NL

Netherlands

CIRCULAR AGRIFOOD & BIOMASS

FOOD & MATERIALS FOR A SUSTAINABLE FUTURE

Content

Chapter 1 8

Turning Global Agrifood Challenges Into Opportunities 8

1.1 Global agrifood challenges 8
1.2 Circular agriculture and biomass solutions 9
1.3 Circular agriculture in the Netherlands 11

Chapter 2 13

AgriFood from design to solutions 13

2.1 Circular food systems 13
2.2 Valorisation of residual and side streams 17
2.3 Food production methods 19

Chapter 3 28

Applications of biomass 28

3.1 Bioeconomy 28
3.2 Valorisation for replacement of raw materials 29
3.3 Biomass processed bioproducts 30

Chapter 4 40

Future visions 40

Future vision 1 Re-rooting the Dutch Food System: from more to better 40
Future Vision 2 Showing leadership in orchestrating the circular agrifood systems change journey in practice 42
Future Vision 3 Rabobank Circular Economy in Agrifood, a bankers perspective 43
Future Vision 4 The Dutch Association of Young Farmers 44
Future Vision 5 The Dutch Food System in 2040, a narrative. 45
Future Vision 6 Biomaterials: a blind spot in the transition to a fossil-free economy 46

Chapter 5 48

A Pathway to a circular future 48

References 51
Colophon 53

Preface

Innovation and cooperation is at the heart of Dutch farming, horticulture and fisheries, helping the Netherlands produce high-quality products, knowledge and technology. In light of current events, the crises our planet is facing and the state of our natural world have underlined the need for a circular transition in the agrifood sector. We need to take care of the health of our soil, air and water in an integral way, and make decisions based on stewardship. To maintain our leading position and to support the world into the future, the Netherlands needs to further embrace circular and sustainable agriculture, together with all the actors involved. Our position in the international agrifood market means we have a key role to play in the transition of the global food system towards a circular and sustainable agriculture.
Recognising this, in its vision entitled 'Agriculture, nature and food: valuable and connected', the Dutch government has presented its ambition to be a global leader in circular agriculture by 2030. At the same time, the Dutch government cannot achieve this alone. Through public-private networks and by working together with our highly innovative agricultural sector and with knowledge institutions and civil society organisations in the Netherlands and abroad, we will be able to face these challenges and make the transition to a circular food system.

It is important that we make this transition as swiftly as possible. Whenever food is wasted, so too are valuable resources like energy, soil and water. A circular agricultural system will close the loop on the linear supply chain and help preserve these resources.
The European Union has also launched the European Green Deal, which aligns well with the Netherlands' ambitions. This strategy aims to create the sustainable future we envision. Another important initiative was the United Nations Food Systems Summit in 2021.
During the summit the Netherlands presented its 'Past the date?' project, which helps consumers identify best before dates more easily. As you can read in this brochure, preventing food losses and food waste is only one of several ways to achieve circular agriculture.
By reusing and recycling as well as by redesigning the food systems, we can push back against losses, waste and excess, and create a sustainable and resource-efficient future.

This is highly necessary, because ecological and environmental issues are growing more urgent by the day. The ecological capacity of the Earth has already been exceeded. The Netherlands has the ambition to be climate-neutral, fossil free and circular by 2050.
The Dutch government regards the use of sustainably sourced biomass as essential to reach these goals as this brochure will illustrated. A growing population and growing prosperity only add to the increasing demand for more sustainably sourced biomass. This reaffirms the pressing need for use of renewable natural capital, a focus on minimising losses and waste, working with nature rather than against it, and the development of new bio-based raw materials.

The challenges we are facing today affect us all, and transitioning towards circular agriculture can be the key to solving them together. We are all working to become smarter about our resource use, and to become more efficient. With your support, creativity and innovative ideas, we can create a circular agricultural system together, for a sustainable future.

I hope this brochure will inspire you, and serve as a stepping stone to a circular transition in the agrifood sector.

Vivianne Heijnen
Minister for the Environment

Piet Adema
Minister of Agriculture, Nature and Food Quality

Introduction and context

This brochure shares the latest best practices from entrepreneurs and insights and lessons learnt from public authorities and knowledge institutes from the Netherlands on a circular transition of the agrifood and biomass sector.

Dutch farming, horticulture and fishing sectors are renowned worldwide for producing good-quality food that is safe and affordable. We want to strengthen the link between nature and agriculture and improve farmers' economic situation in the world. Our goals is to provide healthy, safe and tasty food for 9 billion people within the boundaries of the planet and that can only happen if we work together at the international level.

The authors, a public-private and knowledge coalition consisting of Holland Circular Hotspot, The Netherlands Enterprise Agency, Food Valley, The Netherlands Ministry of Agriculture, Nature and Food Quality, the Ministry Infrastructure and Watermanagement, and Research and the Topsector Agri & Food want to stimulate cooperation at the international level and exploit potential synergies and partnerships between government, knowledge institutions, and businesses.

Efficiency and innovation are key to the Dutch agricultural sector. The Netherlands is one of the world's largest agricultural producers despite its small land surface and high population density. But there is no other way than to convert its efficient conventional model of food production into circular agriculture. The Dutch agricultural sector is characterized by strong export driven agenda and close cooperation with business, governments and renowned educational and research institutions , which ensures innovations are relevant and widely adopted at the farm and agri-food firm levels.

In this publication we point out that the current global agrifood challenges offer unique innovation opportunities , we present the case of The Netherlands and its vision on transitioning to a circular agriculture system (chapter 1). Chapter 2 and 3 show the solutions landscape. Chapter 2 has the focus on the production side of the food system and implementation in the agrifood sector. Whereas chapter 3 shows the opportunities for biomass application in bioproducts and materials. Throughout the brochure we provide inspiration with clear examples of best practices from the beginning to the end of the value chain. We share a number of Future Visions in chapter 4 and aim to stimulate debate by presenting an action agenda for various stakeholders in chapter 5. By publishing this brochure, the authors aim not lecture but share views as well as stimulate debate and action. By sharing lessons internationally, others can accelerate development in a sensible direction and avoid pitfalls. We invite you to read this brochure and work with us and together solve one of the biggest societal challenges of this century.

Turning Global Agrifood Challenges Into Opportunities

1.1 Global agrifood challenges

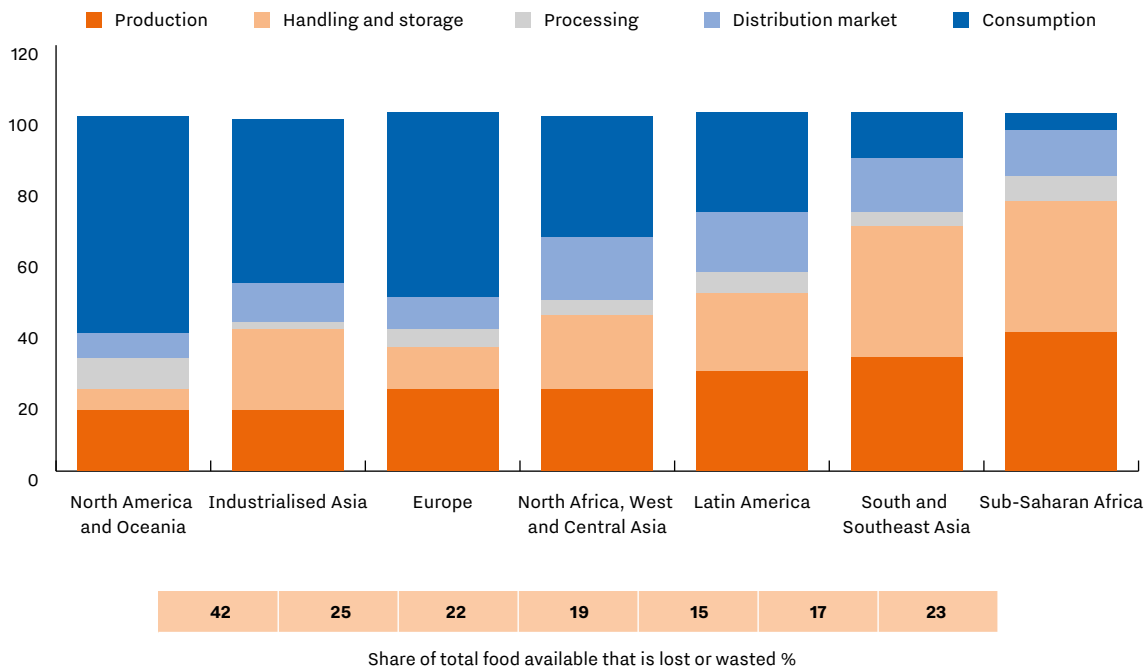
In the coming decades, the global agricultural system must find ways to meet pressing, but sometimes competing needs. This offers great challenges but also immense opportunities. Farmers are essential to keep providing enough food for a population that is expected to reach nearly 10 billion people by 2050. Employing around 2 billion people today, agriculture continues to be an engine of inclusive economic and social development that contributes to poverty reduction. As the global population grows and incomes rise across the developing world, overall food demand is on course to increase by more than 50 percent by 2050. Despite this, even today hundreds of millions of people remain undernourished as local agricultural systems fail to provide enough nutritious food, and economic factors prevent equitable distribution of available food. At the same time the sector is vulnerable, because of the global interdependence within the food chain. To feed the world in 2050, we will need 56% more food without using more land. The food will have to be more nutritiously as well as still affordable, all while reducing greenhouse gas (GHG) emissions and increasing biodiversity (World Resources Institute, 2019).

Agriculture is the largest consumer of the world's freshwater resources, and more than 25% of the energy used globally is expended on food production and supply. The Water-Energy-Food-Ecosystem Nexus approach highlights the interdependence of water, energy and food security and ecosystems – water, soil, and land – that underpin that security. The multiple challenges the agricultural sector faces call for a transformation of the current model of farming that touches upon almost all sustainable development goals.

Food losses and -waste

Food losses and waste are other challenges the food industry faces. Food losses occur during the food production process and account for approximately 70% of total waste, whereas food waste occurs after sales when food products are being consumed and entails about 30% of total waste. Loss and waste occur throughout the food chain, from field to fork. Food loss and waste occurs more 'near the fork' in developed regions and more 'near the farm' in developing regions (FAO, 2011). According to FAO estimates, the food that is lost and wasted could feed 1.26 billion hungry people every year.

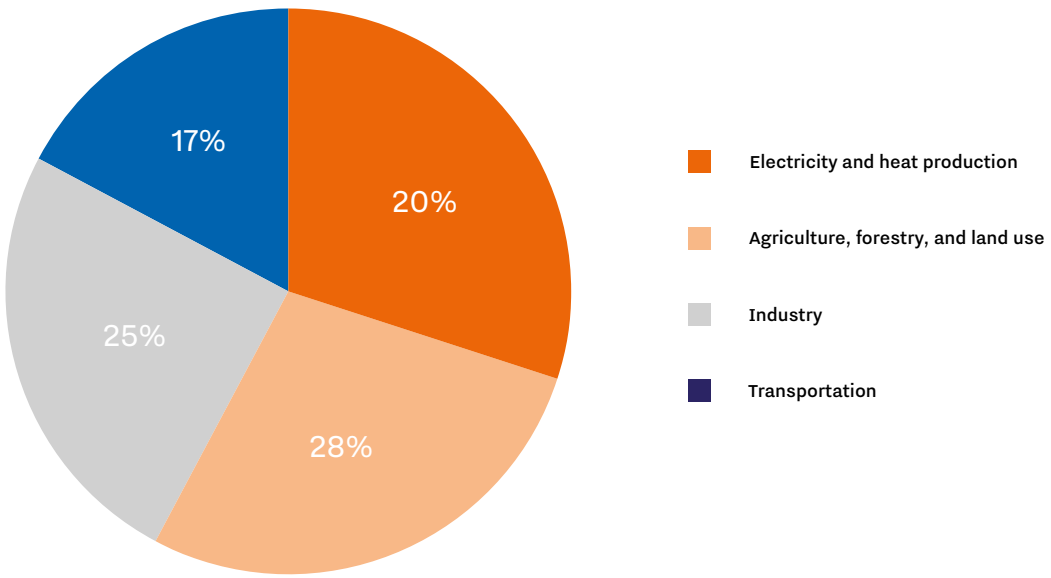
Fig. 1 Percent of kcal lost and wasted. WRI analysis based on FAO. 2011. Global food losses and food waste—extent, causes and prevention.



1.2 Circular agriculture and biomass solutions

The good news is that there are solutions. Circular agriculture, a paradigm that proposes a shift away from growth in production quantities and price reductions with growing impact on the environment. It is a shift towards optimisation in resource use by exploitation of agricultural residual streams and resources and recycling in harmony with nature and extraction and use of new raw materials within our planetary boundaries. Redesigning the European food system on the basis of these circularity principles could bring environmental benefits to Europe and the world. The models in a study by Van Zanten et al. (2023) explore the effects of adopting circularity scenarios and adopting a more plant-based diet, showing a potential reduction of 71% in agricultural land use and 29% per capita in agricultural greenhouse gas emissions. While maintaining a self-sufficient European food system and a potential to upscale to an additional 149% of our capacity to produce food under global food shortages. In circular food systems for example food waste and overconsumption of nutrients—are minimised and, if unavoidable, the residual streams will be utilised (recycled) in the most sustainable way. This approach represents business opportunities to transform material streams currently seen as waste or lost into valuable assets.

Fig. 2 Global manmade GHG emissions by sector (IPCC, 2014)



From waste to resources

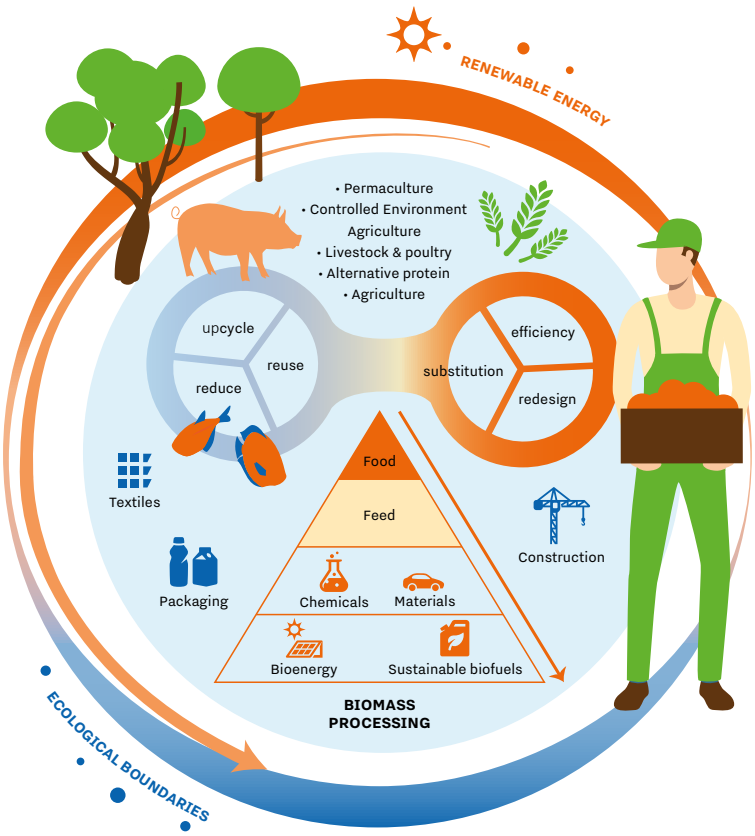
For agriculture the transition to circularity is a huge opportunity, rather than a threat. The sector will start growing crops for a whole range of applications in addition to food. In many cases, crop by-products will also be used. For example, maize stems, the leaves and pulp of sugar beets and tomato plant stems. All of this biomass, rich in carbon and nutrients, has useful components which could replace fossil resources.
All raw materials, including the side streams as valuable ingredients, can create new opportunities and revenue models for farmers and other value chain partners. Agriculture will play a more valuable role in the value chain than just a supplier of sustainably sourced raw materials for food production.
Food systems actors, such as farmers, processing industries and retailers, still have limited interaction outside of their segment of the food chain. As a result, adverse impacts up or down the value chain remain unaddressed. The circular economy is a framework to identify opportunities to save resources, build synergies and reduce waste along the value chain. Hence, managing food losses and waste management and valorising side streams as high as possible by upcycling is an important component of circular agriculture.

