



PBL Netherlands Environmental  
Assessment Agency

# FOOD FOR THE CIRCULAR ECONOMY

PBL Policy Brief



# Food for the Circular Economy

Trudy Rood, Hanneke Muilwijk and Henk Westhoek

Policy Brief

## **Food for the Circular Economy**

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# Summary

The goal of a circular economy is high on national and international agendas. A circular economy is targeted at making optimum use of natural resources, raw materials and products and re-using them. This means that all resources are still used in a way which adds the most value to the economy and causes the least damage to the environment. The aim of a circular economy is to use natural resources for longer and as far as possible avoid waste and environmental pollution.

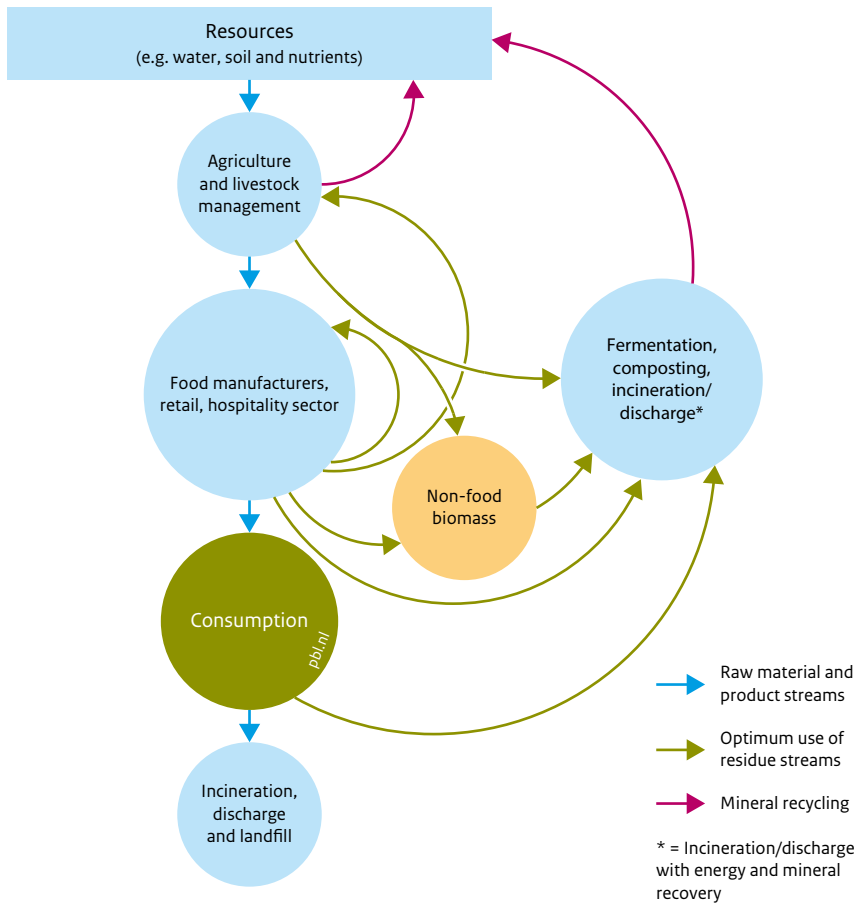
## Three requirements for a circular food system

Making the transition to a circular economy requires a radical transformation of various production chains. The food chain is just one. Various policy areas are faced with the task of precipitating this transition to a circular food system, for example, in agriculture, the environment, trade, green growth, top sectors and innovation. Added value can be achieved by taking an integrated approach to the transition; in this policy brief, we set out a framework for such an integrated approach. We have identified three requirements for this (see also Figure 1).

Firstly, in a circular economy, natural resources must be effectively used and managed. Such resources include soil, water and biodiversity, but also minerals. These resources are essential to be able to produce renewable resources. Secondly, optimum use of food is important. Reducing food waste is an important starting point in this context, as is a diet with less highly processed food, or more vegetable protein and less animal protein. Also important is a reduced use of natural resources and less environmental pressure. Finally, it is important to make optimum use of residue streams, such as tomato stalks, beet pulp and stale bread. In this way, as little biomass as possible will be lost.

All three of these requirements demand action to be able to bring about the transition to a circular food system. These requirements could be included in the implementation of the Government-wide programme for a Circular Economy 'A Circular Economy in the Netherlands by 2050', and the parliamentary letter about the progress of the policy agenda on sustainable, safe and healthy foods.

Figure 1  
**The circular economy for the food production system**



Source: PBL

# 1 Optimum management of resources

## Sustainable use of resources

It is important when using renewable resources to ensure that the natural resources from which the raw materials are obtained remain in good condition. These resources include soil and land, water and biodiversity, and are also often referred to as 'natural capital'. At the moment, these resources, in the Netherlands and elsewhere, are not always sustainably managed. Where these resources are not properly managed, there will be degradation, pollution or depletion, resulting in soil retaining less moisture and reduced bee pollination, for example. To be able to promote a circular economy, effort must be made to ensure the sustainable use of resources. This means that resources must be used and managed in such a way that their continued use can be safeguarded, also for the longer term. Opting for this type of management also affects trade policy, because the Dutch economy also imports considerable amounts of natural resources, intermediate goods and products. By encouraging greater sustainability in economic chains, the Dutch Government could contribute to the more sustainable management of natural resources abroad.

## Efficient use of natural resources

A circular economy will increasingly make use of renewable natural resources (such as biomass). Besides the use of biomass for food production, biomass is increasingly used in medicines, the chemical industry (e.g. bioplastics), construction (e.g. biomaterials), energy and mobility (e.g. biofuels). Part of the residue streams from food production are already being used for these purposes. Cattle bones, for example, are used for porcelain and glue. More large-scale production will be necessary to create more biomass. This type of production requires space. Alongside this, space is also needed, for example, for recreation and business parks. The competition for space will therefore increase. Thus, it is important for the circular economy to make efficient use of the scarce space available.

## Efficient use of minerals

There are considerable benefits to be gained from a more efficient management of minerals, such as nitrogen, phosphate and trace elements. Minerals are used in the fertilisers and artificial fertilisers that are added to the soil in agriculture, where they are absorbed by plants and animals. Minerals are also sometimes added to livestock feed. Agriculture therefore introduces the minerals into human food. With the exception of nitrogen, these minerals are mined. Efficient use of minerals will prevent the rapid depletion of these mines. And, although major shortages of these elements are not expected, in the short term, geopolitical factors or limited extraction capacity could result in temporary shortages.



The efficient use of minerals would also reduce the environmental pressure, given that excess fertiliser (natural or artificial) pollutes both groundwater and surface waters. The regulation laid down by the Fertiliser Act has greatly reduced the pollution of the environment with minerals, but there is still a surplus. Residue streams are created in the food industry, hospitality and retail sectors, and in homes, as a result of which a large proportion of the minerals is lost, for example, in slaughterhouses and in food processing. The minerals which people consume in food mostly end up in the sewers. Residue streams with minerals are generally covered by the definition of waste and EU Member States deal with this in different ways. This prevents reuse, and residue streams are incinerated. Some residue streams may contain pollutants and therefore pose a problem. Medicines and pathogens in sewage sludge, for example, constitute a risk to public health. A clearer understanding of the mineral flows, obstacles and innovations would seem to be necessary to promote the recycling of minerals.

