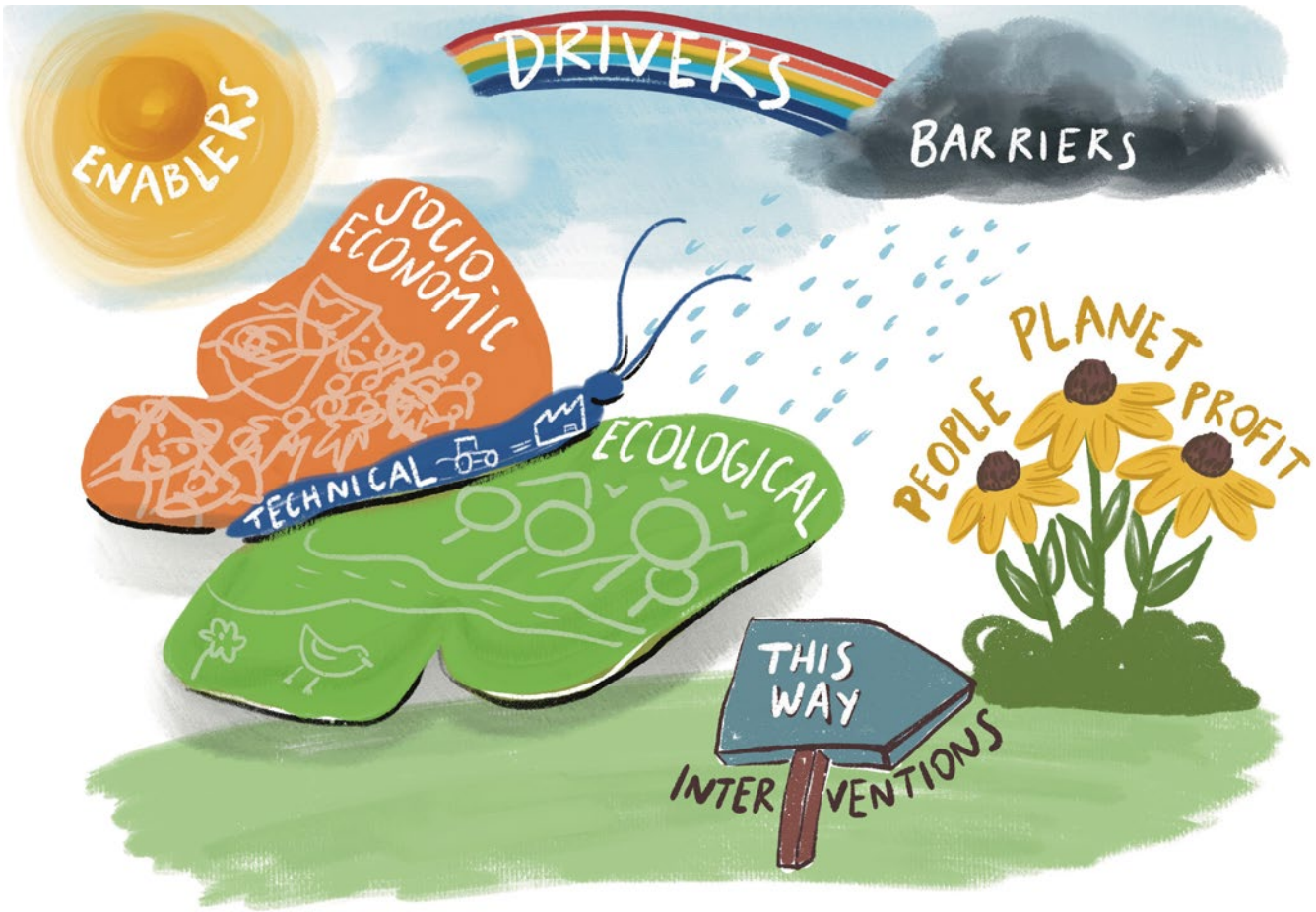
The Butterfly Handbook



Applications of the Integrated Conceptual Framework for Circularity and Climate Neutrality

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DOI: https://doi.org/10.18174/557450

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Introduction and background

This handbook is a practical guide to the application and use of the conceptual framework "the Butterfly Model," which is developed in the Wageningen Research (WR) wide KB programme "Towards a Circular and Climate Neutral Society". The Butterfly Model is developed by a team of circa 10 experienced researchers of widely varying backgrounds and is especially aimed at supporting interdisciplinary understanding in complex projects.

Climate change, resource depletion, global pollution, and species destruction pose major challenges for society. In order to counter these problems, it is widely accepted that we need to organise the economy in a circular and climate-neutral way. As these principles still require a lot of elaboration in many areas, the KB research program on circularity and climate neutrality aims primarily at bringing together multiple disciplines around these societal challenges.

Several lines of research are included in this programme, but many projects face the question of how to approach problems and their solutions in an integrated way. To integrate specific types and topics of research, we developed a conceptual framework, which is extensively described in the accompanying booklet on The Butterfly Model.[1]

This framework is mainly intended for situations of interdisciplinary cooperation in which not only researchers but also policymakers, business strategists, consultants or innovators of different disciplinary backgrounds may work together. In this handbook, the application of the framework in a number of different cases is described to give practical examples that users can refer to for guidance.