Prioritisation of material uses

A major challenge with upcycling is how to create the optimal valorisation for the various substances per raw material stream. This entails handling biomass as effectively as possible (cascading and diversified valorisation), which includes preventing food losses and waste and reducing (food) losses and waste. This challenge goes for the upcycling within feed and food and also within agriculture biomass streams that aren't usable for human consumption.

Often the concept of the value pyramid is used (Moerman's hierarchy). The applications with the highest added value are relatively small in terms of market volume compared to low-grade applications, such as energy. The value pyramid may be useful when striving for high-grade applications: meeting primary needs, food is a priority, followed by feed and material applications that sequester CO2 for a shorter or longer period of time. Lastly, there is the use of biomass for transport fuel and energy, for the last two applications of which the priority lies with those fields where sustainability cannot be achieved by other means yet. An adequate valorisation of biomass and corresponding infrastructure is a precursor and can act as a catalyst to a circular economy. A circular economy is impossible without proper prioritisation of material uses. Figure 2 shows the prioritisation of production within the food sector and in what way to optimise residual streams with respect to the planetary boundaries and efficient use of renewable energy which we will build upon throughout the brochure.

Fig. 3 Based on the circular bioeconomy of well-being by EFI, 2020 and Moerman's ladder



1.3 Circular agriculture in the Netherlands

Efficiency and innovation are key to the Dutch agricultural sector. The Netherlands is one of the world's largest agricultural producers despite a small land surface and high population density. For the Netherlands to be a global leader in circular agriculture in 2030 there is no other way than to convert its conventional model of food production into a circular agrifood economy. It must do so by drawing attention to the complex and interlinked nature of global resource systems and to keep the footprint within the planetary boundaries.

Dutch agriculture today is predominantly a highly efficient linear agricultural system and is mostly based on individual supply chains dedicated to produce as much food as possible, while maximising revenues and minimizing costs. The estimated 95.6 billion euros export of agricultural goods consists of 68.3 billion euros of exported goods of Dutch origin and 27.3 billion euros of re-export of foreign agricultural goods. Whereas, the import value for 2020 is estimated at 67.1 billion euros. Most of the agricultural exports went to our neighbouring countries Germany and Belgium (CBS, 2023). Agricultural intensification centres on optimising production with monocultures of high-yielding crop varieties. While a big part of the crops used for animal feed are suitable for human consumption. Furthermore, current production methods are not without consequences.
The Netherlands faces ecological negative side effects such as the deprivation (of microbiological organisms) of soil, high concentrations of nitrogen, fine particles and deterioration of the freshwater quality and biodiversity loss.

National Policies

The Dutch government's Vision on Circular Agriculture sets out the ambition of the Netherlands to be a global leader in circular agriculture by 2030. The vision entails a paradigm shift from growth in production volumes and cost price reductions towards optimisation in resource use and food production within its planetary boundaries. The vision aims to build on the high degree of innovation and orientation on international markets in the Dutch farm and food industry. The Netherlands will remain a food exporting country but based on higher value-added production.

The government has published its plan of action to turn this vision into reality focusing on:

- Improving soils and water quality
- Reducing emissions and pollutants
- Closing nutrient cycles
- Collaboration at regional level
- Collaboration along the agriculture and food supply chain
- Cascaded use of biomass.
- Shifting the food pattern to more vegetable and less animal products and a more efficient production of animal proteins.

Growing crops for food consumption also created organic residues that can be valorised as materials. Circular agriculture that respects biodiversity creates healthy soils and prevents land degradation. These two approaches invite many innovations. The knowledge that the Netherlands has gained from circular agriculture can assist developing nations in improving their livestock farming and arable farming. Additionally, with broad knowledge and innovations, the Netherlands can assist in tackling specific issues like salinisation, drought, and erosion. Markets are global, and supply-chain networks can extend far beyond national boundaries.

The cycles in a circular building are slotted, as close as possible and as far away as necessary.

The goals are to use organic waste as much as possible in 2030 in the production of food, dairy products, and other non-food products or material applications. The chains are optimally circular designed, and new connections have been made to preserve one's own or another's side- and waste streams. All biomass, land, and forest resources should contribute as effectively as possible to the transformation of human needs.
It should follow the order of the Moerman's hierarchy that goes from food to feed to chemicals & materials to biofuels and energy. The Dutch government opts for a value approach for the use of sustainable biomass, in which low-value applications are phased out and high-value applications are scaled up.
With the European Green Deal The Netherlands is striving to be part of the first climate-neutral continent in 2050. The European Green Deal with its Farm to Fork Strategy has to provide, among other things, healthy soil, biodiversity, and healthy and affordable food.
The Farm to Fork Strategy focusses on 4 goals: to ensure food security in the face of climate change and biodiversity loss (1), reduce the environmental and climate footprint of the EU food system (2), strengthen the EU food system's resilience (3), and lead a global transition towards competitive sustainability from farm to fork (4).

Cooperation within the Dutch Agricultural sector

The Dutch agricultural sector is characterised by a strong export driven agenda and close cooperation with business, governments and renowned educational and research institutions , which ensures innovations are relevant and widely adopted at the farm and agri-food firm levels. Thanks to this close-knit education and research system, new insights and technologies can be applied quickly, and this is how the Netherlands always tries to maintains a knowledge and production lead. This also goes for the food companies with new innovative food technologies and an ecosystem of start-ups and SME's working together on sustainable innovations. Furthermore, these multistakeholder entities have a high participation in international collaborative efforts, and in particular at the EU level (OECD, 2015).

This system of hubs, clusters and foundations is based on operating on the basis of a common goal and shared interests. This initiates the process necessary for breakthrough innovations that individual game changers in the ecosystem cannot realise on their own and this way of transitional collaboration supports the Dutch food system to innovate and stay ahead of the curve. Some examples from The Netherlands:

Greenports

Greenports are amongst others active in the field of greenhouse horticulture, along with growers of vegetables and flowers, suppliers, trading companies, breeders, consultancies, personnel services. They work closely together: with local and regional authorities, with top education institutions and with international research institutes.

They're dedicated to being a leader in circularity and sustainability and aim to find solutions to the challenges the world is facing in terms of feeding and greening the mega cities.

There are seven regional Greenports in the Netherlands that address themes like spatial planning, innovation, energy and logistics amongst others.

Foodvalley

Foodvalley NL is an independent foundation to accelerate the global transition to a sustainable food system that produces healthy, sustainable and affordable food for all. Circular agrifood is one of the 3 focus innovation fields, besides protein transition and food & health, with many cross-overs between.

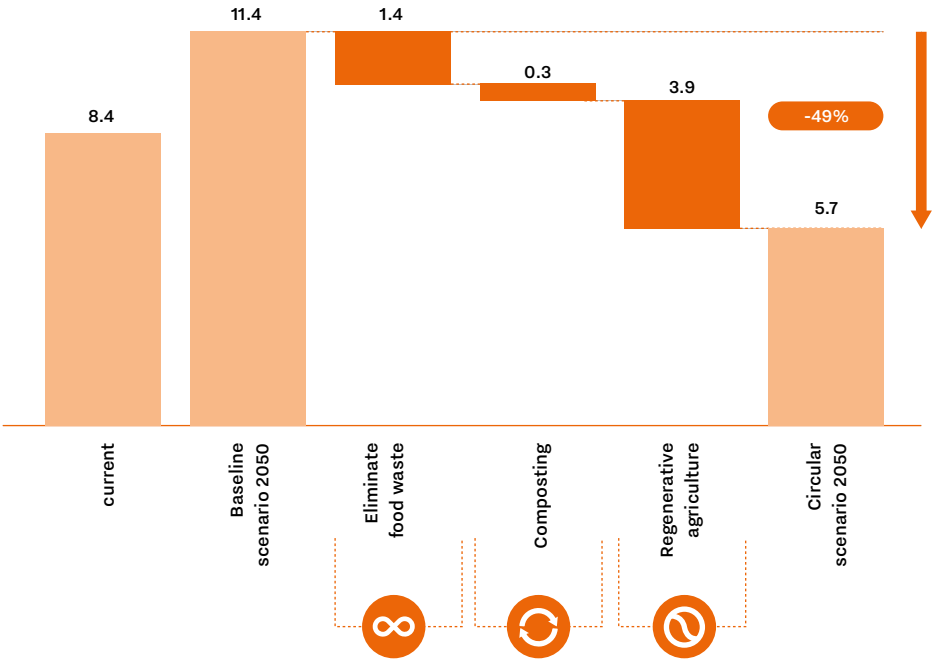
Foodvalley NL works as a practice lead working together with gamechangers, SME's and big multinationals forming farm to fork break through innovations and scaling up new innovative practices. Furthermore Foodvalley NL facilitates quick access to advanced research equipment, facilities and technologies for (start-up) organizations together with Wageningen University & Research and all other Foodvalley NL network partners with research facilities to share.

AgriFood from design to solutions

2.1 Circular food systems

Food systems around the world are facing a triple challenge: ensuring food security and nutrition for a growing population, supporting the livelihoods of millions of farmers and others in the food chain, and doing so in an environmentally sustainable way. Food systems are thus central to meeting the Sustainable Development Goals. Producing, processing, transporting, and consuming food are all part of the intricate network that makes up the food system. Issues concerning the food system include the governance and economics of food production, its sustainability, the degree to which we waste food, how food production affects the natural environment and the impact of food on the population's health (Godfray et al., 2018). Circular economy strategies could reduce emissions by 5.6 billion tonnes CO^2, corresponding to a 49% reduction in the projected 2050 total food system emissions. Achieving this means shifting to more nature-enhancing farming systems and making more effective use of the food that is produced.

Fig. 4 circular scenario for food. In billion tonnes of CO2e per year (Ellen MacArthur Foundation, 2019)



Foodlosses and foodwaste can be avoided by more efficient farming methods and sustainable intensification, consuming in a more conscious way, using a coating or technique for longer shelf life, reusing co-products and residual waste streams (upcycling) and by redesigning agroecosystems.
A great deal of perfectly good food is never eaten and gets thrown away in household rubbish bins.
Large quantities of food are also lost in harvesting, storage and transportation (FAO, 2011).

How to build a better food system:

- **Regenerative food production**
  This refers to growing food in methods that benefit nature, such as improving local biodiversity, soil health and stability, and the quality of the air and water. The result is agricultural land that more closely resembles natural ecosystems. This is accomplished through practices that are tailored to local contexts, such as using a variety of crop, rotational grazing, agroforestry and providing habitat for a wide range of organisms.
- **Eliminating food waste**
  Building a food system that ensures our food never creates waste within the frame of circular economy. It prevents food waste, redistributes surplus edible food to people who need it and inedible food by-products and human waste become input for new products (Gonçalves & Maximo, 2022).

Samen Tegen Voedselverspilling (Together Against Food Waste)
The foundation Together Against Food Waste focuses on preventing, reducing and adding value to food waste throughout the entire food chain. Within the foundation, organisations, government and knowledge institutions are jointly committed to combating waste by joining forces and working towards one common goal: Together we will make the Netherlands one of the first countries in the world to reduce food waste by half.

ORBISK

Each year, 1.3 billion tons of edible food is wasted worldwide, which is roughly one-third of all food produced. The global food waste crisis is a pressing issue that affects the planet in multiple ways. Not only is it a waste of valuable resources such as energy and water, but it also contributes to environmental degradation and pollution. At Orbisk, they believe that it is their responsibility to be a part of the solution. They aim to make a positive impact on the world and contribute to a more sustainable future.

Orbisk created a plug-and-play solution that helps to combat food waste in professional kitchens by using an advanced camera and scale system. The device uses AI to automatically identify what kind of food is thrown away, in what quantity, and at what time of the day.

The data collected by the device is presented in an actionable dashboard, which helps kitchens to optimize their supply chain, purchasing habits, and menu planning. By doing so, our solution helps to reduce food waste and save money. In fact, on average, an individual restaurant can save over 5.000 kg of food waste annually, representing a financial savings of between €20.000 and €60.000.
Orbisk is currently running pilots with many industries that are proving successful. Next to the Netherlands, many other European countries are also starting with Orbisk. These include Germany, France, and the UK. They are also expanding their market outside Europe, with more than 200 devices currently active in more than 11 countries across five continents.

orbisk

Supply chain

One other major cause of waste in the food system is the mismatch between supply and demand in combination with the perishable nature of food products. Mismatches between supply and demand are commonly addressed by buffering products at stock points throughout the supply chain in developing regions, however when keeping perishable products in stock too long waste will be considerable in the more developed countries as well in the consumption phase..

Furthermore, research conducted by the WUR (2021) has indicated that we can intervene and avoid waste and quality loss in three consecutive steps: using sensors to collect data about the ripening process, real-time modelling of quality decay and the application of these predictions within the transport chain. These process steps pose challenges, such as how we will get the right sensor data available in real-time for modelling and how we can intervene in the transport chain.

Fig. 5 Supply chain from Farm to Fork

Lots of fruits and vegetables are being produced in Africa for European consumption and transported to the Netherlands by road, rail or by sea via the port of Rotterdam. Due to a lack of monitoring food waste during transport is over 20%. Besides supply chain planning does not take the product variations after harvesting into account. There are rarely any means of monitoring of the ripening process during travel except from the use of temperature-controlled transport with default settings. This offers opportunities for packaging which can play a crucial role by using technologies such as time-temperature indicators, gas indicators and biosensors.

Furthermore, shortening food supply chains present manifold benefits as well for decreasing waste and boosting local economies. One example is the increase of vertical farming to bring the growing of produce closer to the markets they serve, cutting supply chain distances. Smart cities become key players in this scenario. While urban farming can only provide a limited amount of food required for consumers, cities can get a large share of it from their surrounding areas. Bringing food closer to consumers reconnects them with food and as such helps to addresses food concerns, creates an opportunity to a local fresh food movement and could link food again with nutrition, diet and health. A solid connection between rural and urban areas is therefore needed. In addition, COVID-19 created unprecedented stresses for food systems. Food supply chains had to cope with bottlenecks in farm labour, processing, transport and logistics, as well as momentous shifts in demand. The pandemic underscores the importance of further strengthening resilience.

Liquidseal

Coatings for a sustainable revolution

Liquidseal extends the shelf life of flowers, fruit and vegetables through innovative and environmentally friendly coatings. This means that precious raw materials such as water and fertile soil are optimally used and fewer flowers, vegetables and fruit are thrown away as a result of damage, rot or damage by fungi.
Our sustainable and plant-based coatings are biodegradable and compostable: friendly to humans, animals, the environment and our partners' wallets. In this way Liquidseal contribute to a world in which less is wasted and offers a financially attractive alternative to the use of plastic packaging materials.

Preventing waste is an important core value of our company. Our mission is therefore "preserving global resources by preventing wastage". Our coatings prevent perishable products from losing moisture, which leads to an extended shelf life. The coating also has a protective effect, reducing product failure due to mold, rot or damage during transport.
The retention of moisture and thus the extended shelf life, in combination with a higher percentage of usable products, also ensures that there is less overproduction to absorb these losses. This saves valuable raw materials. And coatings are a cheaper and more efficient alternative to plastic packaging materials for growers, importers and retailers. These 'single use plastics' are of course disastrous for the sustainability of our planet.

The best way to achieve the future you envision is to design it yourself. The world, and certainly the packaging industry, will not suddenly become sustainable. As a Dutch company, we like to contribute to the reputation of Dutch innovation and sustainability. Liquidseal products are now used all over the world: in South America, South-Africa and Europe. In addition, Liquidseal India was recently established. Their message is the same all over the world: the best time to start using Liquidseal was 10 years ago, the next best time is today.

LIQUIDSEAL
preserving freshness

Herenboeren

Herenboeren Nederland is all about shortening the supply chain and bringing it closer to the market it serves. It is a national network of nature-driven mixed farms, each owned by a local cooperative of 200-270 households.
As members of a Herenboeren cooperative, citizens are owners, entrepreneurs, producers and consumers of their own farm. The farm produces fresh seasonal vegetables, fruit, eggs and - for those who wish - also occasionally meat. Together, the cooperative and the farmer(s) decide how the farm is run and which products are grown.

