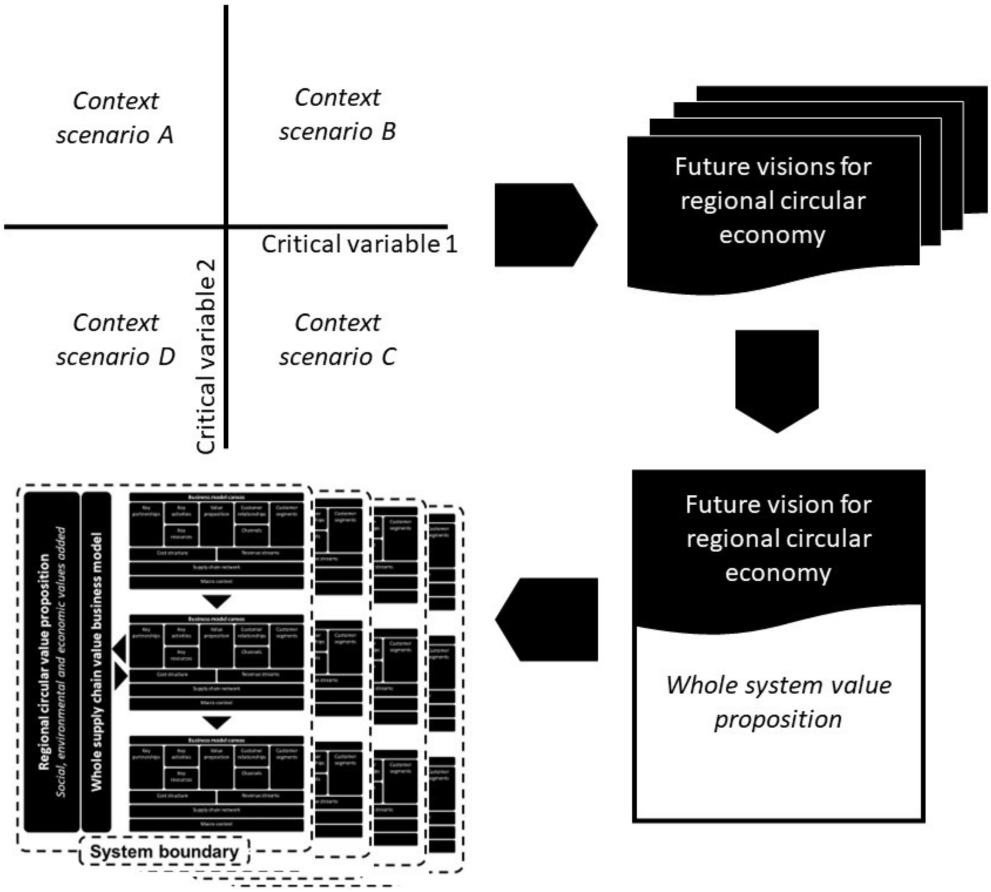

Figure 6: Actions for whole system development, from context scenarios (top left) to future visions for the regional circular economy (top right), a whole system value proposition (bottom right) and business models (bottom left).

5.6 Phase 3: Action plan and implementation

The aim of this step is to facilitate the selection of potential solutions from phase 2 and to coproduce actions plans for their implementation:

1. Coproduce decision making process and guidelines; facilitate delivery of decision-making process.

2. Discuss feasibility and sustainability of proposed solutions, including dependencies and alignment in proposed new circular business model ecosystems linking back to the shared value proposition (linking back to phase 2), including the values to partners and stakeholders that are created, destroyed and possibly missed, internal and external barriers to implementation and plans to overcome them (linking back to phase 1), and carry out SWOT and sustainability scans (linking to Evaluate).
3. Coproduce adaptive management plan covering multiple transition phases, options for solutions at each phase, path dependencies, detailed change process actions for all stakeholders for the first following phase (i.e. next action 4), and guidelines for triggering the next transition cycle within the framework.
4. Prepare for strategic, tactical and operational actions at different system and time-scales, taking a strategic approach towards circular economy transitions and circular business model innovation by covering long, medium and short-term plans at the macro (whole system context), meso (network) and micro (business) level.

Missing from review results and to be added: Details on how and when stakeholders ought to be involved in each of the actions 1-4.

5.7 Evaluate

The aim of this step is to offer regular participatory ex-ante / ex-post evaluations of proposed solutions across multiple system levels:

1. Proactive assessment of uncertainties (phase 1-3).
2. Involve stakeholders in the selection of indicators and weightings for sustainability and circularity MCDA of proposed solutions, based on stakeholders' core values (phase 1-2).
3. Baseline sustainability assessment before co-producing new circular business models including ecosystem alignment (phase 1).
4. Collaboratively develop a "matrix of sustainability assessments" to assess and select aligned options for system change across the macro, meso and micro level (Figure 6), and the focus, level of detail and system boundaries of the assessments (phase 1-3).
5. Compare and discuss outcomes of circular economy scenarios against shared vision and value proposition, and feedback for process iteration and/or implementation (phase 3).

Missing from review results and to be added: Possibly the use of existing circular economy assessment tools to companies and regions, to avoid reinventing the wheel; Quantified assessment in support of PESTEL before prioritising drivers, barriers and levers for change (phase 1).

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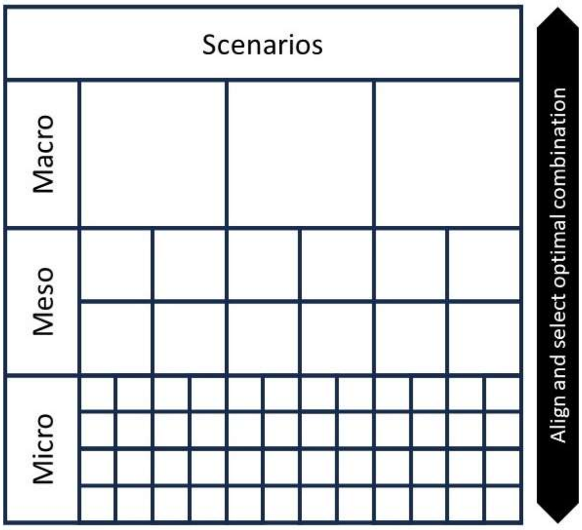

Figure 7: Sustainability assessment of scenarios across system levels, to align options (represented by the boxes) across the macro, meso and micro level and share the information with stakeholders to select the optimal combination of options across system levels.

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6. Pilot 1: Context analysis

This section presents a pilot for the context analysis for circular business innovation in wind using a PESTEL approach.

6.1 Place in framework

The context analysis will be carried out in Phase 1 as part of the system exploration (outlined in Section 5). Action 7 covers the context analysis using PESTEL to analyse current state, trends, drivers and barriers in political, environmental, social, technical, economic and legal domains; including interactions between aspects and between aspects and business models in the mapped supply chains that would normally be identified prior to the context analysis.

The PESTEL will be conducted in two steps: a non-exhaustive literature review that offers sufficient contents to start fruitful conversations with stakeholders, and a stakeholder survey to specify further aspects impacting on circular business model innovation in wind industry.

The PESTEL results need to be specific enough to prioritise drivers and barriers across system levels, to be able to select levers for transformative change (action 8 of the system exploration in Section 5). This in turn will offer the input for actions in Phase 2 of the framework.

6.2 Review of contextual drivers and barriers

In transitioning to circular business models, the focal organisation will have to consider not only its supply chain but also its macro environment which can affect its strategy and decisions. PESTEL analysis which stands for Political, Economic, Social, Technical, Environmental, and Legal, is a widely used strategic management tool (Gasde, Woidasky et al. 2021, Bhuyan, Tripathy et al. 2022) to critically identify and assess the macro environment (external influences) in which the organisation operates. The external key factors that are likely to impact the business in future are identified to determine its implications and decide actions. But there is a possibility for the analysis to become too focused on historical and current experiences instead of future scenarios and it may be difficult to predict the implications of some factors. It can be time consuming and some factors might be changed by the time of implementation. Therefore, a PESTEL analysis might need to be conducted regularly. However, this is still useful to realise opportunities, reveal challenges and avoid threats, develop future scenarios, maximize business development opportunities, and innovate business models (Zhao and Pan 2015, Capobianco, Basile et al. 2021, Junlakarn, Kokchang et al. 2022).