Reading Guide

After a short description of the framework, including the application in general, we give several examples of the application of the framework:

- Development of a novel product: development of a new fossil-free plastic material.
- Development of new technology: new plant breeding techniques.
- Design of a new production system: regenerative oceanic farming.
- Review of a business strategy.
- Analysis of a policy: Dutch policy for circular agriculture.
- Development of quantitative models and identification of indicators.

1 *An integrated conceptual framework for the assessment of transitions towards a circular and climate neutral society*; Wageningen University & Research: Wageningen, NL, 2021 (https://doi.org/10.18174/557449); p.20

Conceptual Framework; short introduction

General description

The framework describes how processes in different parts of society and the physical environment are interrelated. This allows us to show the core meaning of the pursuit of a circular and climate-neutral society. In the following, we first describe the model briefly and then use it to define circularity and climate neutrality.

The Butterfly Model

The Butterfly Model (BM) and its assumptions are extensively described in Bos et al. 2020[1]. The following is a short summary. The model consists of the following components:

Technical system: the bioeconomy. The technical system includes all the processes in which people (try to) intervene in the physical world to improve their quality of life.

The technical system is part of the socioeconomic system and the ecological system (see below).

The technical system has a 'day to day' component and a strategic component. The 'day to day' component covers the bioeconomy: the production and use of natural/ biological resources, e.g. mining, agriculture, transport, agro/food/biobased industry, etc.

The strategic component aims at improving the system. This includes the choice of the goals that the improvement tries to reach. These goals are described separately, using a bouquet of flowers as a metaphor (see below). The strategic component also includes the actual intervention in the system (see below).

Ecological system. The ecological system is the physical manifestation of all living and non-living matter and flows of material. A part of the processes in the ecological system take place outside human influence. Others include humans and their interaction with the ecological system through their physical activities. The ecological system contains several 'great cycles' in which key materials (e.g. carbon, oxygen, nitrogen) are transported through the environment. The ecological system delivers several ecosystem services.

Socioeconomic system. The social system includes economic, social and cultural processes from which a particular positive or negative value is attributed to ecological processes.[2] Economic processes include the production, distribution and consumption of scarce goods and services. Social processes relate to the dynamics in human relationships based on power, rules, habits, personal preferences, etc. Cultural processes relate to shifts in values, meanings and opinions.

Drivers. Drivers are powerful processes in the ecological, technical and socioeconomic system, which have such a large influence that they have been taken apart in the model. Drivers can be seen as non-influenceable processes, but exactly which processes are the drivers in a specific situation depends on the scale at which the model is applied. On a global scale, there are generally fewer processes that cannot be influenced and thus can be defined as drivers (e.g. the oil price). On a local scale, oil price can also be an important driver. Still, for instance, national policies can also act as a non-influenceable driver.

Goals. Goals are concretisations of social values. They determine how changes in the technical, ecological and social system are assessed. Assessing different choices for interventions in terms of the goals helps to determine the more optimal interventions/developments. Goals can be expressed in different ways and on different levels, depending on the scale at which this model is applied. Values behind goals often differ fundamentally but the idea to integrate people, planet and profit goals is widely accepted and relevant for circularity and climate neutrality.

2 The corona virus entering my body is part of the ecological aspect system, my displeasure part of the socio/economic/ cultural aspect system.

Interventions. Interventions are the strategic actions or processes that are aimed at changing the system. In theory, there are several leverage points to change systems, ranging from new techniques to new values. Here we distinguish interventions by developing new technology, interventions by new strategies of companies, interventions through new legislation and government policies, interventions by citizens' initiatives, interventions aimed at a higher level of competencies and knowledge.

In the figure below, these components are depicted by the metaphor of a butterfly.[3] The wings represent the ecological and social system and the body the technical system. The drivers, which are depicted separately, are represented by the sun, the wind and the clouds. They can blow the butterfly towards the goals or obstruct her. The butterfly is flying towards a bouquet of flowers, i.e. the goals, partly directed by a sign-post which stands for the interventions.