This way, the affiliated cooperative members take back control of their food production. Taking part in Herenboeren doesn't only give you tasty and healthy food, it is also fun and educational. The cooperative members all live in a small radius around the farm and come there every week (or sometimes twice a week) to collect their part of the harvest, a short chain is created with very little food waste and a minimum of packaging. In times of abundant harvest, the cooperative members try to prevent food waste by reacquainting themselves with 'old' techniques such as preserving and fermenting, and of course their own freezer sometimes offers a solution.

Herenboeren households each invest around €2000-2500 in the start of the farm. They then jointly take care of the annual operating costs, which amounts to an average weekly contribution of €10-€15. Members collect their harvest share every week. Each cooperative employs 1 to 3 (part-time) farmers, who receive a stable and fair wage. Although the cooperative functions as a company, a Herenboeren farm does not aim for profit. Produce only goes to the members, not the free market. This way the farms are independent in their choices for sustainable, nature-driven food production. Healthy soil, a good life for the animals, higher biodiversity and working towards a closed cycle form the basis of the Herenboeren concept. They also work without artificial fertilizers and chemical pesticides.

There are already 18 Herenboeren farms spread throughout the Netherlands, from Assen to Weert and from Rotterdam to Enschede. There are also more than 42 initiative groups working on the establishment of their own future Herenboeren farm.

Redesign

The majority of food has been designed, from its flavour to its appearance. Circular economy principles should be used in all aspects of food design, from product concept to ingredient selection and sourcing, including the use of upcycled ingredients, through packaging, in order to maximise benefits in the food system and environmental outcomes (Ellen MacArthur Foundation, 2021).

The first step in achieving sustainability at a geographic scale is redesign. To utilise natural processes, agroecosystems and landscapes must be redesigned. This can be accomplished, for instance, by redesigning or altering a breed. Vegetables can be modified to precisely meet consumer needs and have a longer shelf life. Consider lettuce leaves that precisely fit on a hamburger bun, thin-stalked broccoli that consumers prefer over thick stems that are discarded, and cauliflowers that maintain their white colour. Consumers don't purchase cauliflowers that have gone yellow since we believe they are no longer edible.

In order to address the rising food insecurity, agricultural science has concentrated on developing new types of crops with the features of high yield, greater quality, and stress resistance. This was accomplished by utilising cutting-edge molecular methods. Since seeds are the foundation of both sustainable agriculture and food production, effective seed systems are vital to improving resilience. Researchers and professionals working in international development have begun to investigate how robust seed systems are in order to make high-quality seeds available, inexpensive, and accessible.

2.2 Valorisation of residual and side streams

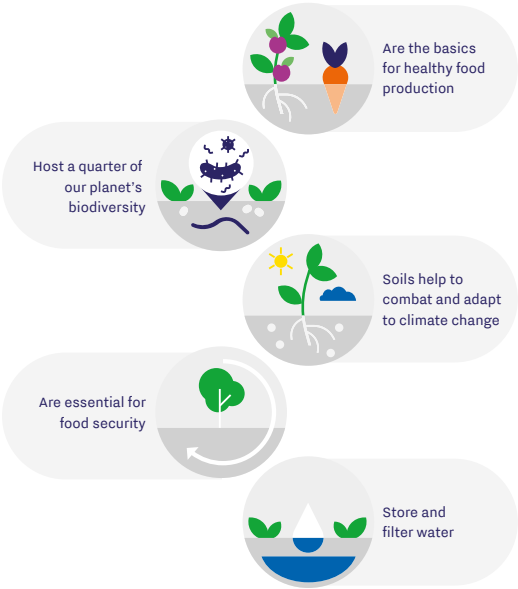
Efficiency aims to make better use of on-farm and imported resources within existing farm structures. Since many agricultural systems generate waste, effective management to cut down and reuse residual streams locally can result in advances in on-farm efficiency. Instead of posing a threat to agriculture, the shift towards circular agriculture is actually a big opportunity. The industry could begin producing rotational crops not only for food but also for a wide variety of other uses on unserviceable land for food. Crop by-products will also frequently be utilised (New opportunities for the redesign of agricultural and food systems, 2020). These by-products could consist of for instance stems and leaves which currently aren't utilised and enter the atmosphere as CO2, even though it's full of valuable components which could replace fossil resources.

Reuse side and residual flows within the cultivation system

By separating by-products, farmers will be much better able to meet their own needs in terms of fertilisers, healthy soils and animal feed. The minerals from by-products will be applied to the land at the right moment in the spring season. And potato and pea foliage won't be left to rot on the land and become a breeding ground for moulds and diseases; instead, this organic material will be processed into something that contributes to the soil's organic matter (WUR, 2021). For crop farmers, circular agriculture means using high quality animal-based fertilisers and crop remnants to stimulate soil life. Crop farmers will also make maximum use of soil agrobiodiversity with mixed cropping systems and smart rotations. With new forms of precision mechanisation, based on developments in sensors and robotics, this is feasible.

Soil is often forgotten. Proponents of biobased approaches are keen on agricultural biomass. However, eliminating 'by-products' from arable farming has a cost as well. As evidenced by regenerative agriculture, they are essential for maintaining healthy soil and nourishing soil life (FAO,2017). Traditional regenerative agriculture practices already learnt this lesson. Making use of regenerative agriculture and circular fertilisers can address the soil and climate challenge linked to synthetic fertilisers.

Fig. 6 Benefits of healthy soils



Valorisation within the food chain, including animal feed

The nature of food losses and waste is diverse and complex. Our food system leads to various by-products such as crop residues, co-products from food processing, food waste, and animal and human excreta. By-products which are not of immediate use for human consumption, such as crop residues, co-products from food processing that are not edible for humans (e.g. beet pulp), slaughterhouse waste, animal and human excreta, or unavoidable food waste, should be recycled back into the food system. All these products contain carbon and nutrients (such as nitrogen and phosphorus), albeit in very different ratios. This makes them valuable as a source of protein, micronutrients, structural material or energy. In principle, by-products can be used for different purposes. This can be done via food technology both high and low tech. For instance animals like insects, pigs, chicken etc. can play a crucial role in feeding humanity by recycling biomass unsuited for direct human consumption into the food system. They convert biomass unsuitable for human consumption into high-quality, nutritious food, and recycle nutrients into the food system that would otherwise be lost.

Upcycling Community

The Upcycling Community is an international group of business partners that collaborate on the topic 'upcycling of food losses'. The community setting creates a safe environment where organisations can share ideas, get inspired on new developments and insights from the market and research. The Upcycling Community exists of business partners who are ambitious about upcycling, come from various parts of the value chain, and vary from scale-up to SME and corporate organisations. The community as a group sets the agenda for scaling up by designing more products made from more upcycled ingredients use. The aim is upcycled ingredients/co-products form farm to fork being appreciated as virgin raw materials. Developing more circular food concepts and realising higher volumes of side streams/ co-products optimally valorised into circular value chains is an enormous transition that requires pioneering systems transitionwork on cooperation with various organisations taking initiative. This is a journey that Foodvalley NL works on as a practiceleader on a day to day basis.

De Clique

De Clique provides a total solution for the hospitality industry and caterers to become part of a circular food chain. De Clique does this by collecting separated organic residual flows such as coffee grounds, cutting and food residues in a CO2-neutral manner and turning them into new products. At the moment, these organic waste streams from the city are thrown away. As a result, these valuable organic residues are destroyed in incinerators. This means that the valuable nutrients that these organic waste streams still contain are not used. The collected organic streams are used as raw material or breeding ground for new products such as oyster mushrooms, bitterballen, kombuchas and breads. In this way they create valuable, shorter and circular chains.

These products are developed and made together with partners in the chain such as Peel Pioneers, Mago Biosolutions and Rotterzwam. The cutting and food scraps are composted locally. Herbs and vegetables are then grown to feed the city. The coffee grounds are used both to grow oyster mushrooms and for compost. The orange peels are processed into oil and fibres, among other things. The products are sold back to De Clique's customers. This creates a local circular chain, in which raw materials from the city form the basis for feeding the city with the raw materials that are released.

After only three years of operation, De Clique has established a network of 200 partners and is removing 100,000 kilos per month from incineration and saving more than 700 tons of CO2 to date. Through cooperation with the national government, De Clique is also active in The Hague and Rotterdam and the local ecosystems are further expanded in the Netherlands. De Clique has been praised several times for its efforts and innovations in the chain, such as winning the Horecava Sustainability Award at the beginning of 2023.

de CLIQUE

Duynie Group

In the past, food producers thought of the materials left over from their primary processes as “by-products”, implying that these products have some limited use or are waste to be disposed of as cheaply as possible. Duynie Group has always believed in the circular value of these raw materials.

Duynie Group takes care of plant-based co-products of food-, beverage and biofuel producers since 1968 and processes them into new products for (pet)food, feed or various industrial applications. In this way the producer can focus primarily on producing raw materials and Duynie can facilitate by valorising these co-products and ensure a circular application.

The highest valorisation is processing into new food ingredients. Brewers’ spent grain is a good example of a natural, plant-based side stream that’s packed full of valuable nutrients. Protein, fibres and fats can be extracted for use in food applications such as meat replacers, snacks and bakery products.

Duynie’s Expertise and Research Center develops new potential uses for co-products creating new value for food processors, customers and the environment. Duynie Group provides LCAs of various products based on plant-based co-products. As co-products do not grow in the ground, but are released at food production sites, they have a low environmental impact. Together with partners in the supply chain Duynie Group is driving the transition from a linear towards a circular economy.

Duynie Group processes around 5 million tons of plant-based co-products, released in the food, beverage and biofuel industry across 17 countries in Europe.

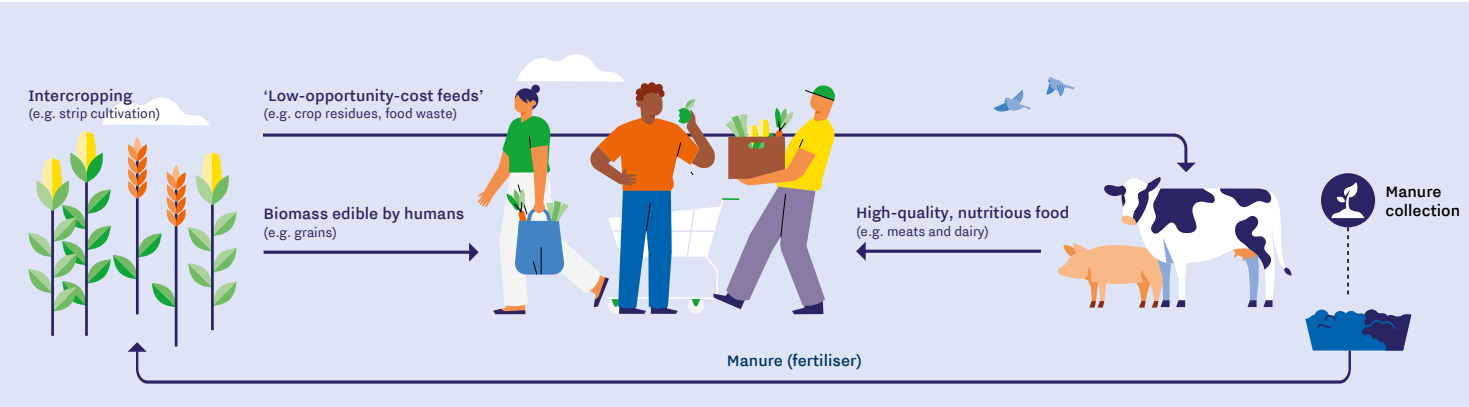
2.3 Food production methods

Changing our food production system to one based on the principles of the circular economy is one of the most powerful things we can do to tackle climate change and build biodiversity. Transitioning to a circular economy means moving towards a food system that builds natural capital and allows nature to thrive. In the sections below several agricultural practices along this line will be showcased. Working along those lines means we need to source raw materials for food, feed and materials in a regenerative way. This should be implemented both at the producer and consumer levels, through practices tailored to local contexts at first, but then on a macro scale.

Regenerative farming

Regenerative food production secures growing food in ways that generate positive outcomes for nature such as healthy and stable soils, improved local biodiversity, improved air and water quality and social and economic improvement of livelihoods. It is implemented through practices tailored to local contexts such as using minimal external inputs, cover crops, no tillage, use of manure and compost, rotational crops and grazing, mixed farming within the farm or between farms, use of perennials and agroforestry (growing trees around or among crops or pasture) can be very beneficial. This results in agricultural land that more closely resembles natural ecosystems like forest and native grassland, providing habitat for a wide range of organisms to grow and secure biodiversity.

The rotation of crops over time not only provides opportunities for green manure and suppression of dominant field weeds, but biodiversity also increases in these crop systems. As a result, arable farming can contribute to biodiversity objectives. The benefits of service crops in terms of the provision of ecosystem services is well-known and recognised nowadays in the agricultural research community, but less so among large scale farmers, because of their lock-in in the current agronomics of the food system. In addition to their ability to increase soil organic matter and fertility, and reduce runoff and erosion processes, service crops provide a large variety of ecosystem services such as weed control. The key concept of regenerative farming in a broader definition in food production of efficiency is circular



agrfood. Under this system, as much as possible of the agricultural biomass and the nutrients it contains are retained in the local agrifood system. In other words, the amount of nutrients leaking out of the agrifood production cycle is kept to a minimum, thereby reducing the need to add nutrients from elsewhere, such as through artificial fertilizer or imported cattle feed. In practice, this means that farming, both arable and pastoral, needs to develop a much more symbiotic relationship with production quantities and offtake than is currently the case. This is reflected in regenerative farms that produce more according to natural ecosystems and are working in short value chains. Of course, this is more challenging to design with a variety of farms and crops in longer value chains with a diverse set of offtakes each with their own way of working.

Smartfarming

Digital technologies including data analytics, artificial intelligence(AI), precision farming, robotics, block-chain technologies, Internet of Things(IoT), Digital Twinning, machine learning, digitally-delivered services and apps are changing agriculture and the food production system.
These technological advances can support the goal of achieving more resilient, productive, and sustainable agriculture and food systems, which better meet consumer needs. With the ability to monitor crop growth and disease more efficiently than the human eye (and at a much higher speed) robots and data systems have the potential to optimize farming throughout the agriculture and horticulture industries.

Precision-based smart farming is an essential part to the future of agriculture. Satellites, drones and infield sensors can also monitor optimal planting times and test soil quality so that farmers only deploy water, nutrients, fertilizer when needed and detect problems. Robotic machinery that can be designed smaller than current agricultural machinery that has become larger and thus will have a positive effect on soil health because of less soil pressing. These robotics could work day and night, assisting in the more labour intensive and more mechanical designed regenerative farming practices like mixed cropping (Javaid et al., 2022).

Controlled Environment Agriculture (CEA)

There are multiple sorts of controlled environment agriculture, varying from greenhouses, aquaponics, vertical farming, cea funghi and combined with outdoor farming. In the Netherlands a lot of greenhouses were developed because of the presence of a cheap Dutch

Dennenhoeve

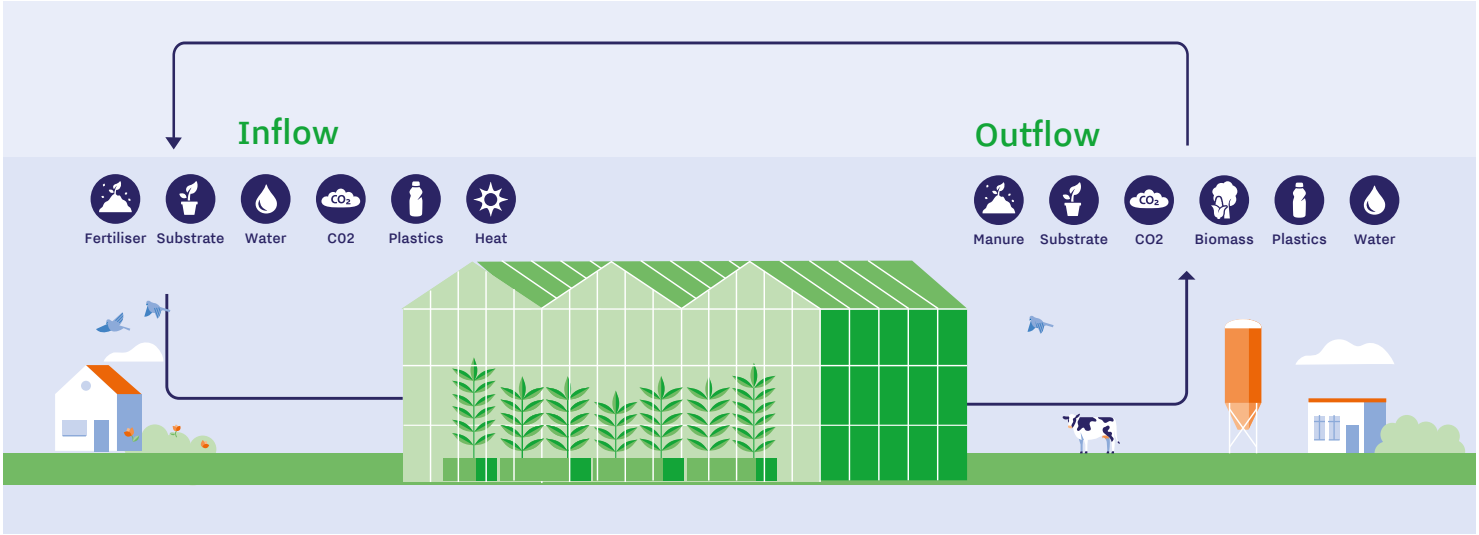
The Dennenhoeve is a biodynamic farm. The 45-hectare company grows several arable products and raises poultry. Previously, the farm focused on one type of crop per plot. That has now been changed by using strip cultivation. A method of cultivation in which our crops are grown alternately in strips on one plot. This makes agriculture more sustainable in which one crop supports the other crop, i.e. mixed cultivation. In addition, there is a natural forest to increase biodiversity.