## 2 Optimum use of food

### Preventing food waste

A third of the food produced worldwide still goes to waste. Since 2009, the Netherlands has pursued a policy against wasting food, but the total amount of food wasted still remains more or less the same. Accurate data are lacking, but the target of 20% reduction by the end of 2015 appears not to have been achieved. Food wastage remains a persistent problem. Particularly in homes, hospitality and retail, there is still a great deal wasted despite the fact that many Dutch people consider it to be 'wrong'. Legislation relating to the expiry date of food may also be a reason why food is wasted. More coherence between policy areas, such as in innovation, food safety and food quality, top sectors and the circular economy, could also help to achieve the reduction target. Food wastage must be prevented and food residues should be used as effectively as possible in the food processing chain. Improving the transparency of companies about residue streams and changing consumer behaviour will be important to achieve this. Promoting a circular economy in which residue streams are prevented as much as possible, and where unavoidable residues are viewed as useful resources, could provide a new impetus for tackling the old issue of waste.

### Processing food creates waste and residue streams

The Dutch are eating more and more processed foods, such as snacks, soft drinks and microwave meals. In the processing of food, residue streams are created which are not used for human consumption but fermented for energy, for example. These residue streams, however, often contain valuable proteins, minerals and fibre. In a circular economy, both residue streams and waste should preferably be prevented, so that all nutrients can be utilised for human consumption and the use of raw materials is limited. Apart from the waste and residue streams, highly processed food has another drawback: it contains a lot of sugar, fat and salt, too much of which is bad for human health. Reducing the amount of highly processed food, therefore, can only bring

benefits, not only to the circular economy but also to public health. This offers an opportunity in food policy to combine promoting a circular economy with promoting public health.

### 3 Optimum use of residue streams

#### Obstacles to more high-value use

In the Netherlands, residue streams from food production are already largely utilised. Many residue streams are used, for example, for animal feed or fermented for energy production. In that respect, the Dutch food production system in some areas already exhibits certain aspects of a circular economy. Some residue streams, however, could be put to better or more 'high-value' use. This means looking for an application that offers the highest economic value with the least damage to the environment. There may be various reasons why this does not happen. Examples include the lack of a market for residue streams or unfamiliarity. The government could play a part here by facilitating cooperation, as well as encouraging innovation and data transparency on residue streams.

#### Conflicting goals

The high-value use of residue streams cannot always be reconciled with the legislation on food safety, fertilisers and waste management. For example, bone meal cannot be used in animal feed because of the risk of disease. Another example of conflicting goals in various policy areas can be found in energy policy. Energy policy aims to encourage sustainable energy and, therefore, the fermentation of residue streams is subsidised. These residue streams, however, could be used more profitably as food, animal feed or as resources for bio-refining, depending on the raw material which is fermented. To promote a circular food production system, therefore, it may be useful to analyse what obstacles and undesirable incentives are affecting policy in areas other than food, so that the government can weigh up the different goals.

#### Use tools, but leave room for tailored solutions

For the transition to a circular economy the most high-value possible reuse of natural resources should be favoured (i.e. cascading). There are a number of tools (giving rules of thumb) which can be used to determine what is 'high value'. For example, the alternative use of food for people (for example food to food banks) ranks more highly than reuse for animal feed, and waste prevention is valued more highly than the use of waste for energy production. But there are always exceptions. Sometimes a low-value use of residue streams brings greater benefits than a high-value use; for example, because the residue stream is contaminated and treatment would require too much energy. This means that there has to be room for tailored solutions. To gain a clear overview of possible exceptions, it is important to establish a benchmark and to be aware of impacts in the production chain and the added value of products.

# 1 Introduction: policy for an emerging circular economy

## **In a circular economy, natural and other resources are optimally used**

A circular economy promotes making optimum use and reuse of raw materials and products in the economy, in order to conserve natural resources. This means that natural resources are used again in a way which adds the most value to the economy and causes the least damage to the environment (Rood and Hanemaaijer, 2017).

This applies to non-renewable resources – such as fossil fuels and metals – as well as renewable resources, such as agricultural produce and wood (biotic raw materials).

A circular economy aims to keep natural resources in the chain for longer and to prevent waste and hazardous emissions to soil, water and air, as much as possible. In a circular economy, fewer new natural resources are necessary. Often this also means that less energy is required, because the extraction of natural resources and product manufacturing uses large amounts of energy. Important goals in the transition to a circular economy include reducing environmental pressure, creating economic opportunities and ensuring natural resource security.

## **The need to make more high-value use of natural resources is growing**

It is becoming increasingly important for natural resources to be managed in new ways, in the economy (Rli 2015); the available natural resources must be used as efficiently as possible. This is because there is the risk of them becoming increasingly scarce; their demand is rising with the growing population and greater prosperity in the world.

This greater demand also leads to more environmental pressure; and thus a greater demand for natural resources may also impact biodiversity, greenhouse gas emissions and the nitrogen cycle (Rockström et al. 2009; Steffen et al. 2015).

## **Synergy with Sustainable Development Goals**

The aim of transforming the food production system into a circular economy fits in with the 17 Sustainable Development Goals (SDGs) that were adopted by the United Nations in 2015. Food is an important SDG theme; promoting a circular economy in the food production system can help to achieve various SDGs, such as ending hunger in the world, achieving food security and sustainable agriculture (SDG 2), ensuring good health and well-being (SDG 3), halving the amount of food wasted (SDG 12.3), efficiently managing natural and other resources in consumption and production (SDG 8.4. and SDG 12), reducing marine pollution (SDG 14.1), as well as halting land degradation worldwide (SDG 15.3).

## Existing policy can be built on to create a circular economy

Policy interest in the phenomenon of the circular economy has only developed recently. This policy, however, can build on a long tradition aimed at closing cycles. Even the first National Environment Policy Plan (VROM 1989), for example, drew attention to the need to close cycles, and, for decades, the Netherlands has pursued ambitious policy aimed at reducing and recycling waste. The idea of a circular economy also overlaps with many of the concepts found in policies on green growth, resource efficiency and a bio-based economy. The bio-based economy, for example, could be seen as the part of the circular economy that is concerned with the efficient use of biotic raw materials. Partly due to the bio-based economy policy, the market for non-food applications of biomass is growing by about 2%, annually (Kwant et al., 2016). Typical of the circular economy is the strong focus on the design of products, cross-sector chain cooperation and new earning models to bring about efficient use, reuse and recycling. In the literature, knowledge about the circular economy builds on three previous perspectives on the economy: Cleaner Production, Industrial Ecology and Cradle-to-Cradle (Christensen & Huggaard-Nielsen, 2015).

Interest in the circular economy in government policy has greatly increased, in recent years. With its From Waste to Resource (VANG) Programme, for example, the Dutch Government has launched an ambitious plan that has inspired businesses, NGOs and other organisations to take action. For example, a number of Green Deals have been entered into, and six organisations are working together in the RACE coalition (Realisation of Acceleration towards a Circular Economy) (Rood and Hanemaaijer, 2014). The Ministry of Economic Affairs describes the circular economy in terms of closing production cycles, the sustainable management of resources and the efficient use of raw materials (Economic Affairs, 2015). Alongside this, since 2009, the Dutch Government has pursued a policy aimed at reducing food waste (Agriculture, Fisheries and Nature, 2009), which also forms part of promoting a circular economy. Cabinet recently indicated that it wishes to continue to pursue its policy on combating food waste and losses (Dutch House of Representatives, 2015a; 2015b).

There is also a great deal of interest in the concept of a circular economy in the EU. The European Commission has expressed the importance of a circular economy as follows: 'The transition to a more circular economy – in which the value of products, materials and resources can be retained for as long as possible in the economy and waste production is kept to a minimum makes a vital contribution to the efforts of the EU to foster a sustainable, low-carbon, resource-efficient and competitive economy,' (European Commission, 2015).

The European Commission sees this as ‘the opportunity to transform our economy and generate new and sustainable competitive advantages for Europe’ (European Commission, 2015). In view of the expected positive impact, in December 2015, the European Commission published its proposal for a circular economy action plan, which also included a plan for cutting food waste. Food waste, however, is just one of the areas touching on a circular economy and food (see Chapter 5: Preventing Food Waste).