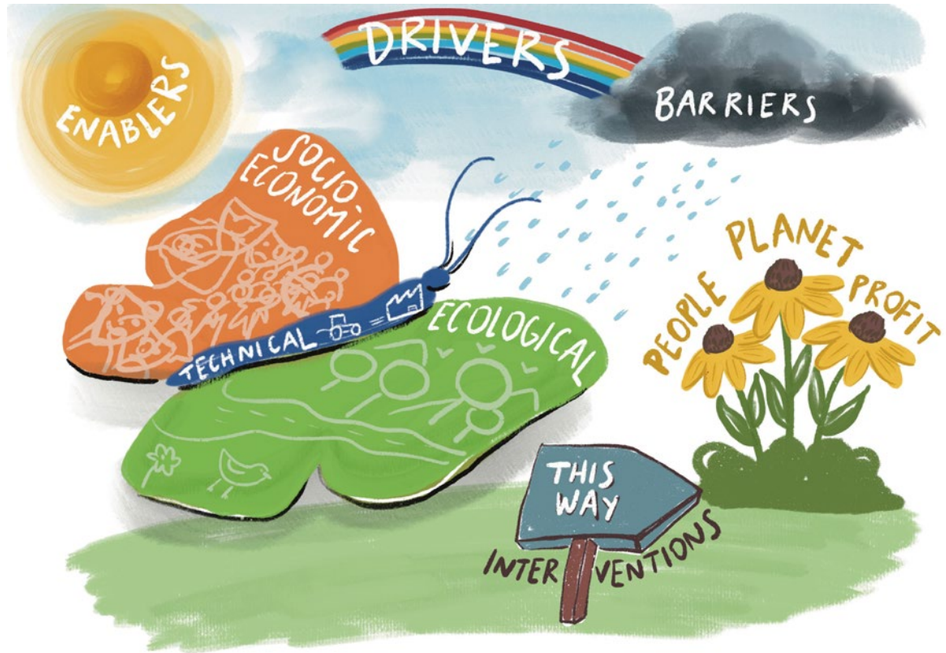

Figure 1 The full framework

3 Butterflies are sometimes seen as the symbol of transformation. The butterfly is inspired by the Ellen MacArthur foundation butterfly diagram (http://www.ellenmacarthurfoundation.org).

Definition of Circularity and Climate Neutrality

What are circularity and climate neutrality in terms of this framework?

Circularity is the reason to set up the technical system in such a way that the input of raw materials and the output of waste is minimal, through new technology, new products or an alternative organisation of the system. In terms of the framework, this is related to the flows between the technical system and the ecological system. Also, the socioeconomic system is involved because a change of behaviour is an integral part of the pathway to circularity. The underlying purpose of circularity is to diminish the use of non-renewable resources, to reduce geopolitical dependence, and above all, to prevent waste flows that affect the functioning of the ecological system. In the framework, these goals are included in the 'flowers'.

The concept of circularity implies a specific strategy to reach the preferred state of the technical system: shaping the streams of materials in circles to have minimum output and input. With this emphasis on means, the circularity concept differs from the climate neutrality concept.

Climate neutrality relates to a state where the impacts on the system by emissions of greenhouse gasses and use of fossil fuels are restricted to a minimum. The underlying aim is to prevent a negative impact on the functioning of the world ecological system as a condition for human existence. An overview is given in Table 1.

Table 1. Intervention logic behind Circularity and Climate neutrality

	Circularity	Climate neutrality
Goals for people planet and profit	Sustainability, including no degradation of the functioning of the ecological system as a condition for human existence	
Preferred state of the system	Minimal use of resources, minimal waste	Minimal greenhouse gas emission
Strategy to achieve this	Refuse, Rethink, Reduce, Re-use, Repair, Refurbish, Remanufacture, Recycle, Recover (9R framework)	Several socio-technical strategies (reduce the use of fossil fuels, enhancing sinks, etc.), but contrary to circularity, the concept does not imply a specific strategy.

How to use the framework

In general, the framework can be used in two ways: as a checklist or as a map.

Use of the framework as a checklist

The following steps can be followed to use the framework as a checklist.

- The use of the framework starts with choosing the scale of the system boundaries and the scale of the system. This choice also determines the difference between the uninfluenceable processes (drivers: enablers and barriers) and the influenceable processes (interventions).
- Then the framework's components can be used to formulate one or more questions about aspects that could play a role in the system. These questions relate to the (problems in) the state of the system, goals (aimed at the preferred state of the system), drivers, interventions, impacts (on the system). These questions are described in general terms in table 2.
- Once the questions have been prepared for all components, they will be answered in a subsequent round. First, the questions can be used to formulate the requirements for the object (machine, product, landscape, policy) to be designed.
- Subsequently, the possible effects of prototypes or concepts can be assessed on the basis of questions from the framework. This answer can be used to improve the technique, product, or strategy depending on the subject to which the framework is applied.

This use as a checklist doesn't have a fixed starting point. In many cases, it is obvious to start with the problems in the system and the goals. Still, in other cases, it can be more appropriate to start with the drivers or with the interventions.

Table 2. Framework questions (in general)

BM aspect	Questions	
General: System Boundaries / Scale / Scope	1	Is the scope in terms of system boundaries of the theme well defined?
Goals	2.1	Are problems / challenges clearly defined?
	2.2	Which clear and ambitious targets are set? Are they complete?
Drivers	3.1	What driving forces are involved?
	3.2	Which drivers are enablers and which are barriers?
Interventions	4.1	Are relevant stakeholders identified and engaged?
	4.2	Are scenarios used to create an image of autonomous development, intended change, and one's own role in it?
	4.3	Are adequate interventions defined?
	4.4	What is the potential impact of these interventions?
Technical System	5.1	What is the state-of-the-art of technology, what can/needs to be changed or improved?
	5.2	What is the role and impact of the technology, process or system to be developed on the broader technical system?
Ecological system	6.1	What is the expected impact on ecosystem components?
	6.2	Are there quantifiable effects on ecosystem services?
Socio economic System	7.1	What are impacts on social practices, (power) relationships between different social groups, current institutions?
	7.2	Is the development/strategy economically viable?