The farm uses green manures to add value to the biodiversity. Green manure is intended as a catch crop for the fertilizers that otherwise leach out in the winter. Green manures root deeply and therefore provide a good structure for the soil and soil life. This, in conjunction with the application of your own compost, promotes water retention and good water permeability.

In addition to arable farming, the company has biodynamic chickens. The term biodynamic stands for a special form of organic, with higher requirements in the field of animal welfare, closed cycles and ecology. The chicken feed comes for 70% from their own land.

In 2019 they started a new challenge producing an edible mushroom. This mushroom wants to grow on straw. After the harvest of these mushrooms for the consumer, the straw goes to our organic chickens. They eat the remains (pieces of stropharia, fungi, proteins) from the straw. The straw with chicken manure is then returned to the land. Where the grain and field beans grow well. That fits in with the circular concept. After harvesting, the grain and field beans are converted back into chicken feed for the organic chickens on our farm. This is how the Dennenhoeve strives step by step towards a circular agricultural economy.

Dennenhoeve
Biologisch Dynamisch



natural gas supply for heating. CEA and horticulture became well advanced and the Dutch expertise in science and business experience on CEA and especially greenhouses and needed CEA services is worldwide renowned.

Greenhouse horticulture

Protected horticulture plays a key role in ensuring high-quality production and contributing to global food security. It also presents numerous opportunities for more efficient resource utilization and a shift towards a circular production approach. Compared to open field cultivation, greenhouse technology offers greater control over production factors, resulting in higher yields per square meter and optimal resource utilization. This is achieved through the implementation of both simple and advanced digital techniques for managing horticulture companies, crop management, and precise resource application (such as water, fertilizers, light (color), energy, as well as insects as pollinators or pest controllers). These measures allow for controlled environmental- and climate impact, as well as resource optimization. In terms of water and nutrient usage, protected horticulture can be considered partially circular. Closed fertigation systems within greenhouses enable the recycling and reuse of water and nutrients, supporting plant growth. However, this can only be achieved through proper greenhouse management, employing precise irrigation and fertigation practices to minimize overuse and to prevent discharge to surface- and groundwater (EIP-AGRI, 2019).

Nevertheless, like many other sectors, greenhouse horticulture relies on finite natural resources that are distributed globally. In the project "Towards Circular Greenhouse Horticulture" conducted by WUR (Boedijn et al., 2023), a guiding vision for greenhouse horticulture in a circular economy has been developed. The vision emphasizes the transition from linear to circular supply chains for six material flows: water, fertilizers, CO^2, substrate, plastics, and biomass. The report focuses on reducing dependency on finite materials by substituting essential resources with alternative (biobased) materials or promoting reuse of resources. Leveraging residual biomass streams from greenhouses presents a challenge but also offers opportunities to establish new value chains that extend beyond individual sectors or areas of expertise. The undervalued flow of biomass – tomato stems and leaves for example – holds significant potential as input for new products, including compounds for fertilizers, organic matter or biostimulants for substrates, fibers for packaging and construction materials, proteins for food and feed, aromas and dyes for the cosmetics industry, and medicinal compounds for the pharmaceutical industry. Research is necessary to determine the most suitable applications for different residual flows and to overcome any associated obstacles.

World Horticenter

World HortiCenter is a knowledge and innovation centre for international greenhouse horticulture. A leading platform where business, education, research and government jointly innovate and share knowledge. World Horti Center has a research centre with 38 greenhouse departments where researchers, entrepreneurs and education institutions jointly conduct research.

World Horti Center is a unique collaboration between education, research, entrepreneurs and the government with an international focus. MBO Westland, Demokwekerij Westland, WHC Expo bv and the Municipality of Westland together form World Horti Center.

Vertical farming

Vertical farming takes the cultivation in greenhouses one step further by growing in several layers on top of each other without the use of soil. This can ultimately mean only 2-4 litres of water per kg of vegetables and 10-20 times less land use. Vertical farming does not use soil. If the farm uses hydroponic systems, then it will use a soilless growing medium with nutrient solutions. If it uses an aeroponic system, then it will not even use a growing medium but in the air or a mist environment.

Vertical farming can revolutionise fresh vegetable production. By growing crops in layers under controlled conditions, guarantees can be given about the quantity

and quality of production, every day of the year, regardless of the weather and climate (change). For example, in vacant office buildings, on top of city roofs, in cellars under living buildings etc. The cultivation can be done sustainably, efficiently and in a fully controlled manner. Using these buildings with vertical farming creates a safe, healthy and sustainable route to provide the growing number of urban residents with locally produced fresh food. When composting of side streams can be transformed into reusable nutrients for this CEA system we can build future local circular agrifood production systems, on small and large scale owned by business or even local building communities or a combination (Avgoustaki & Xydis, 2020).

Livestock & poultry

The Netherlands has a big population of pigs and poultry slightly on the decline. Livestock farmers and the processing industry want to make animal husbandry as sustainable and animal-friendly as possible. The growing concern regarding nitrogen emissions and overabundance of animal manure can act as restraints for the Netherlands animal feed market. Livestock production in the Netherlands is partly dependent on protein-rich raw feed materials from third countries, particularly soy from North and South America with its infrastructure being favourable for the supply of raw materials from overseas (ports) (Silvis, 2021).

In a circular agrifood system geared towards livestock, rather than consuming biomass edible by humans, such as grains and soy, we can convert so-called 'low-opportunity-cost feeds' (e.g. crop residues, co-products from the food industry, inevitable food losses & waste, and grass resources) into high-quality, nutritious food, and recycle nutrients into the food system that would otherwise be lost to food production (Garnett et al., 2015). In the exchange of arable land could be used primarily for the production of food instead of feed crops, adopting such an approach means that animals contribute to nutrition supply without using additional arable land. But removing so-called by-products from arable farming comes at a price too. They're necessary for feeding soil life and keep the land in a healthy condition.

KIPSTER

Kipster is not just an animal-friendly chicken farm, but a farm that produces efficiently with an eye for animal welfare, the environment and the farmer. The company developed a climate-neutral egg, which also gives the chickens on the farm a good life.

Kipster chickens eat residual flows from the food industry, which means they upgrade 'waste' into eggs and meat. The feed therefore does not compete with food that would be suitable for human consumption and they do not need fields to grow chicken feed. As a result, the chickens are not only sources of animal protein, but also processors of organic waste.

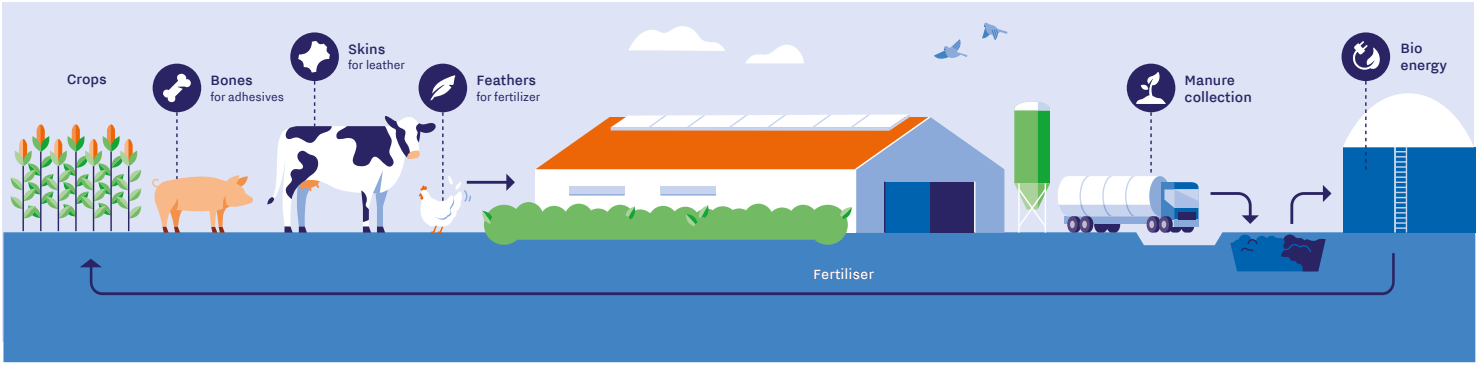
Kipster is the first in the world to produce CO2 neutral eggs. 70% of a chicken's CO2 emissions are in the feed. If you feed the chickens with residual flows, that percentage will be halved.

Kipster recently opened an American branch and the first laying hens have arrived. Since December 2022, the eggs from these hens have been on the shelves of Kroger supermarkets. The concept of the farm is flexible and scalable. Due to the modular design, farms from 24,000 to 120,000 chickens are possible. Not more, because then you'll get into the territory of a mega company.

The company also wants to realize a small Kipster on the Brightlands Campus Greenport Venlo in which they can experiment. They want to stay ahead as a company. Innovation is essential. Here, they will be experimenting with residual flows, particulate matter, water and animal welfare. Which could also be of interest to other poultry farmers.

They are also quite advanced in developing a plant-based egg that does not involve chicken. The world population continues to grow and in order to provide everyone with sufficient protein in the future, alternatives must also be sought.

KIPSTER



Water & Aquaculture

Water

Water and agriculture are inextricably linked. It is no secret that water is a critical input for agricultural production and as such, is essential to food security. At the same time, agriculture is by far the largest user of water, accounting for nearly 70% of total available freshwater withdrawals, and is a major source of water pollution. Combining both the direct and indirect water consumption of animals, we see that animal products are responsible for almost 30% of agricultural water consumption, despite representing only 11% of global agricultural production in kilograms (FAOSTAT, 2019). This demonstrates the variability in water resource intensity between crops and animal-based products. Water consumption is not limited to agricultural production, but is a vital resource throughout the life cycle of food products, especially in food processing (WWF, 2017).

Water management is one of the greatest challenges facing the agrifood sector today. The Netherlands has expertise in water management and agriculture, including in greenhouse cultivation. The Netherlands is designed for rapid drainage of excess rain and river water. However, due to the drier summers caused by climate change, it is also necessary to be able to retain water. Together with water managers, Wageningen researchers are looking at which steps will increase the water availability for agriculture and nature. For example, through (a combination of) the use of deep-rooted crops, soil life, smart weirs and irrigation. And through new technologic solutions like water-level controlled drainage solutions added to for instance already present drainage systems on farm fields. As stated before, agricultural science has also concentrated on developing new types of crops for example with greater stress resistance against drought, excess water or salinity.

Aquaculture

Aquaculture is the practice of farming fish or other aquatic organisms in enclosures in rivers, lakes, at sea, or in tanks. With an increased allocation of space for nature conservation and offshore wind farms, in the Netherlands, the area for fishing will be reduced considerably. However, opportunities are also arising through combinations of wind farms with nature using aquaculture. Innovations will make important contributions to making fisheries ever more sustainable with less undesired bycatch and fewer emissions.

Sustainable fishery requires nature and the economy to be, and remain, in balance with each other. It is more selective, ensures less contact with the seabed, has less undesired bycatch and fewer emissions. Healthy fish stocks are and remain the basis and ensure that fishermen can earn a decent living, both now and in future generations.

When it comes to wastage, the challenge is to limit bycatch and, when it nonetheless occurs, to put this to the most valuable use possible. Innovation could make this possible, leading to better utilisation of residual fish waste and by increasing the added value of, for instance, pharmaceutical applications. Ongoing development of quality marks and certification of sustainable fisheries will ensure that consumers increasingly buy and eat sustainable fish. As a result, consumers will also come to value fish as an important part of daily nutrition.

ALGA.FARM

Alga.farm produces a fresh spirulina paste that is used as an ingredient to fortify existing food products. Our protein contains all essential amino acids and our spirulina is a natural source of vitamins, minerals and poly unsaturated fatty acids. They developed novel led-based photobioreactors that are able to produce the fresh spirulina paste in and near urban environments for a fraction of the ecological cost of other protein sources. By using waste CO2 from a local brewery and converting it into oxygen and biomass Alga.farm can reduce the impact of two businesses at the same time.

Their aim is to produce extremely high quality food products without any negative environmental impact. Therefore, they strife to reuse all our waste heat to help out other nearby companies and 100% reuse our own cultivation medium saving up to 99% water compared to other protein sources.

In traditional agriculture only a small part of the fertilizer that is sprayed on the land is absorbed by the crop. The rest degrades the soil and pollutes ground water. Feeding livestock with these inefficient crops magnitudes this issue since the conversion rates between plants and animal nutrients are low.

By only using the nutrients they need and wasting none the most healthy source of food can be created known to man in a very sustainable manner. In other words, they use cyanobacteria to make both people and the planet healthier!

At the moment the company is looking for partners that want to work together to integrate our nutritious green paste into existing foodstuffs and amplify the nutritional content of these products and make them more sustainable. Since the fresh spirulina paste has a very neutral taste, it can be easily blended into all kinds of food products.

alga.farm

Alternative proteins

The arable land in the Netherlands is limited. Traditional livestock farming practices are resource-intensive and have a higher impact on the environment . Alternative protein production methods, such as plant-based and cell-based proteins, require significantly fewer resources and emit far fewer greenhouse gases. Alternative protein production methods are more efficient than traditional livestock farming, which means they can produce more protein per unit of land, water, and energy input. Therefore, more and more of our required proteins will have to come from other sources. For example, we can already source proteins from duckweed, insects or by converting bacteria, fungi and yeasts into a food (fermentation) and other microbial protein sources. And we can grow them in the lab (cellulair agriculture).

There are many innovative developments in the Netherlands. The Dutch have a “protein experienced” country because of all their dairy and meat experience. The Ministry of Agriculture (LNV) invests in the field of protein processing technology (such as grass refining), insect production, plant-based meat substitutes and so-called ‘novel foods’ (such as cultured meat).

Over 250 companies in the Netherlands are working on the protein transition, creating alternative protein solutions with global impact. The protein transition is about restoring the balance between animal and alternative or plant-based proteins. Restoring the balance is a challenge, not only for the Netherlands but for other parts of the Western world like Europe, the US and Canada. As an example, in the Netherlands in 2019, 61% of proteins originated from animal-based sources. To reduce our resource use and the pressure on the ecosystem the Dutch government has set goals to change the ratio between animal and vegetable protein in our diet compared to now has been reversed from 60% animal protein, 40% vegetable protein to 40% animal protein and 60% vegetable protein by 2050. The total protein consumption per person has decreased by 10-15% in 2050 and the footprint of proteins produced in the Netherlands has decreased by 50%.

National Protein Strategy

In order to become less dependent on import flows of protein-rich raw materials from outside the European Union, the Dutch government will encourage the cultivation of protein-rich crops. Investments are also being made in research into other innovative protein-rich sources for both humans and animals, such as insects and micro-algae. In addition, the government

wants to continue experimenting with preventing food losses and extracting proteins from residual flows, for example from kitchen waste. The strategy further aligns with the Netherlands vision for circular agriculture to stimulate the production of food with the least possible burden on the environment and the valorisation of residual flows – taking further advantage of the agricultural economy's efficiency (i.e., combating waste and the circular use of residual flows).