### **A circular economy requires a broad and coherent approach**

Both the EU and the Netherlands are on the brink of the transition to a circular economy (Rli, 2015; Potting et al., 2017). To make the transition to a circular economy, ministries will need to closely work together and in consultation with businesses and NGOs (Rood and Hanemaaijer, 2014; Rli, 2015). This is because policy aimed at fostering a circular economy has to reach across many different sectors, levels of scale and domains. Cabinet is currently working on implementation of the Government-wide programme for a Circular Economy (*A Circular Economy in the Netherlands by 2050*) to improve cooperation between ministries (Economic Affairs, Infrastructure and the Environment, Interior and Kingdom Relations and Foreign Affairs; Government-wide programme, 2016). It has asked the SER (Social and Economic Council of the Netherlands) for advice on the circular economy (SER, 2016).

In this policy brief, we would like to put a number of conditions or requirements on the agenda for making the food system circular. This knowledge provides input, not only for the government-wide programme, but also for the progress report on the policy agenda on sustainable, safe and healthy foods, and can be used in the further elaboration of both (Ministry of Economic Affairs, 2016). Beyond which, even after the programme and the agenda have been further developed, the requirements for a circular food economy as set out in this policy brief will still be topical.

## 2 Opportunities for the agro-food system

### Agro-food sector can earn from a circular economy

The transition to a circular economy provides opportunities, including for the agro-food sector. However, these opportunities are not simply there for the taking. Investments and new alliances between companies will be necessary, for example, and those with vested interests will be inclined to try to hold back the transition. Government policy will often be necessary to overcome obstacles and get people to take a different view of the importance of natural resources. The opportunities are certainly there (Rood and Hanemaaijer, 2017). The Ellen MacArthur Foundation (EMF), for example, calculated that GDP in Europe could increase by 11% and CO<sub>2</sub> emissions be halved by 2030, relative to the current development pathway (EMF, 2015).

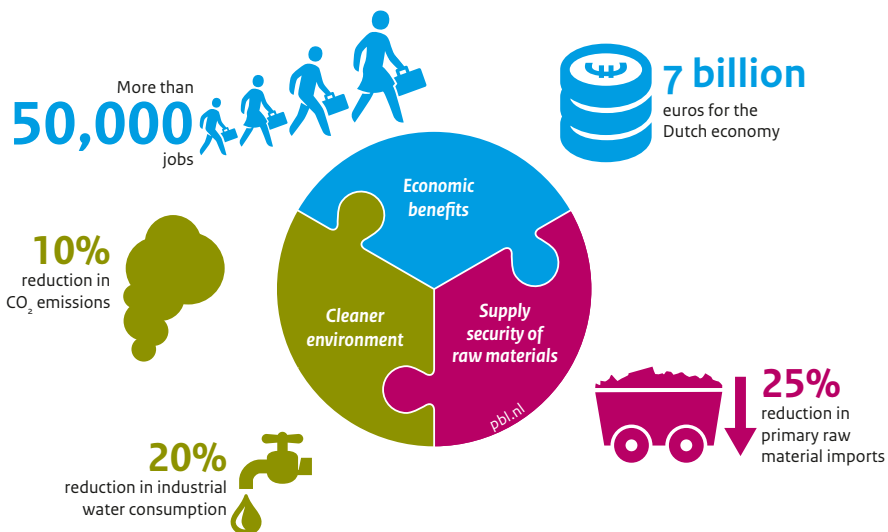
TNO (Netherlands Organisation for Applied Scientific Research) has examined the benefits for the Netherlands (see Figure 2.1). This provides a rough estimate that is merely intended to give an order of size; further research would be necessary to provide robust figures. The benefits of a more circularly operating economy to the agricultural and food sectors has been estimated at EUR 930 million (Bastein et al., 2013). The increase in the share of biogas will contribute to a reduction estimated at 150 kt in CO<sub>2</sub> emissions. The footprint reduction for land use amounts to more than 2000 km<sup>2</sup>.

The positive effects are mostly connected to the use of residue streams. Residue streams from the agricultural sector can be converted into biogas and, through refinery, into other high-value products, such as compost, animal feed and biodiesel (closing external cycles). Besides this use of residue streams from the sector as a whole, there are also opportunities within an agricultural business for closing loops (closing internal cycles). There are currently various initiatives in progress, but it is difficult to quantify the extent of their returns (Smits et al., 2013).

### Closing cycles in the agricultural sector

Natural cycles have always been central to agriculture, because water, nutrients and soil are vitally important to agricultural production. Industrialisation of agriculture has made production more efficient, but it has also become further removed from natural cycles. Closing cycles can be done at various levels: within the business, in new cross-sector chains, in the local environment or internationally. The agricultural sector,

Figure 2.1  
Drivers of a circular economy



Source: TNO, adaptation by PBL

therefore, can contribute to a circular economy, in various ways; by closing external and internal cycles, and through multifunctional agriculture (Buggenhout et al., 2016).

As indicated above, closing external cycles creates opportunities for using residue streams in useful external applications. Agriculture produces food, but also supplies resources, such as for bioplastics and energy production. According to the Rabobank, the chemical industry will start using more biomass and the agro-food sector will start to focus more on biotech and refinery, thus leading to new forms of cross-sector cooperation (Rabobank, 2014).

An example of an initiative is flax cultivation; the seeds are used for food production, while the fibres are used in the textile, construction and composites sectors. Grass refinery also spans various sectors, with products for animal feed and cardboard.

Closing internal cycles will lead to the use and reuse of residue streams in agricultural businesses (Smits and Linderhof, 2015). In this way, residue streams which were previously disposed of as waste or discharged as emissions (such as carbon dioxide, nitrogen and phosphate) are internally used, to minimise the necessary inputs and emissions. These sorts of businesses are also sometimes referred to as ecological recycling businesses, because they are organised in a way which makes optimum use of the available resources (Hees et al., 2009). These ecological recycling businesses combine plant–plant, plant–animal or animal–animal production in such a way that

a residue stream from the production of one is used as input for the production of another. An example of this is mushrooms that produce CO<sub>2</sub> and heat, which can then be used for the cultivation of other crops. Manure can be used in the cultivation of crops and crop production residues become animal feed.

Initiatives which are experimenting with closing internal cycles include polydome, aquaponics, ecoferm and ecological recycling farms.

In multifunctional agriculture, cycles are closed in the local environment. The agricultural business has a different revenue model in which income can also come from non-agricultural activities, such as health care and recreation (PBL, 2013a). A well-known example is the cultivation of mushrooms on locally collected coffee grinds from the hospitality sector (Pauli, 2014). There are also many forms of urban agriculture in the Netherlands, which were often started by entrepreneurs or citizens. In the Port of Rotterdam area, for example, there is a large urban farm, 'Uit je Eigen Stad' [From your own city], and vegetables, herbs and fruits are grown in the city centre; for example, the rooftop cultivation at DakAkker, on top of an office building. In every district of Amsterdam-Oost, there are many neighbourhood gardens where local residents can grow vegetables, pick fruits and plant herbs.

While the urban farm in Almere, for example, is intended to be a centre for urban agriculture, where people can share inspiration and good advice with one another.

### **The Netherlands is well placed**

The Netherlands is well placed to be able to transform itself from a linear to a circular economy. For decades, the nation has already been trying to make as much use as possible of residue streams. One of the reasons for this is that the Netherlands is an agricultural superpower in a densely populated delta (Figure 2.2), which means coping with a high level of environmental pressure.

In addition, the raw material flows and associated infrastructure are very dense.

The Netherlands is a trading nation of import and export trading in which it operates as a revolve, or resources exchange.