The political category refers to the influence of government politics and policies on businesses (Junlakarn, Kokchang et al. 2022). Examples of political factor are, government stability, new or existing policies, etc. Any aspect related to economy falls under economic category (Junlakarn, Kokchang et al. 2022). For example, economic growth, inflation rate, consumer income and spending, market conditions such as competitive product prices, etc. The impact of socio-culture, for example the needs of customers, is also important in analysing an organisation's future. Other examples of societal factors are customer awareness and preferences, lifestyle changes, quality of education and health, and socio-cultural values. The technical factors can range from design, manufacture, construction and installation, operation, maintenance to disposal / disassembly. Under this category, the trends (Gasde, Woidasky et al. 2021) and effects of technology, level of innovation and development (Julnakarn, Kokchang et al. 2022) such as adoption of mobile technology, competing technologies (Gasde, Woidasky et al. 2021), investments in innovation by competitors, are considered. Any attribute related to the environment is deemed under the fifth category. Examples are climate change, greenhouse gas

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emissions, waste reduction targets, depletion of fossil fuels. Finally, rules and regulations that an organisation must comply are also accounted in this analysis. For instance, employment laws, minimum wage, health and safety laws, environmental legislations, etc.

A preliminary search on circular business model innovation in wind industry disclosed that there is a research gap in identifying its drivers and barriers based on PESTEL analysis. A literature review was conducted to bridge this gap. Business model related keywords in the first search stream were cross linked with drivers and barriers (in the second search stream) and wind power related keywords (in the third search stream) and searched within article title, abstract, and keywords using Scopus as the search engine. No time or any other restrictions were applied. The search performed on 27/10/2023 returned 57 hits. However, 17 articles were excluded (out of scope and did not particularly focus on business models in wind industry) and the sample reduced to 40 articles for comprehensive analysis. These articles were then read in full to discover drivers and barriers in business model innovation for wind industry, with findings then grouped into PESTEL categories.

While industries are adapting to renewable energy to satisfy their energy needs and to be competitive in the market (Richter 2012), its quick transitioning will strongly depend on regulatory frameworks (Schleicher-Tappeser 2012). The government support schemes in China have resulted it to be the world leading country in wind energy production (Liu, Wei et al. 2018). The UK government's target to achieve net zero emissions by 2050 is a strong driver for expansion of next generation wind farms in UK (BEIS 2020). This in succession creates business growth (economic driver) and new job opportunities (social driver). Financial drivers can be considered as the most critical category for an organisation towards circularity. Business growth or the potential for new business development and access to new markets and cost reductions are major economic drivers for circular business model start-ups and organisations looking for diversification opportunities (Geissdoerfer, Santa-Maria et al. 2023). Focusing on end of use treatment or next life of used wind turbine blades, business diversification opportunities are viable with different circular economy strategies (Velenturf, Purnell et al. 2021, Mendoza, Gallego-Schmid et al. 2022, Woo and Whale 2022). One motivation for the German utilities to invest in wind projects is the rate of return of offshore wind farms (6-11%) which is above the expected value from a municipality's perspective (Richter 2012). Further, public image as a responsible enterprise in renewable energy is equally important for utilities to compete in electricity market. Establishing wind energy within the community can promote sustainable living and create new jobs (BEIS 2020, Velenturf, Purnell et al. 2021).

If wind turbines are designed with a holistic perspective from the very beginning giving consideration to disassembly, the decommissioning risk can be alleviated (Velenturf, Purnell et al. 2021). Digitalisation, artificial intelligence, and internet of things can offer opportunities for next generation wind energy. Unlike in old designs following predetermined maintenance (preventive maintenance), new turbine blades are built with number of sensors to ensure smooth and safe operation and are monitored in real-time and compared against a baseline for predictive maintenance (Nagy, Mansour et al. 2018) which can extend the lifetime of a blade (long life circular business model). As the core of circular economy is to narrow, slow, and close resource and energy loops, an environmental driver towards its realisation is the reduced resource use and carbon savings. As a result wind turbine manufacturers can benefit from less purchasing cost of resources (Velenturf, Purnell et al. 2021). A legal driver for German wind farms is the feed-in tariff system that offers incentives for wind energy investments (Tanţău and Nichifor 2014).

An emerging trend is the floating offshore wind farms, and Umoh and Lemon (2020) performed a PEST analysis for this system in Scotland and South Africa. Some drivers they identified in Scotland were government schemes (e.g. Scottish government's Renewable Obligation scheme), innovative business models (Corporate Power Purchasing Agreements), availability of suitable sites, existing knowledge on offshore wind, and strong supply chain. The highlighted barriers were grid infrastructure, poor port facilities, and economic uncertainties. Unlike in Scotland, South Africa's technical expertise on offshore wind is at its early stage but the government has active policies for future large-scale wind farms. The above explained drivers are categorized and summarized in Table 3.

Table 3: Examples of drivers for business model innovation in wind industry.

Category	Drivers	References
Political	Government commitment towards net zero emissions	(BEIS 2020)
Economic	Economic growth due to new projects Business diversification opportunities Cost savings through reduced resource use	(BEIS 2020, Velenturf, Purnell et al. 2021, Mendoza, Gallego-Schmid et al. 2022)
Social	New job opportunities Promote sustainable living	(BEIS 2020, Velenturf, Purnell et al. 2021)
Technical	Reduced decommissioning risk Digitalization for next generation wind turbines Ability for predictive maintenance	(Nagy, Mansour et al. 2018, Aboltins, Novickis et al. 2020, Velenturf, Purnell et al. 2021)
Environmental	Reduced resource use and carbon savings	(Velenturf, Purnell et al. 2021).
Legal	Feed-in tariff system Waste management legislations	(Tanţău and Nichifor 2014)

Moving on to the barriers towards circular business model innovation, the followings were identified and categorized in Table 4. Despite the estimations of oil and gas reserves depleting in 40-45 and 50-55 years respectively (Haider 2020) and climate change mitigation policies emerging, oil and gas industries still try to be incumbents in the market. In Australia, conventional oil and gas industries are creating barriers to renewable energy deployment by defeating government policies on carbon pricing and climate change or by ensuring any policies approved have loopholes for them to continue the business as usual (Hudson 2020). Though governments announce their commitments towards renewable energy transitions, sometimes industries find these commitments lacking robust, transparent, and secure policies leading to uncertainties. Another example is the drop in wind farms projects in Romania after 2013 due to the cut in renewable energy support schemes (Tanţău and Nichifor 2014). On the other hand, sometimes the approval process is lengthy and complex which can discourage investors. The strict authorization process for new wind projects in India required approval from 22 departments with reports such as safety evaluation, environmental effect estimation, and electricity assessment which was strongly suggested to be more simplified by the interviewees of the study by Irfan, Zhao et al. (2019).

Economic barriers can greatly hold back industries from moving towards circularity when decisions were made traditionally only upon short term profits which misalign with long term perspectives of circular economy (Geissdoerfer, Santa-Maria et al. 2023) and giving less thoughts to social and environmental performances (Velenturf, Purnell et al. 2021). High upfront cost of new developments was recognised as an economic barrier in many literature (Schleicher-Tappeser 2012, Irfan, Zhao et al. 2019, Mendoza, Gallego-Schmid et al. 2022, Mendoza and Ibarra 2023) which in contrary can be considered as a lifetime investment (Schleicher-Tappeser 2012). Among the four major groups of investors in Germany (independent project developers, large utilities, financial investors, and municipal utilities), small and medium municipal utilities opt for financial based innovative business models to solve this problem (Richter 2012). Reductions in economic incentives can demotivate organisations from trying circular economy solutions (Velenturf, Purnell et al. 2021) or limit sustainability. Yet investments on technology development, value addition, and efficiency improvement are necessary if an organisation is interested in boosting its performance in a competitive market (Richter 2010). Competition against low fossil fuel prices, lack of demand and volatile market for second life products, requirement for robust economic modelling, repowering projects been time consuming and expensive, inability of old wind farms to make profits are among the other economic barriers (Velenturf, Purnell et al. 2021, Mendoza, Gallego-Schmid et al. 2022, Woo and Whale 2022, Mendoza and Ibarra 2023).