Use of the framework as a map

The framework can also be used as a 'map'. For instance, when used for the development of a knowledge agenda. To develop a knowledge agenda, one of the questions is how much research has already been done. The amount of research and its main content can then be 'plotted' on the butterfly to see which aspect of the system is most extensively researched so far and which aspect has had little attention. In this way, the framework reveals knowledge gaps.

Likewise, the Butterfly Model can be connected to relevant indicators that may monitor the transition towards circularity itself and/or its impacts on higher-level societal objectives, such as climate neutrality. Some of these indicators integrate different aspects in the Butterfly and may also incorporate effects over different scales.

Examples

In the following chapters, we give some examples to explain the applicability of the framework in various situations and that can serve as a more practical guideline for the assessment. These examples show that the framework is not an algorithm but a reminder that can lead to different, case dependent questions. The use of the framework in various situations is expected to lead to insights that otherwise might have been missed and thus can help define relevant actions.

Product development

Development of fossil-free plastic material for climate and circularity in feedstock use

Development of a new production process for a chemical building block (such as FDCA), development of a polymerisation process for the bioplastic that can be made from it, and optimising the properties (the combination of degradability and mechanical properties) of the polymer by changing the molecular structure. The project is a collaboration between WUR, an agro-company (starch and sugar) and a chemical company specialised in functional performance polymers. Analysis is based on the perspective of the three collaborating parties.

Learnings

Especially the difference between direct and indirect effects upstream and downstream, inside and outside the production chain, generally gets less attention. Furthermore, the question about which stakeholders are needed and what we hope they will do is generally not asked in the R&D phase. A dialogue with the public might help steer our actions to prevent unwanted direct and indirect effects and improve the technology's uptake.

BM aspect	Questions
General: system boundaries/scale	What are the system boundaries, one company, a production chain of companies or broader?
Technical system.	What is the state-of-the-art, what technology is used for competitive products, what can we learn from that?
	Are alternative circular routes patented? Is there a way to work around them?
	What new catalysts/micro-organisms need to be developed, can an environmentally friendly solution direction be developed?
	Considering the expected process scheme and conditions (e.g. heat transfer, reaction time, reaction vessel design, recycling of residual flows), what would be an optimal scale, does this fit with expected demand, and what would be the investment needed?
	What properties need to be optimised further to make the product more desirable? What does this mean for the molecular design, process, factory design, investment
	Can we do this alone, or do we need to collaborate? If so, what kind of partners do we need (☐ link to actors/actions)
	What /who are we going to influence upstream/downstream, direct effects and indirect effects.
Ecological system	What inputs will we need for the new process?
	Which of the inputs are potentially scarce? – Where will they be produced, and what relations exist (competition)
	What are the hotspots in the new process considering energy and resource use? Can they be optimized? What other resources are available (pref. locally)
	What will be the expected GHG footprint (☐ link to assessment, i.e. the flowers), and which routes are available to minimize this?
	Where would the foreseen production plant be located, what does this imply for transport of inputs and products, and local environmental impact?

BM aspect	Questions
Socioeconomic system	From a techno-economic evaluation, what will be the expected cost-prize of the new polymer and what needs to be done to make it competitive compared to present materials? How can the added value compared to the original, including externalities, be monetarized without making the product uncompetitive?
	For which products/market players can the new product have desirable advantages? Is circularity the reason for that? How to reach them?
	What kind of labelling could help the introduction? What information do consumers need?
	To what extent are vested interests, elements of the political and societal discourse (One-issue NGOs, uncertain/doubting Ministries, unclear policy goals), problems with trust or otherwise, expected to restrict the chances of the new product/technology?
	What is the possible effect of the new foreseen factory (once the development is ready) on other industries, employment, education? (indirect effects)
	Is there opposition to be expected from local citizens towards the production site? On what basis? Can it be avoided, and if so, how?
Drivers	What is the investment climate like in the country we want to build?
	When will GHG emissions finally be taxed properly, and when will the support for the fossil industry finally cease to exist?
	What is the oil price expected to do, considering for instance the electrification of transport, what does this mean for competing processes based on fossil feedstock?
	How will demographics change, and how will that influence demand?
	What trade agreements are expected to be in place in the coming two decades?
	How will climate change influence the availability of feedstock?
Interventions	What actions do we need from our customers, how much effort will be required to convince them, will they have additional costs or will they profit from our development, what actions can we reasonably expect, what do we need to do ourselves?
	What other parties would be needed to help introduce this more environmentally friendly product? These could be other stakeholders in the production chain, retailers, journalists, standardisation institutes, civil servants and politicians. What knowledge do they need to take appropriate action? What can we do to support this.
Goals	What effects do we need to see in order to support or decline the selected activity?
	What is the effect on the human wellbeing of the new business model/technology?
	What does the (ex-ante) LCA of the new technology look like, how can the environmental impact be further reduced? What is the carbon footprint, also compared to the present state-of-the-art of technology?
	How does the new technology compare (in terms of PPP aspects) to existing technologies?
	What can be the effect on employment, human health (e.g. particulate matter)?
	What is the effect on non-renewable inputs
	Which aspects of circularity are improved, does the new technology need less raw material than the present SotA?