The Protein Community, powered by Foodvalley NL, connects alt-protein start-ups and corporates worldwide. Accelerating their innovations and business growth by coupling them with inspiring international partners, capital, unique facilities, and knowledge, and providing in-depth events.

PROTIX

Protix a company in insect-based ingredients for healthy and sustainable pet food, animal feed and organic fertiliser. The company is on a mission to create low-footprint ingredients that solve major issues in the current food system. Protix creates a circular food chain by using organic waste from the food industry as feed for the black soldier fly (BSF). In turn, the insects are processed into valuable nutrients such as proteins and lipids. Protix's customers use these proteins and lipids as high-quality ingredients for animal feed. Moreover, residual streams from the insects are used as organic fertiliser. This way, insects close the loop and bring the food system back into balance with nature.

Protix operates the first-in-the-world industrial insect facility. With breeding and processing under one roof, the company has complete control of the production chain and offers reliable, high-quality supply. As the frontrunner and industry leader, Protix has laid the basis for a broad range of applications in feed and food. The company is now expanding internationally to deliver its solutions on a much broader scale.

Insects are part of the natural diet for many animals. They are a source of valuable nutrients that contribute to healthy growth and development. The larvae of the black solder fly contain more

nutrients than the larvae of other insects because the mature insect does not eat, and has to live off the accumulated reserves. The black soldier fly larvae are able to efficiently convert feedstuff into valuable biomass.

Currently, the protein in animal feed is derived largely from soy and fishmeal. But these use up large amounts of land and water, and there are issues surrounding greenhouse gas emissions, deforestation and overfishing. Alternative sources of protein are needed that are more in tune with nature. To address this challenge, Protix is pioneering the industrial-scale use of insects as a sustainable alternative that brings the food system back into balance with nature.

Benefits of black soldier fly larvae as a sustainable protein source:

- Locally produced
- Efficient nutrient recovery from organic waste streams
- Efficient land use
- Low water usage
- Zero waste

PROTIX

YNSECT

Ÿnsect offers a longterm, sustainable, organic solution to accelerate protein consumption. Ÿnsect uses disruptive technology protected by more than 380 patents, to raise its mealworms in highly automated vertical farms. The company processes insects into high-end, high-value ingredients for the entire food chain.

At Ynsect, they use 98% less land and 50% fewer resources than traditional livestock farming, combatting climate change and biodiversity degradation, while still offering a healthy, premium, and plentiful protein.

How? The company has developed the vertical farm concept which allow them to cultivate our mealworms in a zero waste circular economy model. Their vertical farms are fully automated by robots which feed, harvest and process the insects. Ynsect is committed reduce GHG which extends to the entire supply chain.

Their mealworms are excellent at converting side-streams from breweries and grain- and oilseed processing industries into high quality nutrition. This is continuously a reason for research, as legislation may change and new streams may become available here or in other countries.

Ÿnsect NL developed AdalbaPro, a functional, nutritious, tasty and sustainable ingredient range for human food derived from insects. The ingredients can be used for baking, sports nutrition, pasta, meat alternatives, and many more.

Ynsect

Cellular agriculture

Cellular agriculture is a new emerging technology. It had been developed in the former century in The Netherlands and has developed since. Cultured meat (also known as 'cultivated' meat) is an emerging area of this biotechnology application that aims to address environmental, sustainability and animal welfare issues associated with traditionally reared meat production, by growing meat directly from animal cells, while reducing the dependence on animals in the process. As seen in the vision of the Respectfarms, a concept where farmers produce meat at their own local farms using cells to sustainably transform our food system by integrating the best out of the conventional and the cellular agriculture industry. Respectfarms is currently conducting feasibility studies to find out whether producing cultivated meat decentrally (on a farm) is possible.

MOSA MEAT

Mosa Meat is a Netherlands-based food company pioneering a cleaner, kinder way of making real beef. The team introduced the world's first cultivated hamburger in 2013, grown directly from cow cells. The process starts by drawing a sample of cells from a cow without any harm to the animal. The most active adult stem cells are then introduced to a nutrient-rich broth held at the temperature of the animal (38°C), which triggers them to do what they do in nature, multiplying by orders of magnitude. Next, the cells are introduced to additional nutrients that trigger them to grow into muscle and fat, which is combined to make the same burgers or meatballs that consumers love.

While their 2013 burger sparked entrepreneurs worldwide to use the technology to make a variety of animal proteins (mostly chicken), Mosa Meat has stayed laser-focused on the hard task of making beef because of the contribution of industrial scale cattle production to the climate crisis. Peer-reviewed life cycle assessments have shown that when using renewable energy, cultivated beef uses 95% less land, 78% less water, and produces 93% fewer greenhouse gasses than conventional cattle operations.

Mosa Meat's production facility operates on 100% renewable energy and they have recently become the first B Corp certified cultivated meat company in the world. As they wait for regulatory approvals in various regions, the company is focused on reducing the cost of the cell feed so that Mosa beef can reach price parity with conventional beef in restaurants and grocery stores.

As the cell feed is based on nutrients from arable crops, the company is exploring partnerships with suppliers that will drive new revenue opportunities for farmers in Europe and beyond. Mosa Meat is transparent that cultivated meat is not a silver bullet, but in combination with green reforms to conventional agriculture, it can be a powerful complement to the solutions toolbox for reforming the food system.

Mosa Meat

Ynsect The Netherlands

Applications of biomass

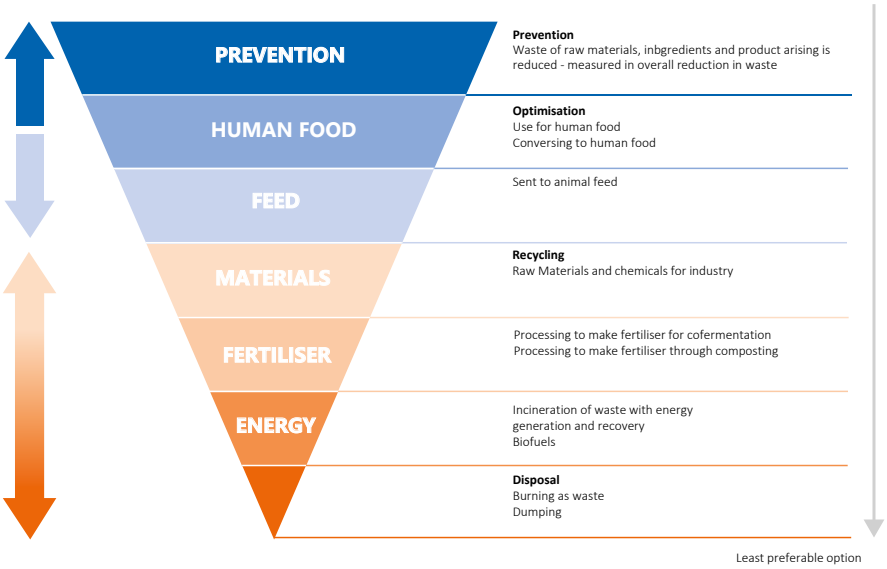
3.1 Bioeconomy

A circular bioeconomy is an economy powered by nature. It is a new economic model that emphasises the use of renewable natural capital and focuses on minimising waste, replacing the wide range of non-renewable, fossil-based products currently in use. Recycling and re-use is important, but there is also a need for new sustainably sourced bio-based raw materials (WUR, 2022).

Biomass should be used in a smart way, including cornstalks from arable farming, beet pulp from the sugar industry, grass, pruning waste and all kinds of other residual flows from the food industry. These should be used to make useful products that replace fossil resources. For example, bio-asphalt, board material for construction and composites for the automotive industry; and also biobased plastics and plant-based chemicals such as lubricants, soap, paints and coatings. Because we can use biomass for many more applications than just energy, it first of all is necessary to know what we can do with which biomass resource.

We have to get our priorities right for the limited feedstock we have. As interests and needed investments are high are ecosystem shifts are complex and politically sensitive we urgently need an assessment framework to ensure that most biomass is allocated to the right application. Because the Netherlands, as a small densely populated country depends on the import of biomass for achieving our goals in terms of sustainable and healthy food, energy, climate and circular economy, we need to focus simultaneously on limiting the demand for biomass for energy by focusing on saving energy and electrification, where possible and cascade use of biomass.

It is the vision of Wageningen University & Research to use biomass as much as possible according to the cascading principle, i.e., with the highest possible added value for nature, soil, people and society. When applied for materials and chemicals, we always first check whether this waste stream is still suitable for human consumption; then if it is useful for cattle feed or pet food, materials and chemicals; and finally, whether it can be used to make biofuels. Burning for



heat and electricity production is the last choice of application. Obviously, this must be within the limits of nature. Effectively this approach implies the bulk of the biomass must be used in chemicals, materials and animal feed (WUR, 2020).

3.2 Valorisation for replacement of raw materials

In order to meet with environmental and societal needs, alternative sources need to be developed next to animal-based meat, dairy, fish, and eggs.
This doesn't only apply to the intake of food but also to other products and materials. Bio-resources, renewable sustainable biological resources (like biomass) will therefore become increasingly important in replacing the traditional fossil based materials or in substituting raw materials with higher impact. Bio-resources can find applications as for example biobased building materials, textiles and chemicals. Chemistry today is an industry without a sustainable alternative. Biomass has a carbon "C" molecule. In combination with an "H" molecule from for example green hydrogen all of today's fossil based molecules could be made renewable or carbon neutral using biomass or captured carbon (CCU). The volumes needed to realise a vision for a carbon neutral chemical sector in 2050 are enormous and can create a pull factor in the market. However, the use of biomass is limited due to finite land, water and nutrient (nitrogen, phosphorus) availability

There is an urgency to move to a society that is fossil free and circular. Careful choices have to be made how to use the available biomass in our economy for applications other than food. There is a level of competition between the various functions of biomass and increasingly for the use of biomass for achieving climate policy goals. In countries like the NL biomass is relatively scarce. We have to learn from the example of market stimulated palm oil production, where tropical rainforest was replaced by palm oil farms with a significant negative impact on climate and biodiversity. We have to balance the various interests like food, feed, chemicals and materials, fuels and energy and impacts in terms of feeding the planet, climate, biodiversity or resource resilience and get our priorities right for the limited feedstock there is and how to use it. Could we for example restrict the growth of crops for bio-materials to land not suitable for food production? It is important to discover the full potential of all varieties of sustainably sourced biomass, including residual biomasses like crop residues, industrial side-streams, and food waste (FAO, 2019), as well as organic municipality waste by transforming it into value-added products. The resulting bio-based product selection consists not just more food and feed, but also chemicals, materials and bio-based fuels.

No Palm Ingredients

NoPalm Ingredients is a start-up brewing a better world by upcycling agri-food waste streams into sustainable palm oil alternatives. While palm oil is recognised as an excellent product thanks to its versatility and affordability, FMCGs are seeking palm alternatives driven by increasing CSR pressure, volatile and increasing prices as well as growing supply chain risks.

In addition, food waste is an issue with 30-40% of all food being unconsumed and accounting for 8-10% of global GHG emissions. NoPalm Ingredients developed an efficient fermentation platform that solves two challenges with one solution: 1. cutting down agri-food waste, 2. producing sustainable, circular, and local alternatives to palm oil, reducing CO2 equivalent emissions by 90% and land use by 99% compared to palm oil.

NoPalm Ingredients solution is fully circular and contributes to a world with zero waste.

The start-up can upcycle many agri-food waste streams, as long as they contain sugars, organic acids or alcohols. Today, about 15 various materials have been successfully screened (orange waste water, chocolate wastes, rejected vegetables, brewer spent grain waste water, dairy wastes, waste cooking oil...) and by tweaking the fermentation and extraction process, NoPalm Ingredients can produce a wide variety of custom-made oils and fats applicable in food, cosmetics, and home care products.

Next to that, a significant part of the biomass entering the system is left at the end with a higher protein concentration. This is a game-changing approach that not only helps to reduce waste and provide sustainable alternatives to palm oil but also provides a new sustainable source of protein.

By concentrating the protein content of the unused biomass, NoPalm Ingredients has created a viable source of human food. Circularity and fermentation are the cornerstones of NoPalm Ingredients' solution enabling cost competitiveness with palm oil, while delivering profound impact with 90% carbon footprint reduction.

NO Palm Ingredients

3.3 Biomass processed bioproducts

Materials

Bio-based materials are wholly or partly derived of biological origin, excluding materials embedded in geological formations and/or fossilised. In industrial processes, enzymes are used in the production of chemical building blocks, detergents, pulp and paper, textiles, etc. By using fermentation and bio-catalysis instead of traditional chemical synthesis, higher process efficiency can be obtained, resulting in a decrease in energy and water consumption, and a reduction of toxic waste. As they are derived from renewable raw materials such as plants, bio-based products can help reduce CO2 and offer other advantages such as lower toxicity or novel product characteristics (e.g. biodegradable plastic materials).

Construction

In the production of conventional building materials such as cement, concrete and steel, enormous quantities of carbon dioxide are released. The significant advantage of bio-based building materials is that they retain carbon dioxide (WUR, 2019). The pursuit of green buildings is characterised by widely accepted approaches such as limiting the use of raw materials, minimising pollution, and increasing energy efficiency. Bio-based materials such as wood and bio composites are increasingly replacing conventional building materials. In 2017, over 60% of all bio-building materials came from forestry. Through new material developments, it is now possible to produce a multi-story building from biobased materials. Inspired by the environmental advantages of wood construction, the city of Amsterdam in the Netherlands recently passed ground-breaking legislation mandating that all new buildings constructed after 2025 consist of at least 20% wood or other biobased material Furthermore, the heat insulation performance of bio-based insulation materials can compete with mineral or fossil-based materials, such as rock wool, glass wool and polystyrene. The technical performance of several renewable insulation materials, such as cellulose and fibres from hemp, flax, kenaf and cotton, is comparable to that of the mineral benchmarks.

ChainCraft

Chaincraft produces valuable circular chemicals, in the form of medium-chain fatty acids (MCFA), out of organic waste streams. A big step forward compared to composting or digestion of organic waste to biogas. For the last decade, ChainCraft has worked on this disruptive circular innovation, scaling up from laboratory via pilot scale to a commercial demonstration factory, capable of manufacturing up to 2,000 tons of MCFA salts annually. Their vision is an industry in which all chemistry is circular with a mission to provide sustainable chemicals to improve our daily lives.

Their sustainable MCFA can directly be used to replace unsustainable MCFA from oleo- or petrochemical origin in animal feed or food Flavouring. In addition, it enables chemical companies to create more sustainable ingredients, such as bio-alcohols, bio-surfactants or bio-solvents, using our MCFA as a building block. Since the products are locally produced, they offer a supply chain benefit particularly for European customers. ChainCraft can utilise many types of feedstock to produce fatty acids.

They can diversify the sourced feedstock among various possible suppliers. The robust fermentation processes can handle more complex feedstocks. The feedstock used for our fermentation process is low-value organic waste material avoiding any competition with food. Since these side streams are aqueous (low active content) they are not suitable to use directly for animal feed. Most of the organic waste streams which can be processed by ChainCraft are currently going towards biogas production.

The gains of their solution for food processing companies are that it combines the valorisation of their residual flows with a strong reduction in their carbon emissions. Via ChainCraft's technology low grade waste streams are being upcycled into higher value products which can be used in agri-food-feed and chemical & material applications. Applications which can be served can be found in a.o. the following markets: home & personal care (surfactants), industrial chemicals (lubricants, plasticisers, paint & coatings), animal nutrition (antimicrobial additive for gut health) and flavour & fragrances (food additive).

CHAINCRAFT

Biobased Creations

Societal challenges such as climate change, subsidence, CO2 emissions and scarcity of fossil fuels demand new, sustainable solutions. The call for a more biobased and circular society and economy is getting bigger and more necessary. But what does a biobased future look like and how are we going to get there? Biobased Creations, by Company New Heroes, is a creative studio specialising in installations, projects and storytelling about the transition to a regenerative and circular world. Biobased Creations can think along with you about all aspects of the transition, from green energy to biobased construction, from a new economy to social innovations. During the Dutch Design Week the projects are presented in the Embassy of Circular & Biobased Building and host a program and discuss the road to a sustainable future for people, animals and nature.