This means that the Netherlands is in a good starting position, but its innovation policy needs to be more keenly focused on overarching cross-sector themes, such as the issue of natural resources. Opportunities do not simply arise within a sector, but are created by a combination of sectors. The themes of the bio-based economy and the circular economy both offer promising cross-sector development opportunities for the Netherlands (PBL, 2014). Innovations are necessary, for example, for developing alternative resources, optimally using natural resources and closing cycles. This also includes innovation for a shift towards a diet with more vegetable and less animal protein (a protein transition). The production process for vegetable protein, as in legumes, is more efficient than that of animal protein, which means that natural resources are used much more efficiently (see also the text box in Chapter 6).

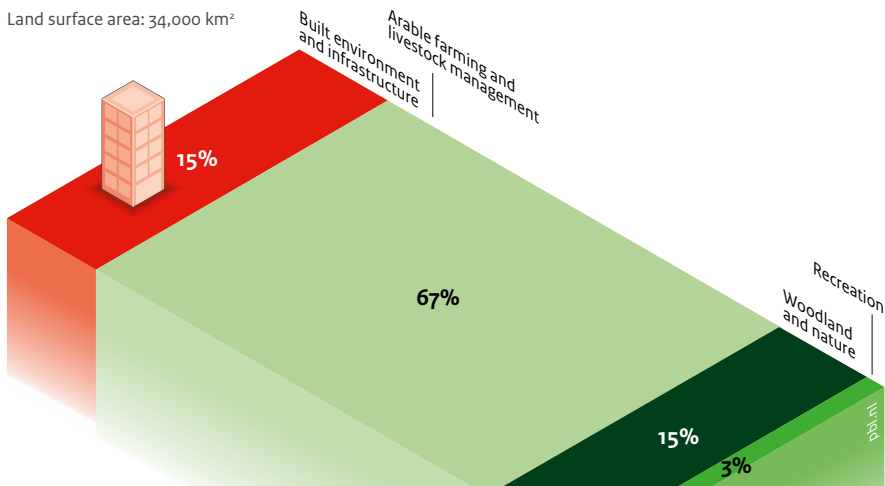


Figure 2.2

**The Netherlands is an agricultural superpower in a densely populated delta**

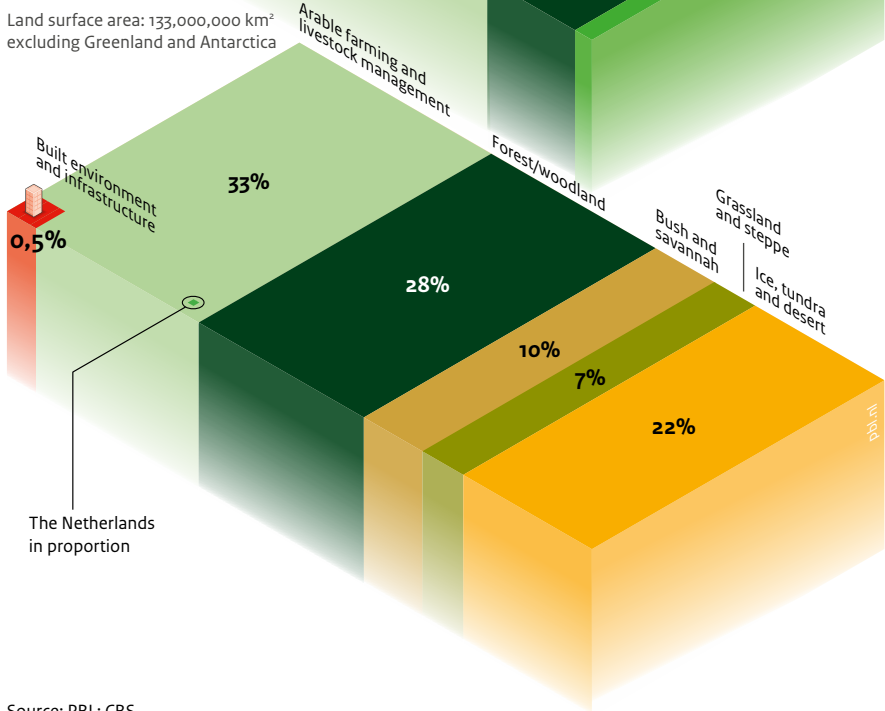
Land use in the Netherlands in 2012

Land surface area: 34,000 km<sup>2</sup>



Land use worldwide in 2000

Land surface area: 133,000,000 km<sup>2</sup> excluding Greenland and Antarctica



Source: PBL; CBS

More radical innovations are also important for the development of an entirely different design, process or material, as in the case of self-repairing materials and 3D printing. At the moment, such experiments are taking place in the Netherlands, such as the 3D printing of food and the development of products with fungi that repair textiles and paintwork (Innovation Expo, 2016; Universiteitsmuseum Utrecht, 2016).

In short, there are plenty of opportunities for a circular economy based on the food production system and various identifiable innovation opportunities. There are a number of conditions necessary for the circular economy to function optimally (Figure 1). These conditions are described in more detail in the following chapters.

# 3 Sustainable management and efficient use of resources

## **Optimum use and management of resources is important for a circular economy**

The sustainable management of natural resources is vital to a circular food production system. These resources are also sometimes referred to as ‘natural capital’ (PBL, 2016). These natural resources (e.g. soil, water, biodiversity, plant seeds, fish stock) provide the basis for food production (UNEP, 2016). With the sustainable management of resources, potentially, it would be possible to maintain food production for decades or centuries. For many of these resources, it is also necessary to look to the long term; on the one hand, because there is no alternative, and on the other, because recovery after less sustainable management can take decades or even centuries, as in the case of the recovery of agricultural land. Only part of the natural resources underpinning Dutch food production and consumption are found in the Netherlands – a large part comes from elsewhere. Outside the Netherlands, this affects both land and resources for the cultivation of products intended for direct consumption in the Netherlands (e.g. grain, rice, fruit, coffee, wine and oils), as well as the cultivation of animal feed (grain in Europe, soya in North and South America), minerals (such as phosphorus) and fish stocks. By making economic chains more sustainable, including the certification of international streams, the Dutch Government can ensure sustainable management of resources abroad (Oorschot et al., 2016).

## **Sustainable soil management in the Netherlands for agricultural production**

This section looks at the Netherlands’ own natural capital, specifically land and soil. Sustainable soil management is a central tenet of Sustainable Development Goal 15.3: ‘By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world’. How sustainably are Dutch agricultural soils managed, currently? There is no clear answer to this question at the moment, particularly when it comes to the quality of agricultural soils and their ability to deliver ecosystem services, such as food production. Firstly, this has to do with several aspects (e.g. chemical and biological quality, and soil structure) which are also not all easily measurable. Secondly, the changes are often gradual, such as the accumulation of certain substances. Thirdly, there is a large degree

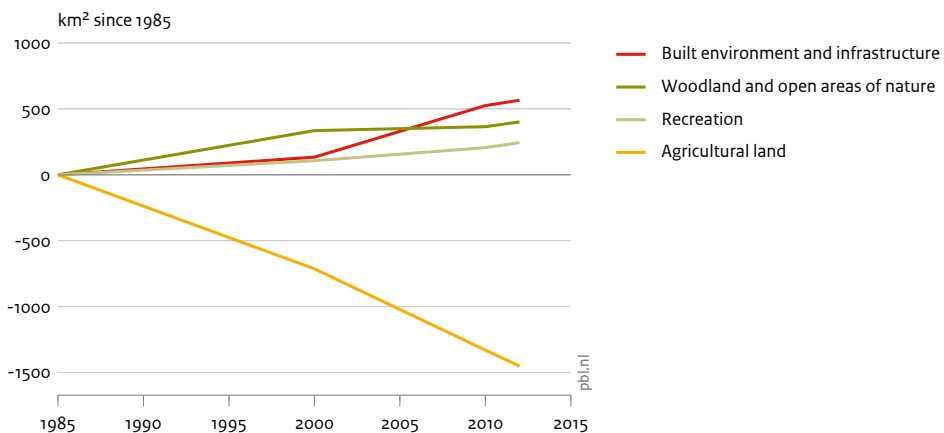
of spatial heterogeneity which means that a monitoring network has to be fine enough. It may be possible to solve part of this by determining the environmental pressure factors (e.g. lowering the groundwater, or the introduction of heavy metals) instead of the soil quality itself.