Implementation of new technology

New plant breeding techniques (NPBT) for circular agriculture to adapt to or reduce climate change

Plant Breeding wants to contribute to new sustainable plant production systems, adapted to climate change or reducing climate change. The idea of breeding for sustainable and circular production systems fits with these higher objectives. New Plant Breeding Techniques (NPBT) can play a role to accelerate the expected outcomes, but are they available, accepted and viable? Do they work? How and where, and what exactly can be expected from them?

Learnings

New Plant Breeding Techniques contribute to integrated production systems that are nature inclusive and are based on more resilient crops that require fewer chemical inputs at the cost of productivity rates, which result in fewer emissions to the environment per unit. The conceptual framework (butterfly) facilitates the reflection on this possible solution in all aspects. It introduces not only technological but also socioeconomic questions which are easily overlooked. This will increase the level of awareness of scientific developers and eventually create better solutions.

BM aspect	Questions
General: system boundaries/scale	What are the system boundaries, company level, national or other?
Technical system.	Which questions from the 9R framework can be applied here? • The useful application of materials (recover and recycle), • Extend the lifespan of the product and its parts (repurpose, remanufacture, refurbish, repair, reuse), and • Smarter product use and manufacture (reduce, rethink, refuse)
	Are there alternative and renewable resources? Are they scarce? Is there (local) competition?
	What local waste streams can be reused, recycled, upcycled, etc.
	What available processing industries should be connected or created for whole crop and waste stream usage?
	What NPB techniques at what scale, by which actor and at which location can be applied?
	What NPB techniques can/should be developed/researched, and for which plant or production system characteristics should be bred?
	At what scale do NPBT create (monetary, environmental, social) value, and for whom? Can it be integrated to a higher level?
	How to create more impact with new NPBT?
Ecological system	Do NPBT create sustainable circular production systems that are adapted to or reduce climate change (living up to the ambitions)? Or should the process be further optimized?
	What (new) and how many materials or ecosystem services are used from the Ecological system?
	How does NPBT affect material flows if it is used for plant production system breeding instead of for individual plant breeding?
	At what scale can loops be closed?
	What trade-offs take place? E.g. in land use?

BM aspect	Questions
Socioeconomic system	How does policy, society, science feel about NPBT? What are their drivers?
	How are social-relations, economic-money/assets, cultural-norms/values affected?
	How should regulations for NPBT be changed?
	What value will be created with NPBT? For whom?
Driving forces	Will consumers accept food from NPBT? What would be necessary for that? What is the social discourse?
	How does consumer behaviour influence processing industries and investments?
	What driving forces would enable/limit NPBT: what is the scientific level, what are NPBT policies, NPBT regulations, what is the effect of population growth or increased food demand?
	What is the need for (quality) food (demographics) and biobased products, at what scale
Interventions	Which NPBT? How to intervene with NPBT? Where to intervene with NPBT? Which effect does the intervention provoke?
Goals	Are we doing it in a circular way?
	What impact variables are required at what scale? Do they differ per location/cropping system?
	How are the environment, human health, safety, welfare, and economy affected by NPBT? At what scale?
	What are trade-offs?

Designing a production system

Regenerative Ocean Farming

Regenerative ocean polyculture farming system (see, e.g. https://www.greenwave.org/) grows a mixture of seaweeds and shellfish that require low non-renewable inputs – making it the most sustainable form of food production on the planet – while sequestering carbon and (re)building artificial reefs. Other than Integrated Multi-Trophic Aquaculture (IMTA) strategies, which are often based on fish farming nutrient inputs, these systems thrive from the natural (or anthropogenic) inputs. Since the farms exploit the water column vertically below the surface, they produce high yields with a relatively small spatial footprint. The technique can be considered a form of reforestation, capturing blue carbon, phosphorus and nitrogen, and commercial farming to grow seaweed and shellfish used for food, fertiliser, animal feed, biostimulants, bio-based products (plastics), and more. In addition, it may help to restore ocean ecosystems by providing artificial reefs.

Learnings

The primary aim of this initiative is to increase/optimise sustainable marine food production while striving to meet our renewable energy goals. From applying this conceptual framework, we learned that this requires analysis of integrated ecosystem-based management (across sectors), multi-use techniques and a consideration of circular food production at larger scales (i.e. integration across marine-terrestrial).