Pavilion of mycelium

The Growing Pavilion is an iconic ode to biobased materials. The 10-ton CO2-negative and 95% circular structure is made up of five cultivated core raw materials: wood, mycelium, residual flows from the agricultural sector, cattail and cotton. By presenting each material as raw as possible, the pavilion has a very distinctive visual identity, organic texture and colour. It stands as a necessary and viable solution to reducing the use of fossil resources and its destructive impact on climate change. Stimulate the imagination to revolutionise thinking, doing and biobased building.

More than 100 biobased materials in one pavilion

The Exploded View Beyond Building is an exhibition in the form of a full-scale house made entirely of bio-based materials, circular construction methods and stories about the changing value chain of which it is part.

The Exploded View Beyond Building shows that a lot is already possible, affordable and manageable, that it is healthier for people and the world and that it is part of a much larger chain as an alternative to the current systems that are built on pollution and exhaustion. All materials have a label with the manufacturer and name of the product and a QR code that leads to the online materials library biobasedmaterials.org. Here you can find more information and in-depth information about all materials. Here you can also easily search for availability, now (approx. 50%), in the near future (approx. 25%) or future (approx. 25%). Nine of the materials from the house have been calculated by TNO in a research project into whether and how they can contribute to CO2 and nitrogen reduction in construction.

BIOBASED CREATIONS

(C) Lisa Wernaart

GreenInclusive

GreenInclusive produces natural raw materials on an industrial scale that are then processed into building materials, such as insulation boards. It was founded to shape natural value chains in the Netherlands with the aim of making a functional contribution to the national emission targets, creating prospects for the agricultural sector and being less dependent on (fossil) raw materials from abroad.

Together with Dutch farmers they produce these materials in a short and closed value chain, they capture a large amount of CO2, which will be sold in the form of CO2 certificates. The proceeds from the valorisation of CO2 certificates flow back to the participating farmers in order to guarantee them a higher and sustainable income.

GreenInclusive focuses on strengthening the regional economy by shaping all business activities in the Netherlands. In this way they keep the chain short and efficient and are able to take back the biobased building materials at the end of the use phase and reuse them as primary or secondary raw materials in high-quality products. The natural insulation materials that GreenInclusive produces for the construction and insulation task of the Netherlands are made from hemp fibers produced by Dutch farmers. The insulation product is suitable for insulating roofs, walls and floors. This makes it an excellent replacement for mineral insulation materials that have an undesirable impact on our environment.

The production of natural raw materials is realised in collaboration with both dairy farmers and arable farmers. Fiber hemp is an excellent dormant crop for arable farmers, so there is no competition with food production. Hemp has added value because no artificial fertilizers and no chemical pesticides are used, which benefits the subsequent food crops. For dairy farmers who have to extensify, this means that they need new income to remain economically viable. GreenInclusive can provide them with the proceeds from growing hemp, supplemented with a CO2 surcharge.

By setting up this value chain in the Netherlands, GreenInclusive is responding to the ecological and social challenges of the coming years. Making the built environment more sustainable and insulating, the required transition of the agricultural sector and contributing to the national emission targets are reflected in the objectives and policy of Green Inclusive.

GREENINCLUSIVE
Gewoon natuurlijk

GreenInclusive

CIRCUROAD: value chain collaboration for bio-based CO^2-reducing asphalt

In the CHAPLIN program, companies, governments and knowledge institutions work together to replace bitumen, the fossil binder in asphalt, with bio-based raw materials that greatly reduce CO2 emissions.

Greening the road construction industry

An example of a biobased raw material that functions as a binder in asphalt is lignin. This substance provides strength in wood and plants and is released as a residual stream during the production of paper and cellulose, among other things, but also in biorefineries. Lignin takes carbon dioxide from the atmosphere and when it is incorporated into asphalt, it captures the CO2 in the road for a long period of time. In this way CHAPLIN makes an important contribution to greening the road construction industry and leads to CO2 reduction.

In addition, CHAPLIN offers the road construction industry an alternative raw material. Improvements in petroleum refining processes are putting pressure on the quality and availability of the residual product bitumen. This effect is further amplified by geopolitical tensions.

Scaling up & industrialisation

The replacement of bitumen with a bio-based binder requires highly innovative new technologies with which CHAPLIN members have already achieved several successes. The bio-asphalt concept with lignin is now being scaled up and industrialised.

In addition, the CHAPLIN partners gain insight into the climate- and environmental performance of lignin-based bio-asphalt. So far, these are very promising. The calculations have shown that CHAPLIN can already achieve a CO2 reduction of up to 75%. There are 136,000 kilometres of asphalt in the Netherlands alone, so the potential of this innovation is huge.

Collaboration across the value chain

The uniqueness of the CHAPLIN program is that the entire value chain is represented. CHAPLIN consists of companies, and governments, supported by research and technology organisations. CHAPLIN partners develop the technology and stimulate the market introduction to make a major contribution to sustainable road paving. As from June 2023 the CHAPLIN program will be adopted by the Dutch Department of Public Works (Rijkswaterstaat).

Building Balance

Building Balance is the national programme for stimulating the conversion of biomass into building materials and to accelerate the upscaling of the use of biobased raw materials in construction. To this end, work is being done in regional field labs that must grow into a profitable chain, using existing initiatives as much as possible. Building Balance is a transition program that traces as many regional starting initiatives as possible and then actively helps them develop a complete chain. These eye-turning initiatives often start on the agricultural side (push projects) or start on the construction side (pull projects).

FRUITLEATHER ROTTERDAM

Fruitleather is a company that focuses on developing sustainable leather-like material, made from fruit waste from the port of Rotterdam. With this they contribute to the circular economy by reducing food waste and promoting the use of renewable raw materials.

They have a multitude of drivers to embrace circularity. First of all, as a company Fruitleather wants to have a positive impact on the environment and contribute to a more sustainable future. “Fruit” and “Leather” connect two worlds in which the waste of one industry is used to radically change the polluting system of the leather industry.

At Fruitleather Rotterdam they handle the cascading principles of biomass use with care. This means that they strive for the highest possible use of fruit waste, looking first at applications in the food chain before using the waste for the production of our leathers. In addition, it ensures that there’s as little residual waste as possible and that this is done in a processed in a sustainable manner.

In comparison to a non-circular approach, the circular approach offers several advantages. This way they reduce food waste and make less use of non-renewable raw materials. In addition, the use of fruit waste contributes to reducing CO2 emissions. Fruitleather Rotterdam offers leather processing producers (and therefore consumers) an alternative to the current ± 18 billion m2 of animal leather that is produced each year. Fruitleather Rotterdam thus contributes to reducing the ± 65 billion kilos of CO2 released during the production of animal leather.

Fruitleather Rotterdam is proud to be located in the Netherlands. In addition, Rotterdam has the most important North European Fruit Port. During the import between the producer and the port of Rotterdam as processor, more than ± 10% of fruit is wasted. In the transport to the wholesaler another 10%, and between the store and consumer there will be another 15% is wasted. Fruitleather Rotterdam helps the city to reduce its fruit waste a circular way.

FRUITLEATHER ROTTERDAM

Textiles

Renewable biomass sources, including natural animal and plant fibers, recycled fibers, and synthetic fibres, can be used to produce biomass fibres. Bio-based fabrics can be a substitute for petroleum-based fabrics. The textile industry is a significant polluter, releasing carbon dioxide, chemicals, and microplastics into the environment. As a result, the demand for high-performance fibres made from plant-based materials has become essential together with the reuse of petroleum based fabrics. Bio-based textiles are produced using a range of technologies that extract starches, sugars, and lipids from sources such as corn, sugar cane, sugar beets, and plant oils.

Chemicals

Between the chemical industry and manufacturers of biobased materials there is a joint search for biobased alternatives and renewable resources are becoming more widely available and can serve as a basis for new industrial chemicals. Biomass has a carbon molecule in combination with an “H” molecule (e.g. green hydrogen) all of today’s fossil based molecules could be made renewable or carbon neutral using biomass or captured carbon (CCU). It is a complex transition requiring renewable energy, green hydrogen and a feedstock transition. Quality, quantity, consistency and continuity of availability and cost of feedstock like biomass are important aspects in building a new value chain for the chemical industry. The volumes needed to realise a vision for a carbon neutral chemical sector in 2050 are enormous. Business models in todays linear economy might favour fuel or energy applications whereas a transition needs to be towards higher material and chemical applications that do not compete with food.

PEELPIONEERS

Since 2017, PeelPioneers has been processing orange peels that remain after squeezing fresh orange juice in the supermarket or restaurant/hotel. They upcycle 100% of the peel into new ingredients for processing into food, cosmetics and cleaning products that end up back in the supermarket. In addition, they recycle the water that remains after the production process to use in animal feed.

Upcycling 100% of the peel for human consumption and use, ultimately saving all orange peels from destruction. PeelPioneers want to achieve this, among other things, by building a factory at the source, where oranges grow. They are going to build a second Peel factory in Spain next to the factory in the Netherlands. They extract raw materials from peels, namely oil, citrus fibre and orangade (sugared cubes of the orange peel) that are used in end products. So the focus is on recycling and partly on reuse, according to Lansink's Ladder.

If you look at the circular business models, PeelPioneers is in the long loop creating more value from residual flows. PeelPioneers is more than just a company that upcycles citrus peels into high-quality ingredients. They are a closed loop company focused on creating value by recovering used resources from discarded products. In circular business models like ours, value creation is based on the principle of recycling waste streams and increasing value. This process focuses on recovering value in the post-use phase, where someone's residual flow or 'waste' is our raw material and is central to creating a new life cycle after processing. This is partly possible due to one of our key PeelPartners Renewi who takes care of the logistics part; the delivery of shells.

Through its innovative approach, PeelPioneers demonstrates that it is possible to create value while being environmentally conscious and at the forefront of closed-loop business models. They are constantly working on optimising sustainability in our company, such as sustainable coffee, waste separation and paper made from recycled material. In addition, they use refurbished machines and equipment and give them a 'second life'.

PeelPioneers

Biorizon: The profitable way to bio-aromatics

Shared Research Center Biorizon, an initiative of TNO and VITO, has been co-creating technologies for the production of bio-aromatics at the Green Chemistry Campus since 2013. Together with industrial partners, Biorizon creates and develops innovative chemical processes for the production of renewable aromatics from residual biomass.

Aromatics are important building blocks for the chemical industry: no less than 40% of chemicals are aromatic, and they bring essential functionalities such as durability and thermal and UV stability to products like plastics, resins and coatings. Bio-aromatics provide new functionalities and an impactful and green alternative for current petrochemical products that are difficult to re-use or recycle, including paints, adhesives and lubricants. Their aim is to enable commercial production of bio-aromatic building blocks by 2025.

Biorizon collaborates with global feedstock providers, technology developers, process operators and brand owners to make commercial production of bio-aromatics feasible by 2025. Biorizon is currently validating its continuous processes and working towards the next stage: demonstration. This makes Shared Research Center Biorizon the most advanced and valued research program in bio-aromatics worldwide.

Highlights of Biorizon's research horizons

- Thermochemical Conversion of Biomass to Bio-Aromatics: Extensive piloting of gasification-based BTX co-production and pyrolysis-based lignin to bio-aromatics to allow technology scale-up and bio-aromatics application development. First industrial application testing shows promising results.
- Sugars to Bio-Aromatics: High quality facilities & focus on scale-up enable the continuous production of novel specialty aromatics. Samples are available at the multi-kilogram scale.
  Application testing by companies shows promising properties for adhesives, polymers, coatings and lubricants.
- Lignin to Bio-Aromatics: In 2022, the 'LignoValue' pilot plant for metal-catalyzed depolymerisation was delivered with an output of 10 kg/h to provide input for the development of lignin-based biopolymers and additives.

Biorizon
The way to aromatics

Bioplastics Hub
The Bioplastics Hub gives a clear overview including insights in the value chain, sourcing, production techniques, sealing and barrier properties, LCA's, end-of-life options and offers microplastics prevention expertise. With bioplastics we refer to nature-smart materials based on biomass, biowaste, microbes but also CO2 or methane based materials.

Experts with in-depth packaging knowledge are on hand for supporting the transition from fossil based to nature-smart materials. Learn which benefits or extra features these innovative materials can offer, get connected to producers or supply chains, learn more about microplastics issues or the recycling of bioplastics.
The Bioplastics Hub operates completely independent and for Dutch startups and SME companies free consults are powered by the Dutch government (ChemistryNL).

Bioenergy/Fuels

In many countries there is a large amount of potentially combustible residual waste still disposed of in landfill. In fast developing countries more than 50% of the landfilled waste is of organic nature. According to the Lansink Ladder or the waste hierarchy instead of landfill more favourable treatment options are prevention, minimisation, reuse, recycling and energy recovery. For organic waste, separate collection followed by composting or digestion is a common and established practice.

This organic matter has the potential to be used as a source of energy, bioenergy. Bioenergy can be used in a variety of ways heat and power generation, biofuels and biogas. One of the benefits of bioenergy is that it can be produced locally, which can help to reduce dependence on imported energy sources. Residual waste containing organics is often incinerated in waste2energy plants delivering (partly) renewable energy and heat. However, this is country-dependent and those countries that first built facilities for burning non-recyclable waste see the market leading to the import of waste to feed these plants in Germany, Denmark, Sweden, Norway, the Netherlands and Austria (Leeuw & Koelemeijer, 2022).

Biofuels are derived from organic matter such as plants, algae, and animal waste, which are processed over a short time span to produce liquid fuels. While biofuels have the potential to play an important role in reducing greenhouse gas emissions, their production is not without challenges. While they are easy to produce, their use has been controversial due to concerns about the impact of diverting food crops for fuel production. On the other hand, second-generation biofuels, are made from non-edible sources such as waste biomass and algae.

HoSt and Infinrg

HoSt & infiNRG are pioneering advanced solutions to address organic waste concerns and to promote a sustainable future.

Organic waste comprises over 50% of the world's total waste, leading to a concerning increase in atmospheric greenhouse gas (GHG) concentrations and emissions, reaching levels unprecedented in the past million years. Organic waste management is a significant challenge for corporations in Asia, where the volume of waste generated is growing at an alarming rate.

The innovative HoSt technology transforms organic waste into a range of valuable energy commodities, including renewable and bio-based energy, liquid CO2 for the food and beverage and chemical industries, and biologic fertilizers.

HoSt is the only global company offering a comprehensive technology portfolio for the bioenergy sector, boasting over three decades of experience in the development and operation of biogas upgrading and biogas production from Anaerobic Digestion technologies. As a result, a proof of concept has been deployed in nearly every continent with over 350 upgrading installations.

However, the biggest distinction is that HoSt and infiNRG are investing up to 100% in the HoSt technology with a build own operate business model to deliver renewable fuel at any specification.

The main drivers are the movement towards a zero-waste society and the reduction of GHG emissions to slow down global warming and adhere to the Paris Climate Accord.

Their aim is to offer the most circular solution to handle the lowest value organic waste, that presents one the biggest challenges to organisations today.
Throughout Asia, there are various industrial sites such as wastewater treatment facilities, farms, and palm oil mills that generate significant amounts of organic waste. Unfortunately, this waste is often disposed of in nature, causing harm to the environment. However, by adopting the HoSt technology, local businesses can experience significant benefits compared to the non-circular approach. In particular, implementing HoSt technology can substantially reduce GHG emissions. In fact, for each location where HoSt technology is used, CO2 emissions can be decreased to a level that is equivalent to the emissions produced by several thousands of cars.

Ultimately, our efforts are aimed towards a reduction in commodities, which in turn will lead to less consumption of energy, water, nutrition, land use, and labor. This will result in a decrease in the global footprint and the direct GHG emissions at an industrial scale.

The Waste Transformers

The Waste Transformers is a Dutch innovative company - globally active - that is changing the status quo of dumping food waste to landfill. How? Their modular, containerised biodigesters called Waste Transformers, turn from 300KG of food waste up to 2500kg per day into renewable energy and a natural liquid fertilizer. That all happens on the site where the food waste is produced, turning an uncontaminated organic waste stream into a new revenue stream for that site.