To develop successful business models, knowledge and experience of different industries will have to be brought together (Schleicher-Tappeser 2012) and require effective engagement of all supply chain actors in the development process (Wiener and Nicoleit 2020, Velenturf, Purnell et al. 2021). Bonou, Skelton et al. (2016) reported that in sustainability related projects, project managers can be key stakeholders in addition to engineers and that adaptive learning and continuous improvements can minimise opposition from management and cross-functions. In Germany, where power-to-hydrogen business models are emerging, a vast range of stakeholders such as government, research and development institutes, renewable energy project developers, utilities (electricity, gas), underground storage providers, power technology companies, car makers, heating device manufacturers, suppliers of the biogas and methanation industry are involved in development projects (Winkler-Goldstein and Rastetter 2013). Similarly, the supply chain structure of a wind farm is complex with many stakeholders and there is lack of clarity on responsibilities at different life cycle stages compelling effective communication between stakeholders. On the other hand, there can be conflicts of values which should constructively and deliberately be addressed for productive outcomes (van der Waal, van der Windt et al. 2020). Residents near a proposed wind farm can stand against the nuisance created by noise and flashing air traffic warning lights and devaluation of property. Environmental organisations are concerned about threats to bird species. In a report by van der Waal, van der Windt et al. (2020), cases where such value conflicts led to overall better solutions by improving awareness of each stakeholder value and dealing properly are described. With regard to end of use management of turbine blades, lack of communications between decommissioning and recycling and recycling and mining stakeholders is highlighted. Another social barrier towards circular business models is reasoning that only low volumes of critical materials are required and believing that innovations will emerge when necessary (Velenturf, Purnell et al. 2021). Customers, who are considered an important stakeholder, might be unaware of the sustainability implications of their consumption and thus create an insufficient demand for a sustainable product or prefer affordability over sustainability (Petrichenko, Sauhats et al. 2022, Geissdoerfer, Santa-Maria et al. 2023).

Unlike fossil fuel, a major drawback of natural energy is the uncertainty and variability in weather that impedes the generation of a constant electricity subsequently making load balancing difficult (Schleicher-

Tappeser 2012). As there is a tendency to generate surplus of electricity at times, it triggers the need for efficient storage capacities and complex optimization to manage the demand and supply (Schleicher-Tappeser 2012). Taking photovoltaics as an example, Schleicher-Tappeser (2012) suggested that temporal power consumption can be managed by shifting the operation time of consumption, storing excess energy, and integrating additional non time-critical loads (e.g., heating, car charging). In situations where shifting is impractical it can be linked with energy storage. These strategies are applicable to wind energy as well where circular sourcing business models like hybridisation (wind-solar-battery) can help to balance the load when storage units are optimally sized and placed (Ghofrani, Arabali et al. 2013). Other advantages are improved grid utilization by resolving transmission lines congestion and reduced transmission losses while high battery prices, difficulties in predicting lifetime, and losing capacity over time are recognized as drawbacks (Ghofrani, Arabali et al. 2013, Świerczyński, Stroe et al. 2013). In the report by Velenturf, Purnell et al. (2021), a number of other technical barriers towards circular offshore wind industry are listed such as need for critical materials and rare earth metals, less consideration on end of use and decommissioning during design stage, intellectual property concerns in sharing data and information, recycling being the main end of use strategy, quality concerns on second life products, and need for interdisciplinary data systems. An inherent drawback of blades is the gradual performance decrease in energy production (1.6±0.2% per year) and average capacity factor (28.5% to 21% over 19 years (Woo and Whale 2022)). Repowering with newer efficient technologies is an approach to overcome this.

The blade decommissioning rate in Europe is around 3800 per year which can generate composite waste of about 12-15 tons per megawatt of capacity installed (Leon 2023) creating a disposal challenge due to land scarcity and environmental regulations. Transporting them to end of use management facilities on the other hand is difficult as the turbine components are oversize and overweight (Wiener and Nicoleit 2020, Mendoza, Gallego-Schmid et al. 2022). This can lead to collection difficulties to end of use management facilities and insufficient waste feedstock (Mendoza and Ibarra 2023). Immature reverse logistics system is considered as a technical barrier impeding end of use treatment (Woo and Whale 2022). The reluctance to share data such as blade composition, varying blade quality, and limited availability of life cycle data trigger the need for flexible and advanced treatment options making end of use treatment even more complex (Mendoza, Gallego-Schmid et al. 2022, Woo and Whale 2022). Though digitalisation is mentioned as a driver, it can also create a barrier to business model innovation due to the requirement of large computational capacity, historical data, commercial software, etc. When internet of things is integrated in wind farm monitoring (to avoid any inefficiencies in energy production, loss of profit, or damage to the turbine) which is data driven, accurate historical data during which turbine was operating correctly is needed. It is also time consuming and costly to include smart devices into existing setups; issues such as hacking and breaching of data and hacking of devices (Aboltins, Novickis et al. 2020); challenges such as creating fair data frameworks, connecting and enabling collaboration, and competition between organisations also exist (Clifton, Barber et al. 2023). In next life circular business models, it is possible for the performance been affected when using refurbished or remanufactured components (Mendoza, Gallego-Schmid et al. 2022). Recycling being the most widely tried end of use management option yet face severe difficulties due to thermoplastic composite materials used during manufacturing. In addition, recyclers are not aware of the composition of turbine components as manufacturers are not willing to share due to the competitive nature in the market. An environmental barrier related to reusing or remanufacturing is needing more material and energy for greater damaged components (Mendoza, Gallego-Schmid et al. 2022).

It has been recognised that there are insufficiencies in laws to regulate and support end of use management of turbine blades (Woo and Whale 2022), thus manufacturers develop their own standards. To overcome the social barrier of uncertainty in second life product quality, proper regulations are required on technical and safety standards. Tax exemptions and subsidies would be worth for industries to invest in circular economy (Mendoza, Gallego-Schmid et al. 2022). As a result of reducing the number of green certificates in Romania, future wind projects were abandoned and existing owners started to sell their assets due to uncertainties (Tanţău and Nichifor 2014). Another legal barrier is the lack of proper regulations to avoid material loss and illegal exports (Velenturf, Purnell et al. 2021).

Table 4: Examples of barriers to business model innovation in wind industry.

Category	Barriers	References
Political	Lack of robust policies Uncertainties in tariff policies Complex approval process	(Südhoff 2012, Tanţău and Nichifor 2014, Irfan, Zhao et al. 2019, Velenturf, Purnell et al. 2021, Petrichenko, Sauhats et al. 2022)
Economic	High upfront cost Reductions in economic incentives Competition against low fossil fuel prices Lack of demand for second life products Requirement for robust economic modelling Expensive and time-consuming nature of repowering projects Inability of old wind farms to make profits	(Schleicher-Tappeser 2012, Velenturf, Purnell et al. 2021, Mendoza, Gallego-Schmid et al. 2022, Petrichenko, Sauhats et al. 2022, Woo and Whale 2022, Mendoza and Ibarra 2023)
Social	Complex ownership of a wind farm Lack of clarity on responsibilities Lack of effective communication between stakeholders Lack of community acceptance Residents' constraints due to noise and flashing light nuisance Loss of property value Assuming that only low volumes of critical materials are required Believing that innovations will emerge when necessary	(Schleicher-Tappeser 2012, Bonou, Skelton et al. 2016, van der Waal, van der Windt et al. 2020, Velenturf, Purnell et al. 2021, Petrichenko, Sauhats et al. 2022)
Technical	Variability in weather conditions Need for efficient storage capacities Need for critical materials and rare earth metals	(Schleicher-Tappeser 2012, Ghofrani, Arabali et al. 2013, Velenturf, Purnell et al. 2021,

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	Less consideration on end of use management during design stage Intellectual property concerns Quality concerns on second life products Gradual performance decrease Complex reverse logistics Insufficient waste feedstock Complex end of use treatment Need for digitalisation	Mendoza, Gallego-Schmid et al. 2022, Woo and Whale 2022)
Environmental	Needing more material and energy for greater damaged components	(Mendoza, Gallego-Schmid et al. 2022)
Legal	Lack of law to regulate end of use management Need for standards on technical and safety quality of second life products Tax exemptions and subsidies Lack of proper regulations to avoid material loss and illegal exports	(Velenturf 2021, Mendoza, Gallego-Schmid et al. 2022, Woo and Whale 2022)

6.3 Pilot methods

As explained above, PESTEL analysis should be repeated in a timely manner for better results to accommodate any contextual changes. The above identified drivers and barriers might not necessarily represent the dynamics of current or future scenarios as they were based on a literature review of articles ranging from 2008 to 2023. However, following the literature review a list of drivers and barriers in business model innovation were noted and this was used as the basis for identifying major factors related to wind industry via stakeholder engagement.