The EU Thematic Strategy for Soil Protection identified the following degradation processes and threats to soil: erosion, decline in organic matter, local and diffuse contamination, sealing, compaction, decline in biodiversity, salinisation, floods and landslides (European Commission, 2006). Not all of these threats are equally relevant to the Netherlands, although in the Netherlands there is another particular threat, which is oxidation and the contraction of peatland. Some of the degradation effects are deliberate, for example the conversion of agricultural land into other forms of use, such as business parks and recreational areas or water collection. Other effects may not be deliberate or take place gradually, such as the compaction of agricultural soil and the accumulation of heavy metals.

The RIVM (National Institute for Public Health and the Environment) has a monitoring network to determine the scale of loss in organic matter and diffuse soil contamination. Because quantities in the soil change slowly, trends can only be measured over a longer time period. Partly because of methodological problems, it is still not possible to be able to draw any conclusions from this monitoring network, such as for heavy metals. Other aspects, such as the decline in soil biodiversity and soil compaction, are also more difficult to measure. A study showed that the average organic matter content in agricultural land on sand and clay soil increased slightly between 1984 and 2004. There were major regional differences, however, as well as methodological problems (Reijneveld et al., 2009). It is suspected that the share of relatively young organic matter in agricultural soil is increasing at the expense of older organic matter (TCB, 2016). This younger organic matter is more easily broken down, which means that if the supply diminishes, over the course of time, the organic matter content will decline. There has been some degree of soil compaction on some Dutch agricultural land, but its nature and scale are not clearly known. Among the reasons for soil compaction is the use of heavy equipment and driving over soil when the conditions are too wet. Heavy metals are still continuing to accumulate in the soil, albeit not at such a rapid rate, also due to more targeted policy on the composition of animal feed (PBL, 2010; CBS, 2013; CBS et al., 2013; Renaud et al., 2015).

What can be more easily measured is soil sealing. This mainly takes place when agricultural land is converted into some other use (see Figure 3.1). The area of land used for agriculture declined by 145,000 hectares (6%) over the 1985–2012 period (CBS, 2012). The area of surface water increased and some of the agricultural land was urbanised and converted into land used for recreation and nature.

Figure 3.1  
Changes in use of agricultural land



Source: CBS

Thus, there are a number of threats affecting the quality and area of agricultural land in the Netherlands. Government bodies (including the water boards) could direct governance more towards sustainable soil use, such as through stricter spatial planning and by facilitating and addressing stakeholders, such as farmers, animal feed suppliers (in relation to the introduction of heavy metals), the dairy industry and retailers. Better monitoring of various aspects of soil quality and related threats is also important.

# 4 Closing mineral cycles

## Efficient management and recycling of nutrients is important for a circular economy

Nutrients, such as phosphate, potassium and sulphur, are essential for plant and animal production as well as human health. There are 15 to 18 of these elements in total, comprising six macro-elements (N, P, K, C, S, Mg, Ca) with the rest being micro-elements. Other than with land and water, for example, the nutrients are contained in the products that pass through the food chain and ultimately end up on a plate. There are essentially two main mineral streams in the Netherlands: those in the Dutch agricultural system and those in the food production system, including the food processing industry (Figure 4.1).

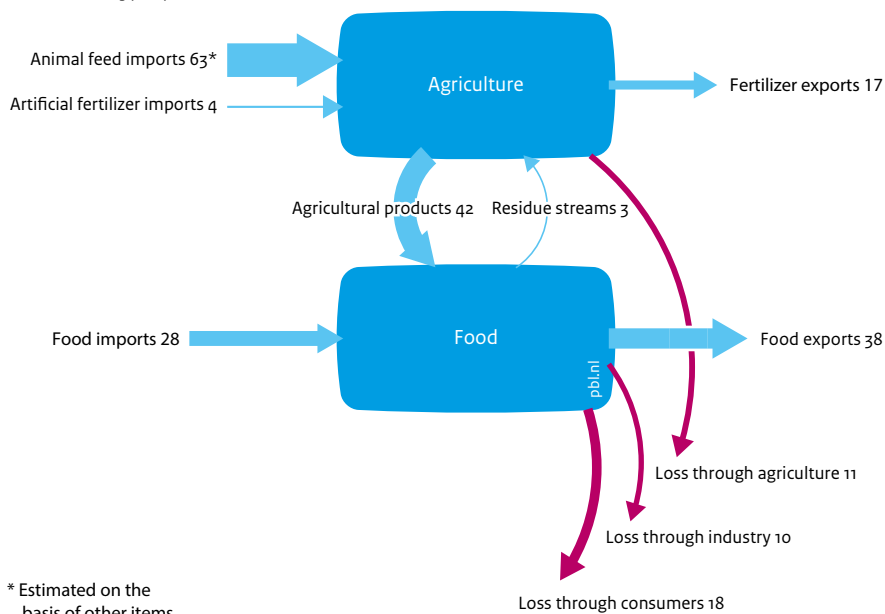
The mineral streams entering the Dutch agricultural system are linked to artificial fertiliser, the addition of minerals to animal feed (i.e. phosphorus, copper, zinc and selenium), imported animal feed and the residue and return streams in the Dutch food production system. Streams exiting the agricultural system include agricultural and horticultural produce, such as dairy, animal and plant products such as grain and potatoes.

There are large mineral streams in the Dutch agricultural system; within farming businesses (through grass and maize cultivation; use as animal feed, recycling through fertiliser) and between them, such as in the cultivation of animal feed by arable farms and the use of animal fertiliser in arable farming and agriculture. A considerable proportion of Dutch agricultural production is exported, thus, with the minerals it contains.

The use of nitrogen and phosphate in the agricultural system is regulated in the Netherlands, under the Fertiliser Act. The primary aim of this legislation is to reduce environmental pollution rather than close mineral cycles. Due to this legislation, in combination with the milk quotas and a growing awareness among farmers, the surpluses (difference between supply and discharge into agricultural land) have declined considerably; between 1986 and 2013, nitrogen surpluses were reduced by 62% and phosphate surpluses by 88% (CBS et al., 2014a). The many years of excessive use, however, have resulted in a considerable proportion of Dutch soils becoming phosphate saturated and some also containing relatively large amounts of zinc and copper.

Figure 4.1  
Phosphorous streams in the food production (2005) and agricultural system (2013)

Units in million kg phosphorus



\* Estimated on the basis of other items

Source: PBL

The reduction in the mineral surplus was largely achieved by reducing the mineral supplementation in animal fodder, reducing the use of fertiliser and the better dispersion of fertiliser throughout the country. However, there are still surpluses. In addition, some of the poultry litter is incinerated, as a result of which the nitrogen in it is lost, while the remaining elements are left behind in the ashes. This ash is exported as a soil improver.

The Dutch food production system is broadly defined, here; it covers, among other things, the food processing industry, as well as the streams to and from the consumer. The streams entering the Dutch food production system are the agricultural products produced in the Netherlands, as well as products produced abroad. This second category mainly consists of products intended for direct human consumption, partly in basic products which are then processed in the Netherlands. With respect to minerals, the main basic product is soya, the oil of which, after pressing, is used as food or as an ingredient used in other processes, while the soya meal is sold as animal feed. In addition, the Netherlands also imports large quantities of soya meal.