The first step for businesses, such as resorts, communities, food production sites, airports and campuses, is to understand their own food waste situation. From there, food waste reduction is the next step. The non-preventable food waste treated in a Waste Transformer on-site saves CO2 from the avoided transportation of food waste to landfill. The food waste is transformed into biogas, which is turned into electricity and heat on-site, replacing fossil-generated energy. The energy is used by the organisation itself that produces the food waste. The nutrients in the food waste are turned into digestate, a liquid natural fertiliser, to replace chemical fossil-based fertilizers. The food waste based fertiliser contains the right nutrients, can restore arid land and increases the water-holding capacity of the soil.

Through the principles of a circular and social economy, you can create a sustainable future for generations to come. By their modular containerised Waste Transformers, a global problem is turned into local direct value. The placement of the biodigesters takes less than a week, and without the need for large structural changes, only an electricity cable, water and solid ground. The value generated by this on-site technology does not only cover the right waste management practices and renewable energy generation.

With a sample of the client's own food waste stream, predictions are given on energy production and fertilizer nutrient content. This allows businesses to understand beforehand what is currently being wasted, and what the positive financial impact could be on their operations transforming food waste inside their own Waste Transformer. They adhere to cascading principles, which means food waste should be reduced as much as possible. They take a careful and considered approach to identifying which waste materials can be repurposed in the most valuable way. Analysis of the food waste is conducted to ensure maximising the potential of all materials. They are constantly seeking out new and innovative ways to turn food waste into something useful, like vertical farm applications and together with UEFA making football stadiums in Europe greener.

The Waste Transformers

Future visions

In this chapter we present six inspiring visions in which the authors provide thought leadership, elaborate on the next steps, present a Call to Actions and open their networks.

Future vision 1 Re-rooting the Dutch Food System: from more to better

Imke J.M. de Boer, Professor of Animals & Sustainable Food Systems - Wageningen University

Animal Production Systems group, Department of Animal Sciences, Wageningen University & Research, the Netherlands

What does a regenerative and nourishing food system in 2050 look like? This was the challenge for those participating in the Food Systems Vision Prize launched by the Rockefeller Foundation in Winter 2019. Here, on behalf of our entire team, I present the main elements of our winning vision (for more detail please visit the website).

To re-root our food system we first need to define a clear set of environmental ceilings for our food system, to ensure that we produce and consume our food while not exceeding the carrying capacity of our ecosystems. Subsequently, we need to clarify our social foundation.

This implies answering the question: what rights for humans and other animals are essential to us?

For example, the right to have access to safe and nutritious food; or, in case we decide to keep farm animals; the right to live in housing systems that are adapted to them, instead of ignoring their needs. Our vision herein is inspired on the 'Doughnut-model' developed by Kate Raworth (Figure 1).

To shift our food system towards the space in between both circles, the so-called, safe-and-just operating space, we need three big changes. First, we need to shift from **linear to circular food systems**. To this end, we developed five key ecological principles (see Box 1) and applied these in our vision. Applying these principles calls for fundamental changes, such as intercropping instead of monocropping, safely recycling (nutrients in) our own poop back into the loop, but also stop feeding crops to animals that could have been consumed by humans, such as grains (for details see full vision).

Five principles to guide us towards a circular, biobased economy (Muscat et al., 2021)

1. **Safeguard.** This principle addresses the importance of safeguarding and regenerating the health of our ecosystems. Biomass production, being the basis of the bio-economy, requires healthy aquatic, arable, grassland, and forest (agro)ecosystems.
   To safeguard the health of these systems, farming, fishing and forestry practices must utilise natural resources at a rate that does not exceed their regenerative and absorptive capacity, to ensure current and future availability of natural resources.
2. **Avoid.** This principle addresses the importance of avoiding the production and use of non-essential biobased production, and the losses and waste of

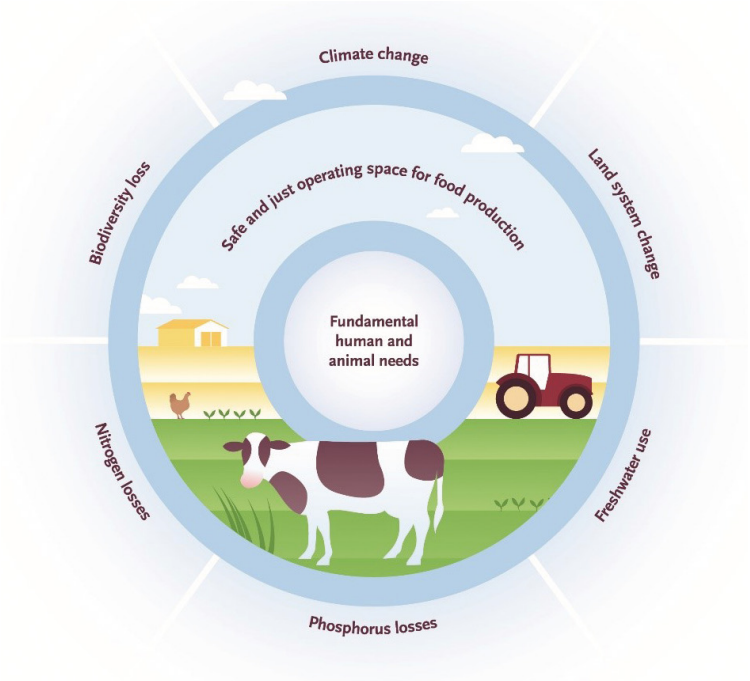


Figure 8. Clarifying the safe-and-just operating space for the food system (inspired by Raworth, 2017).

essential ones. Avoiding non-essentials can prevent unnecessary exploitation of natural resources, especially as impacts of production are unlikely to be fully offset by recovery and recycling.

3. **Prioritize.** This principle addresses the importance to use biomass effectively. It refers to the priorities in use of biomass. It argues that priority should start with basic human needs (e.g. food, pharmaceuticals, clothes) and sectors without sustainable alternatives (e.g. chemical industry).
4. **Recycle.** Even if waste of food and non-food bioproducts is avoided, the production and consumption of essential food and non-food biobased products results in by-products, such as crop residues, manure, human excreta or slaughterhouse waste. This principle calls for nutrients and carbon from by-products to be effectively (see prioritize) recycled into the biobased system.
5. **Entropy.** The driving force behind the recycling of nutrients and carbon in (agro)ecosystems is energy. Increased circularity and recycling costs energy and a fully circular bioeconomy is difficult to achieve given the loss in consecutive cycles. This principle not only advocates moving towards renewables, but also stresses the importance to minimize energy use.

Second, we need to **re-connect people to their food**; so that everyone is aware of how their food is produced; third, we need **a new economy**; an economy that goes beyond gross domestic product, but serves the planet and all its inhabitants. We need to adopt a richer range of indicators to express what is valuable to our society and planet.

Moving the food system towards this future will require action by a broad range of stakeholders, such as farmers, the food industry, retailers, financial organizations and consumers. While many market and civil society initiatives will play a crucial role in achieving our vision, the government will have taken its responsibility by having the courage to define the safe-and-just operating space for human activities, including the food system. Knowing the operating space and associated long term-policy goals provides clarity to food stakeholders and enables them to make informed decisions and meaningful investments. We then can produce and eat our food within the planetary boundaries of the food system and respect the essential rights of humans and animals.
Such a fundamental shift in our food system will not be possible without the energy and spirit of many food system stakeholders. By connecting to our roots – our healthy agroecosystems, and our capacity to collaborate – we will have collectively realized a healthy and regenerative food system in the Netherlands.

Future Vision 2 Showing leadership in orchestrating the circular agrifood systems change journey in practice

Jolijn Zwart-van Kessel - Innovation Lead Circular Agrifood, Foodvalley

The urgency is clear. We face a huge challenge: by 2050, the agri-food sector will have to feed more people. We even know what we need to do to achieve this. Production must increase, but in the meantime, the way we produce our food must become more sustainable and in sync with nature, and the food this agrifood system produces must be healthy, affordable and within reach for all the inhabitants of our planet.

It is the "HOW" for which we need a vision.

This is where Foodvalley NL stepped in as an independent organisation in 2004. In our international network with more than 400 partners, in our communities and initiatives, we see what is happening and what is missing. Individual partners cannot solve the challenges they face alone. They need a transition of the entire food system. And we know this because the transition in food has been happening for centuries. In recent decades, agriculture and food technology have been moving toward efficiency and economies of scale. This is still necessary, but we also need to include a more balanced way of producing food.

Our vision for the 'HOW' lies in a practical approach. A journey, mobilising partners based on a common narrative for ambitions, with a willingness to learn, participate and ultimately join forces in collaborative action. In showcases that demonstrate the feasibility of innovations and engage others to join in. This journey is not a straight line, but rather a winding road. Sometimes we can take shortcuts, sometimes we need a detour to avoid roadblocks.

For Circular Agrifood, this works as follows.
The common ambition of our partners is tasty, healthy food for all, produced in a sustainable way. This means:

1. Within planetary boundaries: Corporate social responsibility is a given;
2. With vital business and healthy sustainable sectors: Farmers, feed & food companies and food service and retail have organised a quality supply for consumer demand and fair supply chains for all partners in the agrifood system;
3. With us people as consumers willing and able to adapt our behaviour and eating preferences.

As Practice Leader, Foodvalley NL brings together unlikely partners from farm to fork. It's about new circular agrifood innovations that emerge from a collaborative and cross-sectoral way of working.

We lead communities where partners share experiences, inspire each other, co-create and set the agenda. In initiatives, our partners turn thoughts and ambitions into reality. Foodvalley identifies what they need, who can help each other further and mobilise for collective action around specific themes. Examples:

1. **Regenerative sourcing:** innovate value chains for sourcing raw materials that facilitate farmers to produce in a regenerative way to maintain biodiverse, healthy water and soil balanced landscapes and social livelihoods;
2. **Insects:** can be used as upcyclers to turn non-eatable side streams even for feed into a valuable alternative protein with a new sector emerging;
3. **Upcycling:** Food loss is prevented because side streams no longer exist. They are all regarded as valuable resources and used 100 percent for agrifood production just like raw materials;

This is what happens at Foodvalley NL every day.
The good news is that we see that the transition is in full swing, but we need to move faster and with more commitment along the whole value chain! As Practice Leader, we want to highlight innovative examples that give a glimpse of this new circular agrifood system in practice. This brochure highlights some great examples from several of our Foodvalley NL partners. Join us on the journey to shaping the future of food together!

www.foodvalley.nl

Foodvalley
Shaping the Future of Food Together

Future Vision 3 Rabobank Circular Economy in Agrifood, a bankers perspective

Although we produce more food than ever before, our food system is under stress. In the coming twenty to thirty years the global demand for food will grow by at least 50%. Meanwhile climate change threatens predictable growing seasons, farmer livelihoods, soil health and biodiversity. About one third of agricultural land is under pressure due to urbanisation and desertification. And an estimated one third of food produced globally is lost or wasted, while almost 800 million people suffer from permanent hunger.
These challenges demand action and structural transition of our food system towards a more circular economy in agrifood, with more reuse of (raw) materials & commodities and less drain on the planet's resources.

To realise this we see, from a bankers perspective, two major challenges. First of all, laws and regulations are lagging behind market developments. For example; to upgrade residual flows from 'garbage' to food or feed, permits are necessary and new food products need to be validated according to 'novel food regulation'. Secondly, our current linear system is too focussed on (short term) profits and cashflow of the individual business. While the more long term benefits of a circular business model, including the positive external effects on the chain and environment, are not always taken in to account. We need new business models and new ways to finance them.

To tackle these two major issues Rabobank operates at three levels:

1. Financing a circular business demands other types of funding than a traditional linear business model. So we have developed so-called Innovation-loans (for innovative start-ups) and Impact-loans (for sustainable frontrunners), but we also work together with equity funds to provide blended funding solutions. We established a Circular Business Desk, to help entrepreneurs with the circular transition.
2. Knowledge: providing enterprises with relevant research, tooling and programs.
   - research: our worldwide operating RaboResearch analysts and economists provide in-depth publications on all developments in agrifood.
   - tooling: with our Circular Opportunity Maps we provide practical insights for companies in specific branches of the agrifood chain.
   - programs: together with our partners we offer entrepreneurs the possibility to follow the Business Innovation Program Food; a hands-on program for SME in agrifood to start with sustainable innovation.
3. Networks: connecting groups of entrepreneurs, knowledge institutions and governments to cooperate on circular innovation and business development and to share insights on circular themes. From the idea that one's garbage or waste can be the input or sourcing for another, we started regional Circular Business Challenges. To bring together various food and non-food enterprises in a region, to form new alliances and to develop circular solutions. And on a national scale we started the Food Forward Membership, creating an ecosystem of game changers in agrifood.

Achieving a sustainable world requires an inclusive approach, as an organisation in our daily work and in the relationship with our clients. We cannot change the world ourselves, but our clients can. So by offering our clients knowledge, network and finance, we help them in their transition towards a more sustainable, circular business model.

More information:
https://www.rabobank.com/sustainability

Rabobank

Future Vision 4
The Dutch Association of Young Farmers

Food and agriculture are inextricably linked. Agriculture and horticulture are at the base of our food chain. Without agriculture there is no food. People from all over the world come to the Netherlands to learn about our agriculture and Dutch people go abroad to transfer knowledge about food production. A number of major challenges await us in the coming years. For example the growing world population, climate change and the soil challenge. But also human health. This requires cooperation. Cooperation in the agricultural and horticultural sector, but also in the food chain (including government). We, young farmers and horticulturists, want to continue to practice our profession in 50 years, want to continue to provide society with the (healthy) basic need: food. The Dutch Association of Young Farmers (NAJK), the young farmers association, sees the following change in the food chain:

1. **The farmer of the future is increasingly connecting food and healthcare**
   In the Netherlands, the availability of food is high and the purchase price is low. However, (welfare) diseases, such as obesity, are becoming more and more common. On the other hand, many consumers are looking more and more critically at the production and processing of food. We (the producers) cannot solve a large part of the health problems, but this is partly a task for the farmer. Food (consumption) is increasingly linked to (preventive) health care.

2. **The farmer of the future is both organic and conventional** Conventional agriculture and the organic sector are learning more and more from each other. Conventional agriculture is increasingly focusing on natural processes and the organic sector is increasingly focusing on efficiency. The Dutch farmer, both conventional and organic, produces within strict rules. Since the demand for non-conventionally produced products is limited, switching is sometimes financially unattractive or even impossible for both the agricultural entrepreneur and the economic stability of the sector. The farmer of the future determines the revenue model based on demand in order to keep the economic market stable.

3. **The farmer of the future is smaller or larger NAJK values the family business.** Within this type of company, there is often heavy investment, as the company is passed on to the next generation. In the future, food will be produced in those places in the Netherlands where there is support for it. This can lead to smaller initiatives (such as urban agriculture), but also to efficient larger companies, where food is produced in a transparent manner.

4. **The farmer of the future works circularly**
   The farmer contributes to solutions for the climate problem in various ways. New techniques are used for this. The farmer of the future is also increasingly aware of the soil. The soil is the most valuable raw material for the farmer and food production. We have to keep these together in good condition. Livestock farming also plays a role in this. The valuable fertilizers are necessary for growing food crops. In addition, animals convert proteins unsuitable for human consumption very efficiently.

5. **The farmer of the future produces what consumers demand**
   The agricultural entrepreneur is increasingly being able to monitor for which products there is a market. Farmers will continue to market their products to market parties in the future, but some of the entrepreneurs will also supply directly to consumers. In this way, the wishes that exist within those markets can be met even more. Differentiation plays a key role here.

6. **The farmer of the future explains**
   The farmer is pre-eminently a person with a great deal of knowledge and expertise in the production of food. Every agricultural entrepreneur must be empowered in his or her own way to produce transparently and to tell the associated story. Today's children, the consumers of the future, must come into contact with Dutch agriculture at an early age.

In order to shape the changes in the food chain, there must be cooperation throughout the chain. Putting our shoulders to the wheel, that's how we can achieve the best.

Future Vision 5
The Dutch Food System in 2040, a narrative.