A closed-ended questionnaire (survey 1) was designed to allow participants to rank the level of influence (in a 6-point Likert scale: strongly disagree, disagree, neither agree nor disagree, agree, strongly agree, not sure) of each driver and barrier and to provide any other major factors they might think are important. Stakeholder types (e.g. investors, material and component providers, blade manufacturers, consultants, constructers, operation and maintenance service providers, decommissioning service providers, end of life service providers, etc.) within the wind supply chain was first listed and expanded with potential stakeholders through an internet search. All stakeholders were contacted via general inquiry email addresses shown on websites. However, only two responses were received. While one participant was from an organisation sourcing as a global materials / components supplier, original equipment manufacturer, and designer, the other participant was from a design and consultancy firm offering services in the UK, Ireland, France, Germany, Poland, Korea, Taiwan, Vietnam, Japan, United States, and Australia.

As the number of responses to survet 1 were low, another survey (survey 2) was conducted with experts from wind supply chain at the EoLO-HUBS month 12 general assembly held at Bremerhaven on 30th November 2023. At this assembly, a short open-ended online survey was opened for the participants to convey what they think are the unique drivers and barriers related to their organisation when transitioning towards circular business models. A total of 13 responses were received representing policy makers, environmental organisation, consultancy, site investigation, clustering

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services, circular economy services, sustainability services, wind turbine end users, end of life services, and research and development in France (1), Germany (2), the Netherlands (2), Spain (5) and worldwide (1) (numbers in brackets express the number of responses received based on countries where the services are offered). It should be noted that some organisations offer multiple of services mentioned above.

Following a deductive approach (the PESTEL analysis) the responses from survey 1 and 2 were merged and coded to identify the frequency and perceived importance of factors in each PESTEL category. The drivers and barriers that were most repeated by stakeholders were considered for further discussion and interpretation of latent meanings (reflect deeper and underlying meanings (Kiger and Varpio 2020)) justified by the literature review.

6.4 Survey results

A summary of responses received from both surveys is provided in Table 5. As survey 1 allowed participants to rank the level of influence of each driver and barrier, only the factors that were 'strongly agreed' or 'agreed' were merged with survey 2 responses. In survey 2, where responses did not tally with the correct PESTEL category, the authors have rearranged them accordingly and provided in Table 5. The number of repeated occurrences of each factor is shown in brackets.

Table 5: Stakeholder inputs on drivers and barriers in business model innovation in wind industry with number of votes in brackets.

Category	Drivers	Barriers
Political	New targets and policies (6) Being an organisation that is partly state financed (1) Being a national representator (1) Tender requirements (1)	Political instability (2) New policies (1) Need for proper framework (1) Opposition by some industries (1) Policy mismatch (1) Late policy development (1) Slow authorisation rate (1)
Economic	New industries (7) Subsidies/ funding (3) Cost efficiency (2) Market demand (1) Being a non-profit organisation (1)	High cost of end of use processes (8) High price of second-life products (2) Price of virgin products (1) Not including CO_2 cost (1) Being a non-profit organisation (1) Limited funding (1) Low fossil fuel price (1) Inappropriate targets (1)
Social	Social acceptance (8) Job opportunities (3) Social recognition (name and fame) (1)	Social awareness (5) Lack of implementation (1) Lack of collaboration (1) Other basic needs to worry (1) Training requirements (1)
Technical	Existing / new processes (5) New research directions (2)	Lack of technologies (5) Quality of second-life products (4)

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	Competitiveness (1) Reduced dependence on constrained supply chain (1) Reduced decommissioning risk (1)	Characteristics issues (2) Intellectual property concerns (2) Lack of scaling up (1) Long developing time (1) Adaptation to second-life materials (1) Complex logistics (1) Less consideration on decommissioning (1) Size limitations (1)
Environmental	Environmental benefits (7) Climate change (3)	Shifting of burden (1) Impact on wildlife (1)
Legal	Regulations (7) Feed-in-tariff (2) Standards (1)	Regulations (7) Lack of standards (2) Need for tax exemption (2) Lack of restriction on the use of virgin materials (1)

The summary of responses of surveys briefly suggests that there are more barriers to overcome than the drivers that could be cooperative in all categories except environment, which was also observed from literature review. While social acceptance on sustainability was the most repeated driver, new market opportunities through innovation, environmental benefits of circular economy, and emerging regulations related to circular economy can be seen as other prevalent drivers. The dominant barrier in circular business model innovation is the high cost of end-of-life processes. Figure 4 shows the percentage of number of drivers, barriers, and total factors identified in surveys for each PESTEL category. From Figure 4, of equal importance to the economic category (with 9 barriers) are the technical barriers to realising new circular business models for the wind industry, where 10 barriers were noted. Considering the PESTEL categories (deductive approach) it is intended to reflect deeper meanings (latent meanings) of the mostly cited factors with justifications from the literature.

Circular economy, as a subset of sustainability, is now an emerging context in government agendas and international organisations drafting policies towards embracing circularity by various industries. Bonou, Skelton et al. (2016) argued that without such a strong external driver it is hard to spark an internal momentum in an organisation for circular strategies. For example, electric vehicle battery manufacturers in India were not concerned to recycle the used batteries due to lack of policies/ laws (Bhuyan, Tripathy et al. 2022). In case of wind industries, stakeholders recognise new targets and policies such as Agenda 2030, EU Green Deal, EU Circular Economy Action Plan, 2050 targets, recycling quotas demand circular practices by the industries. But conversely stakeholders foresee that governments are instable and lacking robust policy development. For instance, stakeholders from The Netherlands have raised that "*new political orientation might limit Dutch involvement in the future*". Thus, it is important that government make solid steps in achieving the announced targets related to renewable energy deployment.

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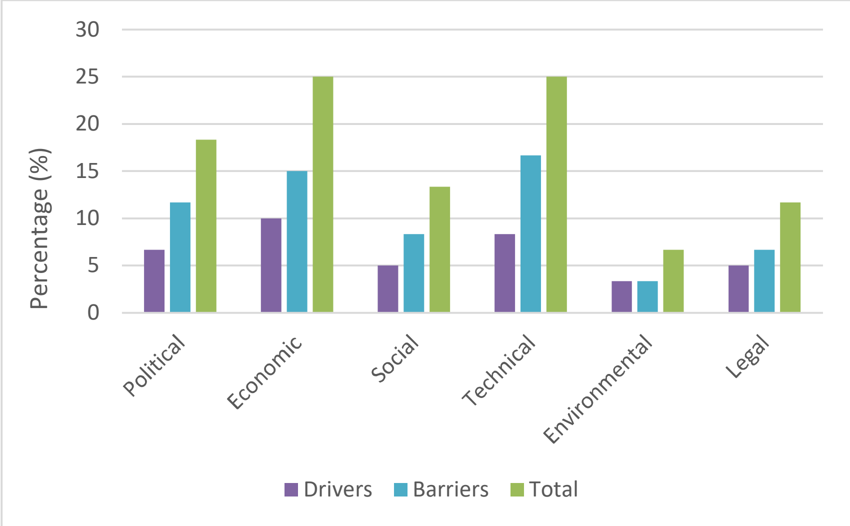

Figure 8: Percentage of number of drivers, barriers, and total factors identified in surveys for each PESTEL category.