Dutch agriculture releases large streams of minerals, but these end up neither on anyone's plate nor return to agriculture. This applies, for example, to some of the minerals in slaughterhouse waste. Some of the minerals from the food processing industry also end up in sewage sludge (Smit et al., 2010). Of the minerals that go to households, it is estimated that two thirds end up in the sewers, in excrement (more than 12 million kg phosphorus), the rest ends up in other household waste (e.g. peels or leftover food). Some of this is incinerated, and some returns to agricultural soils through composting (as biodegradable waste) (Smit et al., 2010).

Agricultural and food production systems are closely connected with one another; some of the minerals from Dutch agriculture end up on the plates of consumers. Dutch agricultural products are also processed in the food production system, creating various return streams, such as spent barley grain from brewing, spent lime from sugar beet and whey powder from dairy production. Imported agricultural products are also processed in the Dutch food production system (such as barley and the soya previously mentioned), with by-products going into Dutch agriculture.

The efficient management of nutrients to ensure the continuity of food production is essential in a circular economy, for two reasons. Firstly, because the easily extractable reserves of a number of elements (e.g. phosphate, potassium) are scarce; estimates vary widely about worldwide availability, from another 100 years to another 1000. Furthermore, these extractable reserves are concentrated in only a few countries or regions (Morocco, western Sahara and China), which brings geopolitical risks. The element nitrogen is an exception; nitrogen gas (in the air) can be captured using energy – usually natural gas – fixed and converted into ammonia or nitrate. Worldwide, this constitutes more than 1% of the use of fossil fuels. Secondly, closing mineral cycles is important, because mineral losses from agriculture and the food production system (e.g. in the form of ammonia, nitrate and phosphate) are causing various environmental problems.

### **Almost all policy activities are concerned with phosphate**

Fertiliser policy is therefore an important aspect of the agricultural system. However, this policy is intended not to improve mineral efficiency but rather to reduce soil contamination, as well as water and air pollution. Alongside the fertiliser policy, there are other initiatives (specifically the Phosphate Cycle Agreement) for managing phosphate streams more efficiently. This is particularly important in relation to the food system. Starting points include the recovery of phosphate from sewage sludge, and the use of secondary phosphate as a source for fertilisers and animal feed. Almost all activities appear to be focused on phosphate, while other nutrients (e.g. potassium, trace elements) are also important for a more efficient management of nutrients. As with the fertiliser policy, the goals of this other policy and its obligations are aimed at reducing environmental pollution (e.g. through instruments such as the Nitrates Directive, the Water Framework Directive (WFD), NEC directive goals, BHD policy



(Programme-based approach)). This policy is also implemented through the Fertiliser Act and has largely contributed to the more efficient use of minerals (CBS et al., 2014b).

A clearer understanding of the mineral streams, obstacles and innovations is necessary to promote the recycling of minerals. The most recent complete overview of mineral streams in the Dutch food production system dates from 2008 (Smit et al., 2010). One of the obstacles to the recycling of minerals is the risk of polluting sewage sludge with heavy metals, medicine and antibiotic residues, and pathogens (Buckwell and Nadeu, 2016). More research is necessary to be able to determine the requirements that would have to be set for recovery schemes. Possible legislative barriers would also have to be more clearly identified.

# 5 Preventing food waste

It is estimated that a third of the food, worldwide, is being wasted. If less food were to be wasted, less would have to be grown and produced and the agro-food sector would need fewer raw materials. In 2013, food waste in the Netherlands amounted to between 1.8 and 2.7 million tonnes (Bos-Brouwers et al., 2015). This represents between 109 and 162 kg per person. The general view is that, in the period from 2009 to 2013, not much changed in terms of the total amount of food wasted. Roughly half of all waste takes place in the home: the average Dutch consumer throws away roughly 50 kg in good food, each year. Wasting food is also a waste of money; every year, EUR 4.4 billion in food is thrown away, in the Netherlands (Wageningen UR, 2016). The goal of a circular economy to make optimum use of natural resources could provide a renewed impetus to the idea of preventing and reducing food waste.

## Changing consumer behaviour

Almost everyone in the Netherlands would like to see less food being wasted and to think that this would make the food production system more sustainable (Rood et al., 2014). Many Dutch citizens would like to reduce the amount of food they waste, but find it difficult to do so in practice – for example, because it is difficult for them to buy and cook the right quantities, or they do not know how to make a meal from leftovers. On top of which, they throw products away when they cannot tell whether these are still usable, or when the ‘best before date’ is expired. In this way, the legally required ‘best before’ date can lead to food being wasted (Rood et al., 2014). Many Dutch citizens believe that greater awareness will lead to less food being thrown away. Promoting a change in consumer behaviour could also be done by emphasising the benefit to their household budget and by appealing to their sense of what is right. The statement that ‘you don’t waste food, it’s not right’, is often mentioned in surveys by people, irrespective of their age, income, education or outlook (Rood et al., 2014).

## A different economic value and greater transparency

In addition to the food wasted by consumers, food losses and residue streams occur in the processing and trading of food. The optimum use of these losses or residue streams would minimise the economic and environmental losses. Examples of tools for optimum use include Moerman’s Ladder or the Value Pyramid (see Figure 7.1 in Chapter 7). According to Moerman’s Ladder, an alternative use for human consumption has the

greatest value in economic and energy terms. Followed by use for animal feed, with incineration at the bottom. Nevertheless, around 40% of food losses are still being incinerated, while not even a quarter is used for animal feed. The share of residue streams that goes to food banks (i.e. for people) is less than 1%. Better use of these residue streams would therefore offer new opportunities for reducing losses.

Since 2009, the Department of Agriculture, Nature and Food quality has pursued a policy target of reducing food waste by 20% by the end of 2015 (former Ministry of Agriculture, Fisheries and Nature, 2009). Various initiatives have been started with the commercial sector, but data on food waste still show no signs of decline (Bos-Brouwers et al., 2015). Food wastage remains a persistent problem. At present, we have a general impression of food system losses, but company-specific information is often lacking (Bos-Brouwers et al., 2015). More data from companies will be necessary to gain a good impression of food losses. Investing in knowledge and transparency by companies will provide more insight into the losses and residue streams, creating opportunities for more efficient use. In addition, innovations to reduce food losses could be encouraged. The cooperation under the government-wide programme on the circular economy provides new opportunities for putting food losses on the agenda in other government policy areas, such as biomass, innovation and top sectors.

# 6 Food processing creates residue streams

People in western Europe are eating more highly processed food than ever before. Figures from Euromonitor International show that, in western Europe, the number of kilograms of unprocessed food per capita, bought since 1999, has declined, while sales of highly processed food, in the form of biscuits, snack bars, ready-made meals and soft drinks, have risen strongly over the same period (Euromonitor International, 2012). This increase coincides with the rise in the number of people with obesity (Monteiro, 2013). In its new guidelines on good nutrition, the Health Council of the Netherlands concluded that eating highly processed food is not good for people's health (Health Council of the Netherlands, 2015).

The NOVA classification of the US WPHNA divides food according to the number and types of processing steps that it has undergone (PAHO, 2015). The first three are categories of food that people can use at home to prepare themselves (Table 6.1). With highly processed food, this is not necessary; this type of food has undergone processing and preparation steps in the industry, which means that it can be eaten or drunk right away or with only a 'minimal culinary treatment', such as turning on a microwave oven.

The industrial processing of food creates residue streams. These residue streams arise both during production and after consumption, for example, in the form of packaging material. The difference between eating an apple and drinking a glass of apple juice made from concentrate, for example, is the streams of apple peel, energy and packaging material. When milk is processed to produce cheese, protein-rich whey is created which is used as animal feed. Spent barley is produced during the production of beer. The result of processing food is a residue stream containing useful proteins, minerals and vitamins which are used for animal feed, for example, instead of being consumed by people. These are not small streams, as shown in the production figures for whey and cheese (FAOSTAT, 2010). Ready-made meals are far more complex to produce than apple juice or cheese. To achieve a circular economy, it is not desirable to have waste and residue streams if these streams could be consumed or used at a higher economic level. The figure below provides an overview of the possible processing steps and the residue streams that these create (Figure 6.1).