Frederike Praasterink – professor Future Food Systems, HAS University of Applied Sciences

The Netherlands, a small country yet famous for its highly productive agrifood sector and its long history of cooperative entrepreneurship. First exporter of agrifood products in the EU and number two worldwide. One of the most food secure countries in the world. But we are at a tipping point. Not just in the Netherland but globally. The way we produce and consume food has a critical negative impact on diverse dimensions of social, ecological and economic sustainability. There is an urgent need for a food system transition that includes more sustainable food consumption patterns and production methods that can feed future generations while protecting humans, animals and regenerating nature and biodiversity.

Fortunately, lots of innovative entrepreneurs and innovators actively work on that transition. They use agroecological farming that restores (soil) biodiversity, produce plant-based proteins, work with food communities and food sovereignty, reconnect consumers through short supply chains, or upcycle waste streams to biobased materials. Increasingly groups collaborate to upscale these system innovations. All of this helps to collectively learn on how to redesign the food system to act within the social and planetary boundaries, to be regenerative, inclusive, circular and equitable. It is important to develop hopeful and inspiring images of the future that promote collective action to address current and emerging challenges.

This is the domain of foresight: futuring methods and tools that help structure the processes of exploring, imagining, and designing scenarios or desirable futures. Using the future is a skill that can be acquired. That is why 'futures literacy', a competence recognized and promoted by UNESCO as essential for the 21st century, is important in our education programmes. From our participatory foresight studies, and various literature sources, several aspects of future food systems emerge. Below is a brief future narrative. Not intended to be exhaustive, but to stretch our imagination about the future and give hope. And hope gives action perspective. That is crucial in this time of urgent global challenges, polarization and conspiracy theories. Especially for young professionals, like our students.

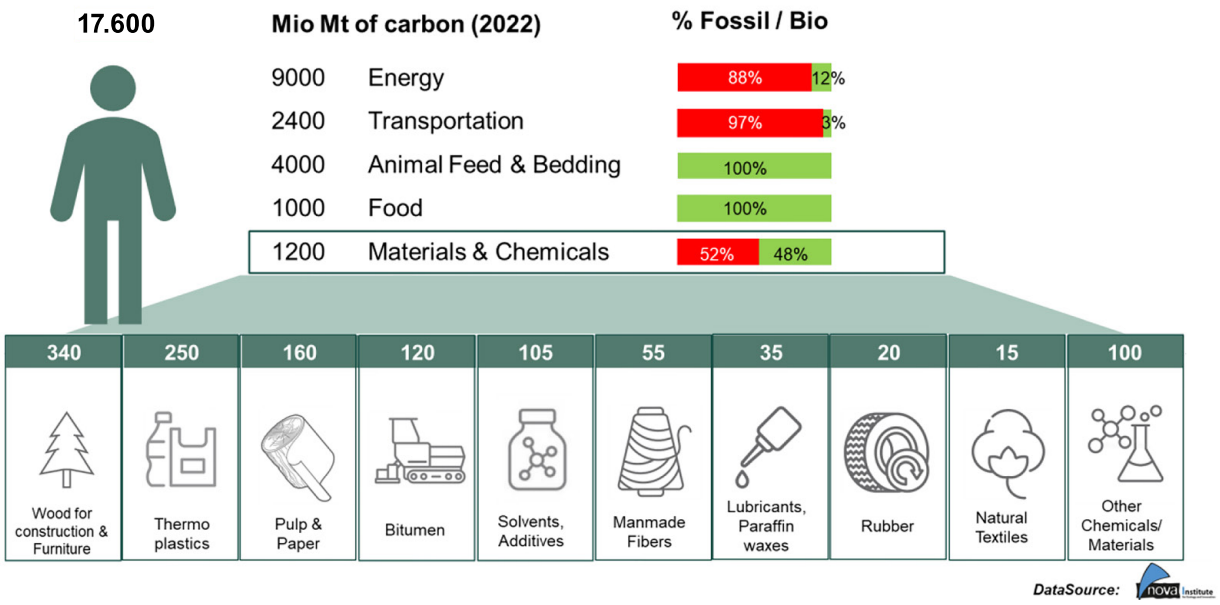
In 2040, a major agrifood transition in the Netherlands is finally completed. Whilst the transition started with the need to reduce nitrogen and greenhouse gas emissions, other targets like water quality and retention (even in the Dutch Delta!), and human health became part of an integral transition agenda that placed our agrifood system within planetary and social boundaries. Our consumption patterns have naturally shifted to much more plant-based foods: about 80% of our diets consist of a rich diversity of vegetables, fruits and legumes. All agricultural crops are used for human consumption and non-food applications like clothing and biobased materials. Nutrient cycles are closed at the level of NW Europe, and for imports of foods, a return system for minerals is developed to avoid depletion of soils elsewhere. The role of animals in the food system changed to 'processors of waste streams' and 'landscape managers' for areas around nature areas and marginal grasslands. With biodiversity, soil and water as leading principles, farming has become regenerative and nature-positive. Greenhouses became energy producers in addition to producing nutritious foods, rich in essential micronutrients.

Maybe the biggest change was the 'regeneration' of the position of farmers - they became valued producers of not just products but also ecosystem services. Up to 30% of our foods is produced locally and in connection with consumers. Cities have become climate-positive through an abundance of ornamental plants and trees in, on and around buildings. Some dynamics occurred when water, like all products, was re-priced to include all societal costs. This turned out to be a poweful leverage point. This lead to sustainable products becoming the cheapest. That, in turn, helped to incentivize sustainable farming practices and food security for all. Looking back from 2040, we effectively developed a 'new normal' in the agrifood sector. The production-oriented system, driven by profit maximization was replaced by a food system centered around health and wellbeing of people, animals and the planet.

Future Vision 6 Biomaterials: a blind spot in the transition to a fossil-free economy

Dorette Corbey and Dirk de Jong

Humans consume carbon for many different purposes, with energy being the largest. Consumption for materials is less than 10% of total carbon demand.



Measures to enable the transition to a climate-neutral economy mainly concern energy and fossil transport fuels. Rightly so, because these categories are responsible for a large part of carbon emissions. Materials have so far been a blind spot in the debate and in policies. Fossil plastics and building materials contribute significantly to emissions, as the figure below (from the NOVA Institute) shows. Biomaterials, in addition to recycling and reuse, are part of the solution. And they offer opportunities for Dutch business, both in agriculture and in the building materials and chemical sectors.

The transition to biomaterials will not happen by itself. The technology is largely available, but scaling up is too slowly. The causes are a lack of market perspective and of financing, and the uneven playing field with "fossil". There is still a tax exemption for petroleum as a feedstock for plastics while subsidies go to replace coal and gas in the energy sector. In addition, it is difficult for the emerging biomaterials sector to build chains. Fossil chains have been professionalized and optimized over the past 100 years: the bio sector, however, is still in its infancy. The report "Biomaterials, a blind spot" holds an inventory of chain building. The initiative for building new chains now comes mainly from starting companies that process agricultural raw materials and residual streams. In addition, some major brands such as Lego, Ikea and CocaCola are playing a role. Despite the historic strong organizational capacity in the agribusiness sector, there are still few initiatives to value residual streams and cultivated crops for materials production. This is a missed opportunity because cultivation for materials alongside cultivation for food and feed can contribute to better business models in agriculture. Processing companies suffer from uncertainty and the ongoing debate about bio-based materials: is there enough arable land available? The report 'Biomaterials, a blind spot' argues that the cultivation of bio-commodities can actually lead to greater food security. The government should help to kick start the biomaterials sector by:

- **Telling the story:** sustainable agriculture and biomaterials are both needed.
- **Contributing to the development of markets** by imposing a mandatory share of 'bio' in packaging, building materials or by setting requirements for products.
- **A level playing field** by better pricing of the negative effects of fossil fuels and by phasing out policies that focus unilaterally on green gas or biofuels.
- **More hands on support** by creating partnerships and by coordinated government action.

A Pathway to a circular future

This last chapter aims to translate intentions into actions by exploring the roles to be played according to the triple helix combination of actors. Which actions can governments and academia take today to move towards a towards a more sustainable and circular economy in the agrifood sector? What can business do? Food and materials for a sustainable future: that is where the transition towards a circular agrifood & biomass should lead us.

General measures for a circular system

In recent years, there has been a growing awareness of the need to transition. A circular agrifood system in which waste is minimized, resources are conserved, and materials are kept in use for as long as possible at their highest value. There are four general measures in which we can make our use of materials more circular:

1. Reducing raw material usage
2. Substituting raw materials
3. Extending product lifetime
4. High-grade processing

The examples and stories in this brochure showed that every actor in the triple helix (government, businesses, and academia) have a role to play to implement these general measures in order to transition towards a circular agrifood & biomass System. To work towards an integral agrifood and biomass circular economy all actors in the policy fields should work on integrated goals and standards to aim towards the same goal. The circular economy requires a collaborative effort in order to reach a systemic change across the entire agrifood sector, from farm to fork. It requires sustainability at every step of the food supply chain.

Who gets the biomass?

The growing demand for biomass has also sparked a battle for resources, as different stakeholders seek to control and exploit this valuable resource. Biomass, beside the use in the agricultural food system will become increasingly important in replacing the traditional fossil based materials. The volumes needed to realise a vision for a carbon neutrality in 2050 are enormous and can create a pull factor in the market. Therefore, a framework should be developed to address the dilemma of competition between food, feed, and biomass for materials.

Action on European level is needed

However, many of the systems and structures in the sector are deeply entrenched and resistant to change to a circular approach. This is also because all players in the system are in a locked in where the current market dynamics, policy regimes, affected (being animals, nature, people etc.) and alternatives keep each other in the current system. In Europe as we have seen from the EU's Farm to Fork strategy there are many policy recommendations that are tweaking the linear economy to go into a circular direction (see textbox "Example of policy measures on an European level"). These changes policy measures are needed to create the conditions for change.

Example of policy measures on an European level

Sustainable diets

- Science-based recommendations for healthy diets that could result in a mandatory front-of-pack nutritional label and stimulation of more nutritious food, where using side stream derived upcycled fibres and proteins could benefit in this ambition
- Addressing overconsumption of meat and highly processed foods with high salt, sugar and fat content for example by setting maximum intake levels.

Greenhouse gas (GHG) emissions

- Must regulate and set ambitious targets for emissions from agriculture and related land use, including
- strict criteria for biomass-based renewable energy
- Natural carbon sinks must be restored and enhanced.

Organic farming

- EU's organic land should be increased by 2030
- Need for initiatives - promotion, public procurement and fiscal - to stimulate demand
- The budget for the agricultural policies should be increased in line with the objectives of sustainability.

Type of action in the road towards system change

The circular economy requires a collaborative effort in order to reach a systemic change across the entire agrifood sector, from production to consumption. To overcome the limitations of the entrenched systems and structures, system factors need to change together in the same transition pace. Making small steps towards a new systems equilibrium becoming the new more sustainable and circular norm.

We therefore recommend to create the right enabling ecosystem in the context of an economy that today is predominantly linear to work towards a circular economy for agrifood and biomass. We do this along the lines of the four phases transitions go through: Inception, competitive advantage, pre-competitive collaboration and institutionalization. Each phase asks for a different set of interventions of the involved stakeholders to tackle system changes.

Phase 1: inception

The first phase is about creating awareness and the starting point of the transition.

- Increase consumer awareness

Collaboration in the agrifood sector should also focus on increasing consumer awareness about the benefits of a circular economy. This can be achieved through education campaigns and awareness-raising initiatives. Consumers should be encouraged to make sustainable choices, such as reducing food waste and buying local.

- Invest in high impact (circular) concepts

The principles of a linear economy and linear regulatory regimes will force circular entrepreneurs to make concessions to their circular principles to attract funding or remain interesting for current investors. These founders are not helped by general 'venture' or entrepreneur support, but need support from experts with experience in regulatory, financing, legal and contractual matters regarding circular business models.

- Promote innovation and technology adoption

Innovation and technology can play a critical role in promoting circular economy in the agrifood sector. For instance, technologies such as precision farming, artificial intelligence, and blockchain can be used to optimize resource use and reduce waste. Therefore, collaborations should be geared towards promoting the adoption of these technologies to create a more integrated and interconnected food system that is better able to share resources and optimize efficiency.

Phase 2: Competitive advantage

In this phase we stimulate via financial institutions and government the introduction of new business propositions with new labels entering the market.

- Find an agreement between conflicting goals between innovation within circularity and food safety policies: The innovations within reuse and recycling of food, alternative protein and agricultural products are prohibited by concerns about food safety
- Need for harmonisation and implementation of norms and standards that promote sustainable practices. These norms and standards can take many forms, such as regulations, guidelines, certifications and can be applied at every stage of the agrifood supply chain, from production to consumption.
- Holistic view is needed to face trade-offs between efficiency and sustainability: The circular economy seeks to promote the efficient use of resources, but this can sometimes come at the expense of sustainability. For example, intensifying agricultural production to increase efficiency can lead to soil degradation, water pollution, and biodiversity loss. Balancing efficiency with sustainability requires careful consideration of the trade-offs involved.
- New balance on equity and fairness in the circular economy: The circular economy has the potential to create new economic opportunities and jobs, but it can also perpetuate existing inequalities. For example, small-scale farmers and producers may struggle to access the resources and technology needed to participate in circular supply chains. Ensuring equity and fairness in the circular economy requires attention to the social and economic impacts of circular practices.

Phase 3: Pre-competitive collaboration
In this phase competitive companies join forces and decide what barriers need to be taken away and what new norms and standards to stimulate moving towards the circular agrifood economy are needed.
To encourage transition in phase 3:

- Encourage multi-stakeholder collaborations:
  To achieve a circular economy in the agrifood sector, it is essential to foster collaborations between multiple stakeholders and various value chains. This includes farmers, processors, retailers, waste management companies, and policymakers. These collaborations should focus on sharing knowledge, resources, and best practices to reduce waste and improve resource efficiency and provide the right incentives by policies to encourage the innovations needed to shift towards a circular agrifood economy. Achieving systemic change requires collaboration and coordination among stakeholders and a willingness to challenge existing norms and practices.
- Implement sustainable supply chain practices:
  Collaborations in the agrifood sector should focus on a sustainable supply chain. This involves ensuring that all stages of the supply chain, from production to consumption, are optimized for resource efficiency and waste reduction and total use of all raw materials.
- Encourage policy and regulatory support:
  Collaborations in the agrifood sector should also focus on encouraging policy and regulatory support and organize the right incentives for circular economy initiatives. Governments should be encouraged to develop policies that promote sustainable practices, provide financial incentives for circular economy initiatives, and promote research and development in the field. In each phase of the transition a different role for each stakeholder is needed.
- Balancing environmental and economic benefits:
  Circular practices can bring both environmental and economic benefits, but the two are not always aligned. For example, using recycled materials may be more environmentally sustainable, but it may also be more expensive than using virgin materials.
- The challenge of scaling up circular solutions: Many circular solutions are still in the experimental phase and have not been fully tested at scale. Scaling up circular solutions requires significant investment and infrastructure, as well as the support of policymakers and stakeholders. The role of the government is to set the ambition (long term goals) and boundary conditions (regulation and policies) and temporarily provide the incentives to kickstart and change the system till the system and market is self-sufficient.

Phase 4: Institutionalisation
In this phase legislation, policies, norms and institutions have been changed. This is not where we are at in Europe and the Netherlands yet. This is a huge challenge to reach together. However, in this brochure we showed a wide range of examples and pathways for transitioning towards a circular agrifood and biomass economy.

The Future is ahead of us

In conclusion, the circular economy presents a number of hurdles and challenges for the agrifood and biomass sector. Addressing these challenges requires careful consideration of the trade-offs involved with attention to the social and economic impacts. We have to address these dilemmas, by using science and include all relevant stakeholders in and outside the agrifood system. Invite them each to play their necessary part in every transitioning phase. The agrifood sector not only in The Netherlands and European Union, but all over the world has to realise the potential of the circular economy for it to work.

This brochure showed how innovations and entrepreneurship can help in order to find solutions for current problems, yet their potential for significant impact becomes evident when these innovations are scaled up. Hopefully this challenges the reader to take action, reach out to these exemplary companies, and remember that no one can achieve this alone. Collaborative efforts are key to driving meaningful change.

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Colophon

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Authors RVO
Thies Peters

Editorial board
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Freek van Eijk – Holland Circular Hotspot
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Jolijn Zwart-van Kessel – Foodvalley NL
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Website
www.hollandcircularhotspot.nl

Email
info@HollandCircularHotspot.nl
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