It can be seen that economic factors play a prominent role in both steering (with 6 drivers) and hindering (with 9 barriers) organisations in circular business model innovation. The dominant barrier identified in this survey is the cost restriction related to end of use processes. Executing end of use circular economy strategies such as recycling might need installation of new and complex unit operations – high voltage pulse shredding or crushing in mechanical recycling; incineration or pyrolysis in thermal recycling performed at high temperatures; solvolysis in chemical recycling (Leon 2023). In realising reuse as a next life busienss model that grants low capital cost, industries will have to consider its economic feasibility, remaining lifetime, costs for refurbishment, costs during operational phase, other related costs, availability of spare parts, inspect for technical conditions, safety aspects, and hazardous materials, etc. As suggested by some participants, subsidies for early-stage circular solutions, infrastructure upgrade fundings, and funding for research and development can potentially initiate momentum in industries. Consequently, circular strategies could create innovative businesses and business diversification opportunities to overcome the investment cost. For example, turbine blades can be repurposed as sound barriers, storage tanks, building roofs (Mendoza, Gallego-Schmid et al. 2022); or as structural and aesthetic elements in playgrounds, seats / benches, pedestrian bridges, beams and panels for construction (Woo and Whale 2022); or as plant pots, reception desks, community gardens, lookout towers, bike shelters, promenade. Alternatively, blades can be crushed and used as fillers or burnt for energy recovery in cement plants; or recycling for metals, electronics, and resins can generate new markets (Mendoza, Gallego-Schmid et al. 2022). Some components of a wind turbine can certainly be reused as spare parts; research and development need to innovate low-cost end of use treatment methods. However, conflicting is that the same participant mentioned been a non-profit organisation both as a driver and barrier which need further clarification.

In addition to political force, society, a vital stakeholder in the wind supply chain, might lack the awareness on possible benefits of circular economy which can demotivate industries from offering circular solutions. For example, a consultancy and design firm (one of the respondents to survey 1) in wind supply chain mentioned that they are not developing, using, or offering any circular economy solutions as there is "*no client demand*". Contradictorily, some stakeholders reveal social acceptance as the most predominant driver towards circularity by elaborating as "*sustainability issues in the society*", "*some social sectors (and young people) are increasingly aware of sustainability issues and*

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demand appropriate and quick solutions", "*social pressure to favour the transition to a circular economy*", and "*more ecologically conscious users*".

According to Figure S1 technical challenges are the most critical in realising new circular business models. Some stakeholders reckon that there is still a gap in suitable technologies to extend circular economy, especially recycling. Four stakeholders related to quality concerns stating, for example, "*uncertainty in quality and suitable market for second life products*" and "*materials obtained are not as good to use in other industries such as aeronautics*". Similar to being revealed in the literature review, where difficulties were met in end of use management due to thermoplastic composite materials used in wind turbine blades, one stakeholder mentioned "*thermodynamic issues constrain some CE practices*" and the situation becomes even complicated when original equipment manufacturers were reluctant to share component composition due to intellectual property concerns and market competitiveness. As another technical barrier it was mentioned that "*a lot of research is happening, but scale-up is missing in some sections*" and developments take long time. However, the drivers mentioned are opportunities to conquering technical obstacles in circular business model innovation for wind industry. Innovative processes such as "*methods to easily break down blades*", "*combined techniques for CE*", and "*new service offerings*" are emerging due to research and development but fast track development of innovative processes is needed. Wind industries can embrace digitalization such as internet of things to benefit from advanced algorithms and monitor more components, electricity generation, and transmission quality in grids, receive error messages and control, diagnose and forecast faults in turbine components, etc. simultaneously (Nagy, Mansour et al. 2018, Aboltins, Novickis et al. 2020). It can create new market opportunities (increase product attractiveness), increase efficiency, safety, reliability, and productivity. For instance, Aboltins, Novickis et al. (2020) reported that Vestas, a world leading blade manufacturer, moving to internet of things provided customers with additional digital tools to make smarter decisions, low cost and increased revenues, and better plant management. Open-source software can be integrated for smarter and more cyber secured grids (Klein 2008). New models can be used for many purposes such as to find best locations (Aboltins, Novickis et al. 2020), simulate and predict financial implications at different stages of a wind farm lifecycle (Judge, McAuliffe et al. 2019), forecast weather conditions, and mitigate electrical surges (Vijayalakshmi, Genish et al. 2023).

Only two environmental barriers were identified to circular business model innovation ("*need for appropriate tools to quantify net environmental savings to avoid shifting of burden*" and "*impact on birds/ sea mammals*") while most participants considered it as an obvious need granting environmental benefits. But 'environmental benefits' was not explicitly elaborated by the stakeholders except where some suggested as "*CO_2 savings*", "*less landfill materials*", "*reduced environmental pollution (by using secondary raw materials)*", and "*reduced material and energy use*". An equal number of responses were received on 'regulations' being a driver for some organisations and a barrier to others and was lightly explained. For example, "*lack of regulations to avoid material loss and illegal exports*", "*EU waste regulation lacking the concept of waste as a resource*", and "*dust emission regulations*" were stated as barriers. Cutting blades onsite is an appealing option for subsequent end of use processes but requires careful preventive measures as dust and process waters need to be collected and handled properly and noise emissions are also a factor from an environmental perspective. Nevertheless, to influence organisations towards circular economy it is necessary to develop strict laws and standards on technical, safety, and quality characteristics of second life products and impose restrictions on using virgin materials. Two stakeholders from the Netherlands and Spain specified that "*upcoming EU legislations require more transparent information on*

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circularity" and "*is emerging to promote circular economy*". The authors suggest that as in the case of oil and gas industries, decommissioning guidelines giving priority for sustainable concepts are also necessary for wind farms nearing their end of life.

6.5 Evaluation

The PESTEL analysis approach taken so far to understand a wind industry's macro environment was effective in identifying drivers and barriers which could affect its strategy and decisions towards circular economy. Via the systematic literature review, various factors that can promote circularity as well as challenges to overcome throughout were identified. Similarly, even with a small sample of stakeholders other distinct and practical reasons were listed which are useful in next steps of the development of the framework.

However, there are some drawbacks of this approach which need rectification in the future to obtain better results and thorough insights into the wind industry's macro environment. First, a large group of stakeholders should be reached for input, and they should represent several types of supply chain actors such as investors, consultants, materials and components suppliers, original equipment manufacturers, logistic providers, environmental organisations, policy makers, circular service providers, etc. One-to-one interviews are suggested instead of surveys to have transparent understanding of stakeholder views. For instance, responses such as '*regulations*', '*policy*', '*cost*', '*political priorities*', were mentioned in survey 2 which were vague to be explained. On the other hand, authors understanding as explained above might be different to what was actually meant. If one-to-one interviews were conducted, it could help to resolve such conflicts and get further deep clarifications.

The initial results of the PESTEL analysis shared above will suffice to invite broad input from stakeholders during the case studies, functioning as effective conversation starters combined with further desk research – linking to the steps on stakeholder involvement action 9 on broad stakeholder input and phase 1 system exploration action 8 to analyse the regional context.

7. Pilot 2: Analyse core values

This chapters present a pilot to test the rapid assessment of core values of stakeholder organisations.

7.1 Place in framework

Analysing the core values of stakeholder organisations is part of the stakeholder involvement during phase 1 to explore the regional circular economy system for wind energy infrastructure (Sections 5.3 and 5.4). This is an important part of analysing the stakeholders involved. Stakeholder core values will be combined with the formal institutional values derived from policy and regulation in the context analysis, with the results forming a value framework. This will be the basis for further coproduction for the regional value proposition during phase 2 (Section 5.5) and the selection of indicators and their weightings for sustainability assessments throughout phase 1-3 (Section 5.7).

Understanding the core values is also part of managing the stakeholder diversity. It will help spotting opportunities for integration of perspectives. It will also help identify threats of divergence in stakeholder views, to allow for their proactive management to avoid unresolvable conflict for example when it comes to coproducing and deciding about actions in phases 2 and 3.

7.2 Background

The terms "value" and "values" are used commonly used within circular economy literature (Stec and Zwolinski 2018). Successful implementation of circular economy depends on the presence of a sustainable culture and values within organisations (Burke, Zhang et al. 2023). Senior managers have a high influence on the organisational values and culture, which can be shaped through texts and other communications on core values, vision, mission / future directions that would ideally be aligned with circular economy (Jin and Drozdenko 2010, Wijethilake and Lama 2019, Burke, Zhang et al. 2023).

The Graves model specifies eight core value systems i.e. a consistent system of values, beliefs and behaviours (Van Marrewijk and Werre 2003). Such value systems can be observed in people as well as in organisations. The value systems are thought to develop in order, from survival to security, energy and power, order, success, community, synergy and holistic life system. Value systems are directly driven by the macro context in a given location and time (Van Marrewijk and Werre 2003, Avota, McFadzean et al. 2015). Organisations have to adapt to their context or risk low chances for survival. On the other hand, value systems and organisational behaviours are shaped by internal individual, group, structural and management processes (Avota, McFadzean et al. 2015). Understanding why certain values are important is critical to understanding the underlying value systems (Van Marrewijk and Werre 2003). People within an organisation can display a wide range of values, but at the level of organisational culture generally one or two value systems become dominant. Personal and organisational values can be in synergy with each other but can also conflict (Avota, McFadzean et al. 2015).