Table 6.1  
NOVA classification of food

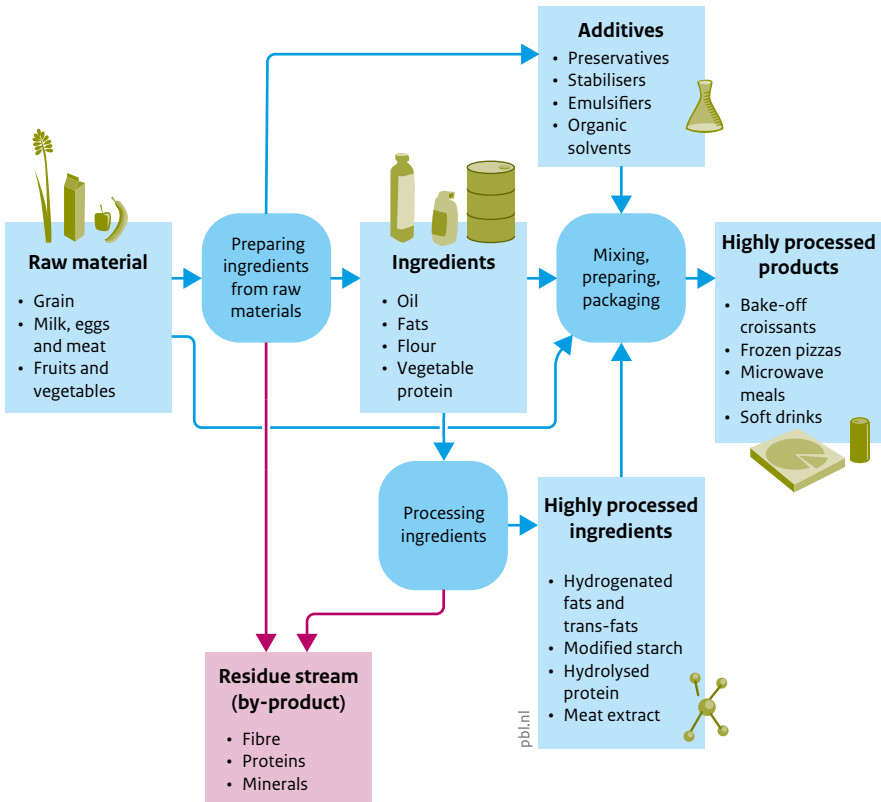
Type of food	Examples
Non-processed or minimally processed food	Fresh, dried or frozen (deep-frozen) fruit, vegetables, grains, meat, fish, eggs and milk
Processed basic ingredients	Oils and fats, salt, sugar
Processed food	Bread, cheese, cold cuts (meat), vegetables, meat and fish in cans or jars
Highly processed food	Crisps, savouries, snacks, ice cream, chocolate, sweets, bake-off bread, sweetened breakfast cereals, energy bars, margarine, soft drinks, sweetened dairy drinks, baby food, deep-frozen meals, microwave meals, and fast food.

Source: PAHO, adaptation by PBL, 2015

Products resulting from the processing steps are often less healthy (do not fall within the Food Pyramid) than unprocessed products. Valuable nutrients, such as proteins, fibre and micronutrients, disappear to become animal feed, while fats and sugars are left behind. This is one of the reasons for the lack of nitrogen efficiency along the entire chain; nitrogen losses from production to consumption in the European Union amount to 87% (Westhoek et al., 2015).

Reversing the trend towards more often eating highly processed food, form part of promoting a circular food production system. A shift in the diet from less animal towards more vegetable proteins would also fit into a circular food production system, because this requires fewer natural resources (see text box). From a public health perspective, too, it would be desirable for people to eat highly processed food less often. Food policy here touches upon public health policy, as also shown in SDGs no. 2 and 4: ‘End hunger, achieve food security and improved nutrition and promote sustainable agriculture’ and ‘ensure healthy lives’. This presents an opportunity to combine policy on the circular economy with public health policy.

Figure 6.1  
Residue streams due to food processing



Source: Monteiro 2013; adaptation by PBL

### **Livestock management and a circular economy**

A large proportion of arable farming crops – both domestically grown and imported – such as grains, silage maize and soya meal, is used as animal feed. For example, in Dutch livestock management, approx. 8000 million kg of grain a year on average is used as animal feed, and more than 2000 million kg of soya meal (FAO, 2016). In addition, more than 10% of Dutch agricultural land is used for the cultivation of silage maize (CBS, 2015). Its use for livestock management has become so large as a result of the greatly increased demand for animal products, on the one hand, and the lower prices for arable farming products (compared with 50-100 years ago), on the other. This price drop is due to such factors as mechanisation, the use of artificial fertilisers, better crop protection and seed refinement, which have greatly increased both soil and labour productivity. At the same time, livestock management (again compared with 50-100 years ago) has become much more efficient, as a result of which the animal feed requirement per kg of product has greatly reduced. Besides the use of specially cultivated arable crops, by-products are still often used in livestock management, such as ‘expellers and meal’, beet and citrus pulp. Some of these by-products have arisen specifically because of the processing of basic foodstuffs to create ‘highly processed’ food; for example, citrus pulp which is created from the production of orange juice. One of the most important ‘meals’ is soya cake (or soya meal), which is produced by pressing soya beans. Given that the cake represents around 60% of the economic value of the soya bean (i.e. more than the oil), this cake can no longer be considered as a by-product of the oil production (PBL, 2011). This is different from sunflower oil, for example, where the seeds contain more oil and the seed meal is less protein-rich. In Dutch dairy farming, grass is still generally the most important feed product, although the cows are also given large quantities of concentrates and by-products in addition to grass and silage maize. It is well-known that large losses (in terms of energy and proteins) are incurred during the conversion of plant products into animal products. Depending on the product, 2–15 kg of animal feed is necessary to produce 1 kg of meat, cheese or eggs (PBL, 2011). This means that reducing the consumption of animal proteins would help to make the use of natural resources more efficient.

# 7 Making optimum use of residue streams

## High-value use of residue streams

The production of food has always created residue streams; the cultivation of wheat produces straw as well as grain, spent grain is the residue left over from the production of beer. These residue streams were not thrown away but used as animal feed, fertiliser or as raw material for another product. The circular economy ahead of its time, in fact. Today too, residue streams from food production are utilised. TNO estimates the current economic value of the 34 most important residue streams in the Netherlands at EUR 3.5 billion (Bastein et al., 2013). There are initiatives for making better use of residue streams, which fit in well with a circular economy. A recent meeting organised by MVO Nederland (CSR Netherlands) entitled ‘How can you make a profit from residue streams?’ shows that the topic is gaining ground (Agribusiness, 2016). The question is whether the traditional market value of residue streams can be increased and what barriers there are to new innovative ways of dealing with residue streams.

The sugar and potato industries are actively searching for ways to deploy residue streams at the highest possible value (Baltussen et al., 2016). In the dairy and pig farming sectors, some by-products and residue streams already have high-value use in human food, while some use is low-value, in which manure is incinerated or fermented. Closing nutrient cycles will be an important challenge for these two sectors (Baltussen et al., 2016).

The present deployment of residue streams from Dutch food production partly takes place in the form of cascading, as may be expected on the basis of the Value Pyramid or Moerman’s Ladder (Figure 7.1). Sometimes residue streams are deployed as a lower value than would be preferable based on the tools. There are various reasons for this, such as the lack of infrastructure, the residue (stream) volume is too small, obstructive legislation, and conflicting goals between various policy areas (trade-offs).