BM aspect	Questions
General: system boundaries/scale	Should the whole marine ecosystem be considered?
Technical system	What is state-of-the-art? What technology is used for competitive products, what can we learn from that?
	What is the optimal balance between seaweed and shellfish production?
	Which (local) waste streams (nutrient surpluses) can be exploited? Is it possible to exploit nutrient surplus coming from land-based agriculture through run-off?
	Which products can be used in different applications, like food, feed, fertilizer, bio-based products, cosmetics, etc.?
	What available processing industries should be connected or created for marketable products and waste stream usage?
	At which scale and by whom can the system be applied?
	Does the size of the system fit with expected demand?
	At what scale does the system create (monetary, environmental, social) value and for whom?
	What is the capacity of the ecological system to sustain this activity, and how does this affect other marine activities? Will the system deplete or pollute the ecological system or solve problems for the ecological system, like consuming nutrient surpluses and improving water quality?
	What other impacts (e.g. physical or biological and direct or indirect) on the ecosystem and biodiversity in general?
Ecological system	At what scale can loops be closed? Within the marine system and/or in a marine-terrestrial system?
	Are there accumulation effects of hazardous substances?
	How will the expected products be valued in terms of their contribution to human welfare/ wellbeing?

BM aspect	Questions
Socioeconomic system	How can the impacts on the ecological system be translated into impacts on human wellbeing?
	What kind of labelling could help the introduction? What information is needed?
	To what extent are vested interests, elements of the political and societal discourse (One-issue NGOs, uncertain/doubting ministries, unclear policy goals), problems with trust or otherwise, expected to restrict the introduction of the new system?
	What is the possible effect of the new system (once the development is ready) on other industries, employment, education? (indirect effects)
	What is the investment climate like?
	Will GHG emissions be taxed properly? And what about nitrogen and biodiversity?
Drivers	How will demographics change, and how will that influence demand?
	How will (worldwide) consumption patterns of 'seafood' change?
	What trade agreements are expected to be in place in the coming two decades?
	What is needed to develop and finally implement this system technically? Which knowledge is lacking? Are there any regulations to be adapted?
	What other parties would be needed to help introduce this more environmentally friendly system? This could be other stakeholders in the production chain, retailers, journalists, standardization institutes, civil servants and politicians. What knowledge do they need to take appropriate action?
Interventions	How much carbon is sequestered by the system?
	How much nitrogen is captured?
Goals	Can we include the effect on biodiversity?
	Which aspects of circularity do we need to improve?
	What should be the effect on employment, human health (through dietary changes), food safety, or other human wellbeing indicators?
	To what extent does circularity need to contribute to achieving SDGs, and how will this be valued?

Reviewing a Business Strategy

Van Oord Dredging and Marine Contractors, a company with several offshore activities, like dredging and wind parks, has developed a sustainability strategy for their supply chain, which will be used in procurement procedures. In the strategy, five themes are distinguished: Transparency; Reduce greenhouse gas emissions; Reduce air pollution; Reduce single-use plastics; Stimulate circular business models. Wageningen Research was asked to assess this framework for which the Butterfly Model was used.

Learnings

The questions have contributed to the next step of the strategy by drawing attention to the indirect effects of the strategy and to the importance of considering the impacts of the strategy for the entire chain rather than just for the supply chain.

BM aspect	Questions
General: system boundaries/scale	What is the added value of the focus on the supply chain?
Goals	Do the goals of the Sustainability Strategy meet people, profit and planet targets?
Drivers	Which driving forces are implied in the rationale? What is their impact on the company's activities and the supply chain?
Interventions	Will the strategy be discussed with the stakeholders in the supply chain?
	Are the interventions based on an image of the wider environment and the role of the company in it?
	The strategy is worked out in a concrete roadmap. Is this enough to meet the targets on the five themes?
Technical system	What are the role and the impact of the supply chain in the environmental impact of the whole chain (suppliers + Van Oord + customers)
Ecological system	What is the expected impact on water, air, land?
	What are the trade-offs on environmental components which are not mentioned in the strategy, like biodiversity and land use?
Socioeconomic system	Though the strategy is not aimed at socioeconomic goals, is it nevertheless possible to identify societal impacts?

Analysis of a new Policy

Dutch policy on circular agriculture (kringlooplandbouw)

The Dutch government of LNV will work together with all farm and food industry stakeholders to create the necessary conditions for the transition to circular agriculture. The government aims to create the conditions that provide a rationale for cycling energy and nutrients on the smallest scale possible, with minimal avoidable losses. The government's vision is not meant to be taken as a blueprint but as a guide for collaboration to find new sustainable ways of producing food. The vision aims to build on the high degree of innovation and orientation on international markets in the Dutch farm and food industry. According to this new policy, the Netherlands will remain a food exporting country but based on higher value-added production.

Learnings

One of the findings is that for policies analysis, it is relevant to distinguish requirements from the ecological and socioeconomic systems before formulating goals and impacts on these systems. Furthermore, the questions from the model show the importance of paying attention to:

- drivers on which the policy has little influence;
- consequences of the difference between a policy on a national scale and the food system that is largely organised at a global level.