Decisions are driven by core values that are deeply embedded within people (Stec and Zwolinski 2018). Personal values are relatively stable (Bardi and Schwartz 2003). There are ten core values recognised throughout societies, these are: self-direction, stimulation, hedonism, achievement, power, security, conformity, tradition, benevolence and universalism (Schwartz 1992). Of these ten values, 1) tradition i.e acceptance of customs, respect for traditions, 2) stimulation i.e. excitement and challenge, 3) hedonism i.e. pleasure and enjoyment, 4) self-direction i.e. choosing own goals, curiosity, and independent thought, 5) universalism i.e. understanding of all people and nature, and 6) power i.e. social status and dominance over others, impact behaviour the most (Bardi and Schwartz 2003, Avota,

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McFadzean et al. 2015). Organisational values related to sustainability include respect, fairness, accountability, global citizenship, customer focus, quality, creativity, innovation, use of technology, integrity and premium return on assets (Van Marrewijk and Werre 2003, Avota, McFadzean et al. 2015).

Wijethilake and Lama (2019) assessed sustainability core values through a series of statements that participants from companies could respond to along a scale to indicate the extent to which they agreed. Jin and Drozdenko (2010) analysed values systems with a questionnaire for thousands of people across companies, presenting them with statements that were linked to value clusters. Van Marrewijk and Werre (2003) discuss the DBR-values-audit approach, which measures personal and current and ideal future organisational values. The audit asks participants to select the top ten most essential values from a long list of 126 values in total; with values being linked to value systems to connect deeper meanings to the responses.

7.3 Pilot methods

The assessments described in Section 7.2 are time intensive, both for the stakeholders involved and for the process facilitators of the circular economy transition. Here we pilot a method for composing a value framework with a minimal effort to gauge whether sufficient insight for the delivery of the further process can be obtained, or whether a stronger effort might be required.

This pilot was carried out with the EoLO-HUBS team and tested specifically:

A. The duration of completing the core values survey.
B. The quality of information collected through the survey in a workshop setting.
C. The types of documents where organisations have published their core values.

A rapid survey was prepared for stakeholders to share their core values in a workshop setting within three minutes. The survey could be accessed via QR code or a hyperlink during the EoLO-HUBS general assembly in November 2023. The survey consisted of five questions:

1. Please state your name
2. Please state your affiliation
3. What type of organisation do you represent? (Multiple choice: Company, Government body, Non-profit organisation, Private research institute, University, Other)
4. What do you believe are the top 3 values of your organisation? These are often single words such as "Sustainability", "Inclusive", "Integrity", "Ethical", "Green", etc.
5. Are there any documents or webpages where we could read about these organisational values? If yes, please add titles and/or links.

7.4 Results

7.4.1 Respondents

The survey was completed by 26 EoLO-HUBS consortium members from 13 different organisations. Some respondents did not fill in their organisation; they answered with their job role (2/26) or did not answer at all (2/26). The average response time was 3 minutes and 16 seconds.

7.4.2 Organisation types

Respondents from the same organisation characterised their organisations as different types. Especially the status of non-academic research institutes appeared uncertain, with respondents characterising such organisations and private research institutes, non-governmental organisations,

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governmental bodies, companies or something else. While some of these organisation types could be embedded in the same organisation (e.g. private research institute and company), others are less compatible (e.g. private research institute and governmental body).

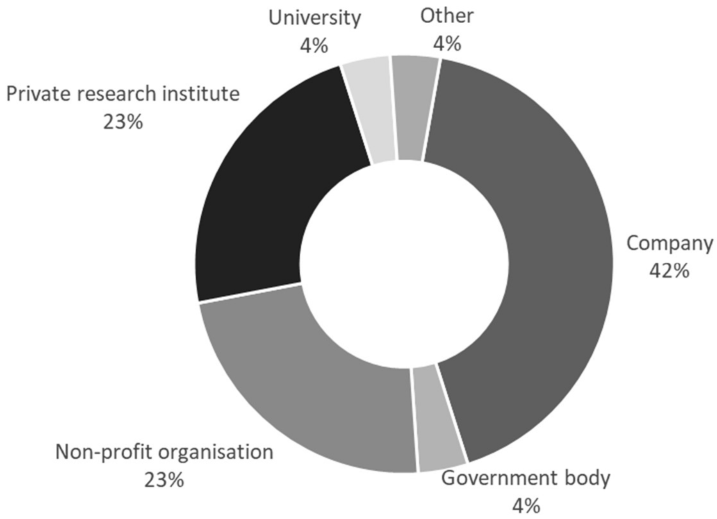

Figure 9: Types of organisations that took part in the core values pilot.

7.4.3 Core values

The answers on the core values were thematically analysed to group the same or very similar replies together. In total 26 different core values were put forward (Table 6). Sustainability was by far the most mentioned (15 times), followed by innovation (8) and enabling change / making impact (6). Working in an ethical and responsible manner (4) and with integrity (4) was also considered multiple times, as was research (also 4). There was a relatively long tail of other core values named 1-3 times each.

Table 6: Core values listed by EoLO-HUBS consortium members.

Sustainability	**15**		Inclusive / social	2
Innovate	8		Solutions	2
Change / impact	6		Technological progress	2
Ethical / responsible	4		Curiosity	1
Integrity	4		Customer focus	1
Research	4		Data	1
Communication / network	3		Excellence	1
Flexible	3		Growth	1
Recycle	3		Lead	1
Transition	3		Products	1
Collaborate	2		Quality	1
Composites	2		Renewable energy	1
Create value	2		Shared value	1

Many of the core values would likely form synergies when combined, such as innovation and research and enabling change / impact for sustainability, or working in a social and inclusive manner would support collaboration. Some core values could become a source of divergence, but this would depend on the exact interpretation of the identified results, for example growth within the wind industry would be a synergy with most other core values but growth at a whole system level for the economy would go against sustainability within most of the European context.

7.4.4 Formal documents

Types of sources recommended to read more about the core values of the participating organisations were almost exclusively online. Out of the 26 replies, fourteen recommended to analyse a general website of the organisation and six recommended specific webpages dedicated to introducing the organisation and its core values. Five could not recommend any further information source, and one preferred to continue the conversation rather than referring to a formalised source.

7.5 Evaluation

Linking the pilot results back to the objectives, completing the survey took just over three minutes. This suggests that slightly longer may have to be scheduled into a workshop programme to complete the survey questions.

The quality of the information collected in this manner was probably relatively poor. It would be better to share the survey before the workshop, for participants to complete the questions in a quieter environment where they can concentrate and think more about the answers. Given the role of senior managers in determining and embedding core values in their organisations (see e.g. (Jin and Drozdenko 2010), it would also be recommended to survey participants at senior level especially.

An alternative approach could be to ask more closed questions, for example asking participants to select their top three-five core values from a list. Offering over a hundred, such as in some studies, would likely be overwhelming though and a more strategic approach to unravel sufficient core values to relate results to specific value systems could be a better approach. Insight into the presence of circular economy related values (see (Barboza, Bertassini et al. 2022) could also be useful to check general alignment with the overall purpose of the co-creation network. Surveys could be (in part) tailored to regional contexts, by analysing websites / dedicated webpages to value systems, missions and /or visions of organisations involved, to ask more directed questions about the regional value framework. This too, however, would add time investment to the process facilitator. These alternative approaches would demand more time from stakeholders. A balance needs to be struck between depth of results and practicality of ensuring stakeholder involvement. This will require further piloting in the development case studies.