Research by TNO shows that residue streams which are currently used as fertiliser or are incinerated, could be used as a raw material for bio-refining or could be used in an improved process to make biogas. These processes, however, generally still have to be technologically and commercially proven. The exception is the production of biogas



from fermentation, which may be considered an existing technique (Bastein et al., 2013). Even with innovations such as these, it is important to keep on thinking. For example, what if maize were to be added as a fuel to co-fermentation? Maize is, of course, also food and therefore could be used for human consumption, which in a circular economy would be the preferred choice.

### **A circular economy is more than fermentation**

Fermentation in order to generate energy is often mentioned as an option for the processing of biotic residue streams (biomass). Subsidies for sustainable energy (Sustainable Energy Production (SDE) scheme) make the production of biogas commercially very attractive. Another option is the co-fuelling of biomass, which would then be included in the calculation of the percentage of renewables in the Netherlands. Based on European agreements, this share must amount to 14% by 2020. The SDE subsidy and agreements on biomass provide an incentive for fermenting or incinerating biomass for energy – all low rungs on Moerman's Ladder (Figure 7.1). Residue streams of biotic material can often be deployed at a higher level. In the production of sugar and beer, for example, residue streams are created which can be used as animal feed. Here, there would appear to be a conflict between the policy on sustainable energy, on the one hand, and policy aimed at promoting a circular economy, on the other. It will be important to carefully weigh the different goals against one another, in both the short and the longer term.

Something similar occurs with CO<sub>2</sub> reduction targets. Although these can be achieved in various ways, not all of them contribute to a circular economy, as shown by the legislation on biomass. This quickly leads to lock-in situations; once a fermenter or waste incinerator has been built, it has to be operated. In CSR policy, too, there may be conflicting goals, such as between the goal to be a climate-neutral company, on the one hand, and operate a circular economy, on the other.

### **Tools for cascading**

In a circular economy, the aim is to use and reuse all residue streams. This will lead to almost no waste anymore. For renewable resources (e.g. biomass, food losses), various conceptual frameworks have been developed to determine what the best or most high-value use of a stream would be. Two known conceptual frameworks which are often used are Moerman's Ladder and the Value Pyramid, previously mentioned (Figure 7.1). Moerman's Ladder is used in policy relating to preventing food wastage. The Value Pyramid sets out the most high-value application and was the conceptual framework used in the Policy Document '*Meer waarde uit biomassa door cascadering*' [more value from biomass through cascading] (Economic Affairs, 2014). Both frameworks can provide a tool (to be used as a 'rule of thumb') for determining whether a process, business case or practical example meets the goals of a circular economy. This should also leave room for tailored solutions and the option of deviating from the 'rule of thumb' tool where there are trade-offs or co-benefits to be had.

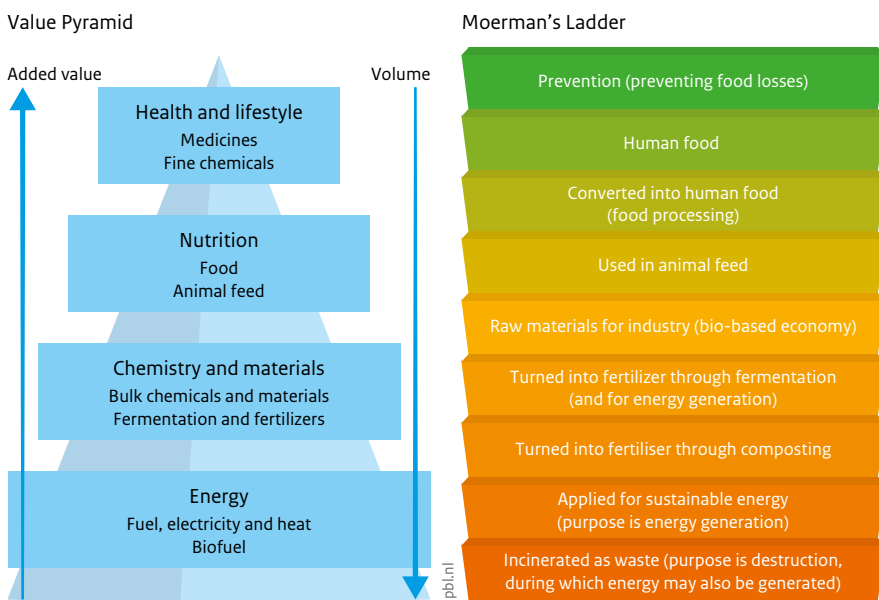
The conceptual frameworks or tools provide a practical means of understanding what is meant by cascading biotic material. With each step lower down the ladder or pyramid, the use of the raw material or residue stream is slightly lower in value. In both conceptual frameworks, an important difference with non-consumable materials can be seen; biotic material can only be used, reused or recycled to a limited extent (see also Figure 1.1). Eating of the product is the end of the line, as such, thereafter it becomes manure.

Both conceptual frameworks largely agree; the use for human food is always preferable, followed by animal feed, then use as a resource in the bio-based economy and, finally, streams can be processed to create fertiliser or be incinerated to generate energy. There are minor differences, which can be seen supplementing one another; the Value Pyramid places medicines, herbs and specialty chemicals higher than human food. This is because these products have more commercial value than, for example, grain or potatoes. Considering that this relates to small streams, it is an addition to the prevention of food losses on Moerman's Ladder.

The conceptual frameworks are easy to use: they provide tools to help policymakers and companies evaluate and prioritise the use of residue streams. However, the devil is in the detail of a production process and the environmental impacts associated with it, as well as any lock-in effects from previous investments. In any policy aimed at promoting a circular economy, it would therefore be sensible to provide room for tailored solutions and accommodate flexibility. The tools could provide a starting point and room could be provided to deviate – based on sound reasons. Instruments are therefore needed which can be used to substantiate why it would be better to deviate from the 'rule of thumb', in a particular case. These instruments are under development (Brein, 2015; Vellinga et al., 2016).

Studies are necessary to look at where, when and what effects occur, *and* whether the effects of an innovation are better than in the present situation. The use of a product stream at a higher rung on the ladder could lead to trade-offs. The Insects for Food, Feed and Pharma Green Deal provides such an example. In this Green Deal, insects are used as an alternative source of protein to meat or animal feed. By breeding insects instead of producing meat, the authors of the plan wish to achieve the following goals: reduce greenhouse gases, prevent waste through breeding on residue streams, sustainable cultivation, low water consumption, preserving biodiversity by replacing fishmeal with insects, space gains and a high percentage of edible biomass from the insects. Research by PBL shows that the environmental benefits relative to the original process, such as meat production, are variable (Ganzevles et al., 2016). If larvae are used as animal feed, this requires less land and more energy than when soya meal is used.

Figure 7.1  
Tools for high-value reuse



Source: PBL

For mealworms as consumable protein, it appears to make a difference depending on with which animal protein product the comparison is made: relative to beef (animal protein with the highest environmental impact), the mealworms are more favourable in terms of greenhouse gas emissions, energy consumption and land use, relative to chicken and milk, the difference is small. A clear benchmark is therefore necessary to be able to make an assessment. This raises the question of whether the use of mealworms at the highest rung of human consumption is actually an optimum choice. Their use at a lower rung, with larvae as animal feed, often appears to be better, provided that the energy required can be sustainably generated. The message offered by these two examples of mealworms and larvae is that we need to be vigilant about whether there are any real environmental benefits to be gained, relative to the original situation.

The conclusion based on the examples in this chapter is that there may be various obstacles to the high-value use of residue streams. There are various reasons for this: there are many different streams and production processes. This makes it necessary to undertake a thorough analysis of how residue streams can be used in a way that offers high-value, with multiple market values and coordination of policy areas. Policy can be used in this context to create the right incentives and encourage desirable applications.

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