BM aspect	Questions
General: system boundaries/scale	What are the boundaries of the system which is addressed? Does this policy include the whole food system, including farmers, food processors, retailers, consumers, but also the environment and animal welfare? What are the consequences of the scale difference between this national policy and the international scale of the current food system?
Goals	*Inclusiveness*. Does the policy objectives include people, planet and profit aspects?
	Consistency. To what extent are the goals consistent with long term welfare optimization?
	Rationale. Which problems are mainly addressed? Are they expressed in certain indicators: societal as well as environmental ones? How are circularity and climate neutrality perceived?
	Alignment. Do they refer to other national or international policies? Are they aligned with other policies?
Driving forces	What are the main forces that determine the development of the relevant social-economic and ecological environment? Are they identified in the Circular Agriculture Policy?
	Which drivers increase or reduce the opportunities for the policy?
	How can this be responded from the Dutch Circular Agriculture -policy?
Technical System	Is it clear to what extent the intended objectives and interventions are already technically, industrially, organisationally and structurally possible? Does the policy require different technology, other business systems, or another organization of the technical system?
	What is the list of opportunities for technologies (including behavioural changes) that may solve some of the externalities? What is the technology readiness of these technologies?
	What are the potentials of these technologies with respect to environmental, social and economic aspects from an LCA perspective?
	Is there already an idea about what processes should change and to what goals innovations should contribute?
	What are potential barriers and enabling factors for implementing these new technologies?
Ecological system: requirements	What are the boundaries of the ecological system that are at hazard, and what is the role of the agricultural system in this?
	What is the carrying capacity of different types of ecosystems for different types of agriculture?
	How does the agricultural and food system influence the circular flow of materials? Where are the main leakages in the system?
	What are the dynamics of the system that may have adverse effects on future agricultural production?
Socioeconomic system: requirements	Does the policy require unusual or new requirements on the economic system: the way in which the market is organised, price formation, the economic structure, etc.
	Social system: practices and habits with regard to food consumption; actors rights. To what extent will the policies get problems with interest groups and vested interests, including local interests?
	Cultural system: are standards adhered to regarding animal control, value to nature, food values and living style and values of people?
Interventions	What are the planned interventions to realize the goals of the project or policy?
	What is the character of the interventions: legislative, economic, communicative, planning and programming, educational, innovation, etc.? What are the instruments for implementing the Circular Agricultural policy?
	To what extent are the interventions related to the fundamental problems identified in the ecological, technical and socioeconomic system?
	To what extent do the interventions take into account the driving forces that cannot be influenced?
	To what extent can the policies be expected to solve the problems that have been diagnosed?
	What is the vision of pressure groups and political parties on these interventions?
	Was the process of choice of these interventions inclusive; is it tried to form a 'coalition of the willing'?
Consequences for the ecological system	What is the impact of the interventions on the components of the ecosystem: soil, water, air, vegetation for each region? What is the effect on the accumulation of contaminants? Wat are the ecological trade-offs and impacts on the diversity of ecosystems?
	What do these impacts mean for the different ecosystem services per region?
	What are the indirect effects on other parts of the world? For example, if less feed is bought from Brazil the consequences of emissions in Brazil should be included, but if more land is used in the Netherlands because of a less intensive agriculture or producing more feed locally, the consequences of this shift in land use in the Netherlands should also be included in the policy rationale.
Consequences for the social economic system	What are the societal costs and benefits of the policy on circular agriculture?
	Who benefits and who has costs?
	Does the change result in fundamental changes in the social (practices, routines, habits), economic (business-models, economic structure) and/or cultural system (perspectives, meanings, norms)?

Development of quantitative models and identification of indicators

Models can be used in the heart of the framework within the butterfly. Models try to represent part of the bio-economy and can, for example, focus on the technical, ecological or socioeconomic system or a combination of systems. Models can therefore be located or depicted within the drawing of the butterfly. For example, a purely ecological model can be located within the ecological wing of the butterfly and a technical model within the body of the butterfly. In this way, one gets an overview of which part of the problem is covered with a specific model and how the use and possible linking of various models can give a broader coverage of the problem and a more holistic view of the butterfly. To really let the butterfly fly, a bioeconomy should represent the technical, ecological and socioeconomic systems in a connected way. Models are helpful as they represent part of the system (in a qualitative or quantitative way) and are able to quantify the impact of drivers and interventions they cover within their model on the goals they are able to cover within their model. Indicators or indicator models measure the performance of the system with regard to the goals in an ex-post or ex-ante manner. The indicators are represented within the flowers of the drawing and give direction to the system. They measure and can be located within the social, economic or environmental dimensions of sustainability. If indicators signal that a goal is not reached, additional interventions are needed.

Learnings

One of the findings is that it is important to see where your model or indicator fits in the overall framework of the bioeconomy. Which are your strengths and weaknesses? How can you obtain fuller coverage by cooperating or linking models and indicators? Furthermore, the Butterfly Model shows the importance of paying attention to:

- Getting to a holistic picture of the problem at hand or future;
- Knowing your model or indicator strengths and limitations and, therefore, the potential use of your model.