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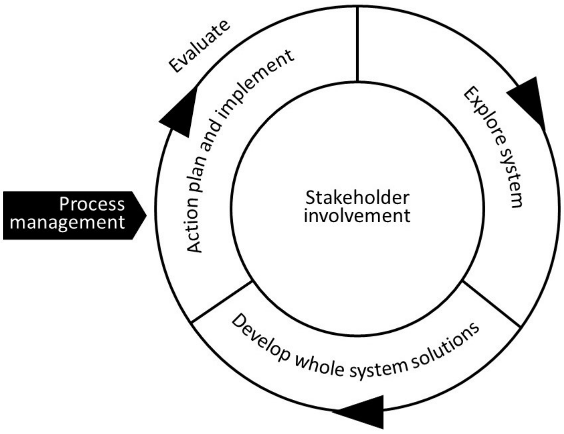
8. User interface

The regional circular economy decision-making framework will be made available through the knowledge hub, developed in WP1. This section presents initial ideas for the user interface. Within the knowledge hub, there will be a separate webpage for the framework, showing a professionally produced version of the overview diagram (repeated below from Figure 4, Section 5).



The framework will be introduced with a brief explanatory text about what it is, what it is for, what the main phases are, and for whom it is intended to use. Users will be able to click on the various process phases in the diagram to move to them directly, or they can scroll down for a process journey experience.

Each phase will be briefly explained in separate sections below each other, using diagrams and embedded videos to enable accessibility to a wide audience. A list of the activities with estimate delivery times will offer an overview of the activities that are to be undertaken in each phase. Users can then click to open a detailed subpage within the knowledge hub in a separate tab to read more about each activity and to access accompanying tools. Some of the tools will be made available in two versions: one freely accessible and one on a paid / membership basis only e.g. by hiring partners such as Leeds, ECHT etc to help deliver the step, by accessing training to learn to do the step themselves, or by buying the detailed activities guidance and tools to use for a certain amount of time. (to be specified during the exploitation planning in Task 3.3). Links will also be embedded to pages with background, technical, policy, business model or partner details, either available within the knowledge hub or on external websites. On the framework overview page, users will be able to continue to scroll down through the process journey.

At the end of the journey at the bottom of the webpage, an overview table / diagram will summarise the phases and activities within them, repeating links to detailed information about the activities and tools and with links to the process phases moving back up the webpage to the respective sections.

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9. Next steps

Over the next 2-3 years the framework will be developed in full through a series of themed case studies and three pilot case studies across EoLO-HUBS demonstration regions.

Table 7 lists all steps that are currently included in the framework. The table proposes seven thematic case studies that group the full development of tools and guidelines for some of the steps in the framework, using the development case study regions (Section 3, Table 1) and in collaboration with the listed related EoLO-HUBS work packages and tasks:

a. **Challenges:** [PM2] Initial process exploration to specify main challenges to resolve and/or targets to achieve, and for whom and why; [P1.1] Challenges / problem specification; [P1.2] Identify solution directions / (formal) targets such as set out in (regional) economic strategy.
b. **Stakeholder:** [PM3] Initial introduction with key initial stakeholders; [S1] Identify stakeholders; [S3] Stakeholder analysis and selection of participation level for stakeholders within the network; [S4] Circularity skills and maturity assessment; [S13] Specification of possible stakeholder groups, e.g. whole system experts, supply chain network, and forum.
c. **Flows:** [P1.3] Set and review system boundaries; [P1.4] Map material and energy flows; identify potential opportunities for greater circularity; [P1.5] Analyse current wind supply chain and business models including dependencies on other products, value chains and infrastructure; [E3] Baseline sustainability assessment before co-producing new circular business models including ecosystem alignment (phase 1).
d. **Values:** [S6] Analyse core values (organisational and/or personal); [S2] Coproduce a shared long-term purpose for the co-creation network; [P2.3] Articulate shared whole system / network value proposition based on a collective vision for the regional circular economy and long-term sustainable business opportunities; [E2] Involve stakeholders in the selection of indicators and weightings for sustainability and circularity MCDA of proposed solutions, based on stakeholders' core values (phase 1-2); [E4] Collaboratively develop a "matrix of sustainability assessments" to assess and select aligned options for system change across the macro, meso and micro level (Figure 5), and the focus, level of detail and system boundaries of the assessments (phase 1-3).
e. **Context:** [S9] Broad input on drivers and barriers for change and possible solutions, with regular expert evaluation; [P1.6] Desk review for initial (incomplete) drivers and barriers, as basis for initial stakeholder interactions; [E1] Proactive assessment of uncertainties (phase 1-3); [P1.7] Context analysis using PESTEL to analyse current state, trends, drivers and barriers in political, environmental, social, technical, economic and legal domains; including interactions between aspects and between aspects and business models in the mapped supply chains (action 5); [P1.8] Prioritise drivers and barriers across system levels to select levers for change.
f. **Future:** [P2.1] Building on the context analysis from phase 1, identify two critical system variables per transition phase, and specify plausible narrative context scenarios for the whole system; [P2.2] Specify possible future visions for the regional circular economy within the context scenarios (building on previous step).
g. **Business model:** [P2.4] Specify circular business models and relations between them to deliver on the shared value proposition, within future regional circular economy visions (building on previous steps). Use tools such as adapted versions of the business model canvas adding a multi-level perspective to include the business ecosystem and wider sustainability context,

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possibly coproducing initial ideas first with a simplified list of questions (who, what, how and why) to consider a multitude of options, before detailing prioritised circular business model options; [P3.2] Discuss feasibility and sustainability of proposed solutions, including dependencies and alignment in proposed new circular business model ecosystems linking back to the shared value proposition (linking back to phase 2), including the values to partners and stakeholders that are created, destroyed and possibly missed, internal and external barriers to implementation and plans to overcome them (linking back to phase 1), and carry out SWOT and sustainability scans (linking to Evaluate); [E5] Compare and discuss outcomes of circular economy scenarios against shared vision and value proposition, and feedback for process iteration and/or implementation (phase 3).

For some steps it will be difficult to develop the tools / guidelines within the development case study regions, without running the process in full. For these steps, pilots will be carried out within the EoLO-HUBS team. Other steps have already been developed / do not need further development, or are impractical to develop in a partial case study, and hence will be piloted directly in the demonstration regions.

The pilot case studies were originally planned to start after completion of all development case studies (as introduced in Section 3). Due to the length of the delivery of the full framework, the pilot case studies will now start from month 18 in July 2024 instead.

Table 7: Framework steps overview with planned further development in T3.1 thematically focused case studies, and links to other EoLO-HUBS work packages and tasks.

Actions	Development cases in T3.1	Other EoLO-HUBS parts
[PM] Process management secretariat		
[PM1] Prepare a team to facilitate the participation process including a lead facilitator and research and innovation team members.	EoLO-HUBS	
[PM2] Initial process exploration to specify main challenges to resolve and/or targets to achieve, and for whom and why.	Challenges	
[PM3] Initial introduction with key initial stakeholders.	Stakeholder	
[PM4] Feasibility check to confirm if resources to deliver process are likely sufficient for addressing the challenges in a meaningful way.		With WP6
[PM5] Develop a public identity for the participation process / community.		With WP1
[PM6] Continuity planning for when initial resources end, plan for more resources or other team members for process management for the next transition phase(s).		With WP6, T3.3
[S] Stakeholder involvement		
[S1] Identify stakeholders and develop a co-creation network (NB latter only in pilot cases).	Stakeholder	With WP1, T3.3
[S2] Coproduce a shared long-term purpose for the co-creation network.	Values	
[S3] Stakeholder analysis and selection of participation level for stakeholders within the network.	Stakeholder	With WP1, T3.3
[S4] Circularity skills and maturity assessment.	EoLO-HUBS	

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	Stakeholder	
[S5] Prepare, maintain and deliver knowledge exchange and circularity transitions literacy hub.		With WP1
[S6] Analyse core values (organisational and/or personal).	EoLO-HUBS Values	
[S7] Build relations and trust in interactions with a schedule of regular meetings including space to resolve differences throughout the process.		
[S8] Visual and inclusive communications.		With WP1
[S9] Broad input on drivers and barriers for change and possible solutions, with regular expert evaluation.	EoLO-HUBS Context	
[S10] Share, discuss and reflect upon solutions and actions.		
[S11] Analyse the costs, benefits, capabilities and role of stakeholders in delivering a possible shared value proposition and associated circular business models.	Business model	
[S12] Evaluate participation process.		
[S13] Specification of possible stakeholder groups, e.g. whole system experts, supply chain network, and forum.	Stakeholder	With WP1, T3.3
[S14] Detailed outline of timeline / planning with the types of stakeholder engagement actions such as interviews, focus groups, workshops, etc.		With WP1
[P1] Phase 1: Explore system		
[P1.1] Challenges / problem specification.	Challenges	
[P1.2] Identify solution directions / (formal) targets such as set out in (regional) economic strategy.	Challenges	With 3.2
[P1.3] Set and review system boundaries.	Flows	With WP2
[P1.4] Map material and energy flows; identify potential opportunities for greater circularity.	Flows	With WP2, WP4
[P1.5] Analyse current wind supply chain and business models including dependencies on other products, value chains and infrastructure.	Flows	With WP2, 3.4
[P1.6] Desk review for initial (incomplete) drivers and barriers, as basis for initial stakeholder interactions.	EoLO-HUBS Context	With 3.2
[P1.7] Context analysis using PESTEL to analyse current state, trends, drivers and barriers in political, environmental, social, technical, economic and legal domains; including interactions between aspects and between aspects and business models in the mapped supply chains (action 5).	EoLO-HUBS Context	With 3.2
[P1.8] Prioritise drivers and barriers across system levels to select levers for change.	Context	
[P1.9] Identify inspiring examples of companies adopting circular practices, from within and outside the region.		With WP1
[P2] Phase 2: Develop whole system solutions		
[P2.1] Building on the context analysis from phase 1, identify two critical system variables per transition phase, and specify plausible narrative context scenarios for the whole system.	Future	

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[P2.2] Specify possible future visions for the regional circular economy within the context scenarios (building on previous step).	Future	
[P2.3] Articulate shared whole system / network value proposition based on a collective vision for the regional circular economy and long-term sustainable business opportunities.	Values	
[P2.4] Specify circular business models and relations between them to deliver on the shared value proposition, within future regional circular economy visions (building on previous steps). Use tools such as adapted versions of the business model canvas adding a multi-level perspective to include the business ecosystem and wider sustainability context, possibly coproducing initial ideas first with a simplified list of questions (who, what, how and why) to consider a multitude of options, before detailing prioritised circular business model options.	Business model	With 3.4, WP4, WP5
[P2.5] Research and development to build up expertise (feeding into stakeholders' knowledge hub).		With WP4-5
[P3] Phase 3: Action plan and implementation		
[P3.1] Coproduce decision making process and guidelines; facilitate delivery of decision-making process.	EoLO-HUBS	With WP4
[P3.2] Discuss feasibility and sustainability of proposed solutions, including dependencies and alignment in proposed new circular business model ecosystems linking back to the shared value proposition (linking back to phase 2), including the values to partners and stakeholders that are created, destroyed and possibly missed, internal and external barriers to implementation and plans to overcome them (linking back to phase 1), and carry out SWOT and sustainability scans (linking to Evaluate).	Business model	With 3.4
[P3.3] Coproduce adaptive management plan covering multiple transition phases, options for solutions at each phase, path dependencies, detailed change process actions for all stakeholders for the first following phase (i.e. next action 4), and guidelines for triggering the next transition cycle within the framework.	EoLO-HUBS	
[P3.4] Prepare for strategic, tactical and operational actions at different system and time-scales, taking a strategic approach towards circular economy transitions and circular business model innovation by covering long, medium and short-term plans at the macro (whole system context), meso (network) and micro (business) level.	EoLO-HUBS	
[E] Evaluate		
[E1] Proactive assessment of uncertainties (phase 1-3).	Context	
[E2] Involve stakeholders in the selection of indicators and weightings for sustainability and circularity MCDA of proposed solutions, based on stakeholders' core values (phase 1-2).	Values	With 3.4
[E3] Baseline sustainability assessment before co-producing new circular business models including ecosystem alignment (phase 1).	Flows	With 3.4

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[E4] Collaboratively develop a "matrix of sustainability assessments" to assess and select aligned options for system change across the macro, meso and micro level (Figure 5), and the focus, level of detail and system boundaries of the assessments (phase 1-3).	Values	With 3.4, 2.1
[E5] Compare and discuss outcomes of circular economy scenarios against shared vision and value proposition, and feedback for process iteration and/or implementation (phase 3).	Business model	With 3.4
[E6] Identify existing circular economy assessment tools to companies and regions.		With 3.4
[E7] Quantified assessment in support of PESTEL before prioritising drivers, barriers and levers for change (phase 1).	Context	With 3.4

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Table 8: Quarterly delivery planning for completed decision-making framework.

		24/1	24/2	24/3	24/4	25/1	25/2	25/3	25/4	26/1	26/2	26/3	26/4
	Design briefs for related WPs / Tasks												
a	**Challenges:** [PM2] Initial process exploration to specify main challenges to resolve and/or targets to achieve, and for whom and why; [P1.1] Challenges / problem specification; [P1.2] Identify solution directions / (formal) targets such as set out in (regional) economic strategy.	UK DK											
b	**Stakeholder:** [PM3] Initial introduction with key initial stakeholders; [S1] Identify stakeholders; [S3] Stakeholder analysis and selection of participation level for stakeholders within the network; [S4] Circularity skills and maturity assessment; [S13] Specification of possible stakeholder groups, e.g. whole system experts, supply chain network, and forum.		EoLO All	EoLO All									
c	**Flows:** [P1.3] Set and review system boundaries; [P1.4] Map material and energy flows; identify potential opportunities for greater circularity; [P1.5] Analyse current wind supply chain and business models including dependencies on other products, value chains and infrastructure; [E3] Baseline sustainability assessment before co-producing new circular business models including ecosystem alignment (phase 1).		EoLO UK DK	EoLO UK DK	EoLO UK DK								
d	**Values:** [S6] Analyse core values (organisational and/or personal); [S2] Coproduce a shared long-term purpose for the co-creation network; [P2.3] Articulate shared whole system / network value proposition based on a collective vision for the regional circular economy and long-term sustainable business opportunities; [E2] Involve stakeholders in the selection of indicators and weightings for sustainability and circularity MCDA of proposed solutions, based on stakeholders' core values (phase 1-2); [E4] Collaboratively develop a "matrix of sustainability assessments" to assess and select aligned options for system change across the macro, meso and micro level (Figure 6), and the focus, level of detail and system boundaries of the assessments (phase 1-3).	EoLO UK DK	EoLO UK DK	EoLO UK DK	EoLO UK DK								
e	**Context:** [S9] Broad input on drivers and barriers for change and possible solutions, with regular expert evaluation; [P1.6] Desk review for initial (incomplete) drivers and barriers, as basis for initial stakeholder interactions; [E1] Proactive assessment of uncertainties (phase 1-3); [P1.7] Context analysis using PESTEL to analyse current state, trends, drivers and barriers in political, environmental, social, technical, economic	EoLO All	EoLO All	EoLO All									

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	and legal domains; including interactions between aspects and between aspects and business models in the mapped supply chains (action 5); [P1.8] Prioritise drivers and barriers across system levels to select levers for change.												
f	**Future:** [P2.1] Building on the context analysis from phase 1, identify two critical system variables per transition phase, and specify plausible narrative context scenarios for the whole system; [P2.2] Specify possible future visions for the regional circular economy within the context scenarios (building on previous step).				UK DK	UK DK	UK DK						
g	**Business model:** [P2.4] Specify circular business models and relations between them to deliver on the shared value proposition, within future regional circular economy visions (building on previous steps). Use tools such as adapted versions of the business model canvas adding a multi-level perspective to include the business ecosystem and wider sustainability context, possibly coproducing initial ideas first with a simplified list of questions (who, what, how and why) to consider a multitude of options, before detailing prioritised circular business model options; [P3.2] Discuss feasibility and sustainability of proposed solutions, including dependencies and alignment in proposed new circular business model ecosystems linking back to the shared value proposition (linking back to phase 2), including the values to partners and stakeholders that are created, destroyed and possibly missed, internal and external barriers to implementation and plans to overcome them (linking back to phase 1), and carry out SWOT and sustainability scans (linking to Evaluate); [E5] Compare and discuss outcomes of circular economy scenarios against shared vision and value proposition, and feedback for process iteration and/or implementation (phase 3).					UK DK	UK DK	UK DK	UK DK				
	Pilot complete framework					ES GE NL	ES GE NL	ES GE NL	ES GE NL	ES GE NL	ES GE NL	ES GE NL	ES GE NL

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