BM aspect	Questions
General: system boundaries/scale	What are the boundaries of the system which has to be modelled? addressed? Is the focus on ecological, technical or socio-economic issues. Should the model include the whole food system, including farmers, food processors, retailers, consumers, but also the environment and animal welfare? Which drivers or interventions need to be represented within the system? What scale is needed?
Goals	*Inclusiveness*. Does your model or indicator model represents people, planet and profit aspects?
	Consistency. To what extent are the goals consistent with long term welfare optimisation?
	Rationale. Which problems can your (indicator) model address? Are they expressed in specific indicators: societal as well as environmental ones? How are circularity and climate neutrality treated in your model?
	Alignment. Does your (indicator) model cover a broader range of indicators, or is alignment with other models and indicators needed to get a more holistic picture.
Driving forces	What are the main forces that determine the development of the relevant social-economic and ecological environment in your model? What are the exogenous drivers in the system? For example, are climate change, technological change, consumer preferences, oil prices, wages, etc., endogenous or exogenous for your system.
	What is the mechanism within your model how a driver increases or reduces the opportunities for the policy?
Technical System	Which aspects of the technical system are represented by your model?
	Does your model represent different technology, other business systems, or another organization of the technical system?
	What are the potentials of these technologies with respect to environmental, social and economic aspects from an LCA perspective?
	Which processes can change, and what innovations can be represented or generated within your model?
	What are potential barriers and enabling factors for implementing these new technologies included in your model?
Ecological system: requirements	What are the boundaries of the ecological system within your model that are at hazard, and what is the role of the bioeconomy in this?
	What is the carrying capacity of different types of ecosystems for different types of the bioeconomy within your system?
	How does the bioeconomy influence the circular flow of materials? Where are the main leakages in the system?
	What are the dynamics of the system that may have adverse effects on future biomass production?
Socioeconomic system: requirements	Which parts of the economic system are represented within your model. Which economic policies are included within your model
	Is your model able to deal with whether a policy or measure requires unusual or new requirements on the economic system: the way in which the market is organised, price formation, the economic structure, etc.?
	Social system: Is your model able to deal with practices and habits with regard to food consumption; actors rights. Can your model cover whether the policies get problems with interest groups and vested interests, including local interests?
	Cultural system: Can your model deal with standards regarding animal control, value to nature, food values and living style and values of people.
Interventions	What are the interventions your model is able to represent to realise the goals of the project or policy?
	What is the character of these represented interventions: legislative, economic, communicative, planning and programming, educational, innovation, etc.?
	What are the instruments for implementing the CA policy or a climate policy?
	Is your model able to include circular technologies, residues, waste, recycling, diet shifts, etc., in case of a circularly oriented policy?
	Is your model able to represent mitigation policies such as technical mitigation measures, CO_2 taxes, innovation subsidies, knowledge investments, negative emission technologies (e.g. BECCS, CCS, afforestation, bioenergy)?
	To what extent are the interventions related to the fundamental problems identified in the ecological, technical and socioeconomic system?
	To what extent do the interventions take into account the driving forces that cannot be influenced? To what extent can the model be expected to give insights into the problems for which it is developed? How sensitive are the outcomes on indicators for policy and driver changes?
Consequences for the ecological system	Does your (model) indicator cover ecological aspects that provide insight in the ecological or environmental oriented policy goals?
	Which impacts does your (model) indicator cover regarding the interventions on the components of the ecosystem: soil, water, air, vegetation for each region? What are the ecological trade-offs and the diversity of ecosystems?
	What do these impacts mean within your (model) indicator for the different ecosystem services per region?
	What is the impact of the chosen system aggregation level of your indicator or model indicator in terms of, e.g. (i) commodity coverage, (ii) regional coverage and (iii) time coverage? What are the indirect effects on other parts of the world?
Consequences for the socioeconomic system	Does your (model) indicator cover socioeconomic aspects that provide insight into the socioeconomic oriented policy goals?
	Which impacts does your (model) indicator cover regarding the interventions on the components of the socio-economic: GDP, value added, international trade, employment, wages, interest rates, terms of trade, welfare, factor and\ or commodity prices? Wat are the socioeconomic trade-offs and the diversity of the population (distributional issues)?

Conclusions

The conceptual Butterfly Model presented here is a general system description that can be converted into a checklist that can be used in different situations. This report elaborates on several different applications, from product development to policy analysis. In general, we learn from these applications that the Butterfly Model contributes to a broader, inter-disciplinary, and more integral view of the project environment or the problem at hand.

More specifically, the model highlights the following points of attention:

- Identification of external drivers (depending on the scale at which the project is focused) and their positive or negative contribution to the project;
- Identification of possible impacts higher and lower in the production chain;
- Consideration of circular food and non-food production at larger scales;
- Awareness of the importance of engaging stakeholders.

We recommend starting projects in the field of circularity and climate neutrality with a scan of the project environment, for which the Butterfly Model can be used.