Together towards a more Circular Foodvalley

Tracing Food-losses and underutilized waste streams

An Academic Consultancy Report

Prepared for Living Lab Regio Foodvalley Circulair

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Executive summary

The Foodvalley is a highly innovative region in the Netherlands. In this region, there is a high number of food-producing companies present. Together, these companies create food waste streams that end within the different efficiency scales on Moerman's ladder. The focus of this project was to identify, evaluate, and advise Living Lab Regio Foodvalley Circulair on how to shift up the waste streams in the region according to Moerman's ladder. Firstly, a good understanding of the situation was gained by mapping out the network of food waste, and the underutilised streams were highlighted. Secondly, the waste streams were evaluated in terms of kilograms and CO_2 footprint. The results of the research indicated large waste streams and CO_2 impact in the meat industries. The animal feed industry was very open to new waste sources, linking animal feed companies with the meat industry might provide opportunities. Important bottlenecks for circularity that were identified in this research were food safety concerns or regulations. Another finding from this research is that there is a limited local connection between the food processors and the local municipalities. Most of the waste streams from processors in the region end up in another region. This given, in combination with the international scope of many interviewed companies, a larger area than Foodvalley for circularity should be considered for the large processors. Another piece of advice suitable for Foodvalley is to focus on managing waste streams of food processors inside the region. In addition, it is suggested to increase awareness on food waste and its impact within organisations. To identify further opportunities, the poultry sector should be investigated on waste streams. What would also be useful is promoting the participation of start-ups to better use new opportunities. A final piece of advice for Foodvalley is to create a common network to enable better communication.

Abstract

In the Foodvalley region, a high amount of food relative companies is present. From these companies, the waste streams are not mapped out for the commissioner, Living Lab Regio Foodvalley Circulair. In this research, the aim was to identify what food waste streams are currently being underutilised in the Foodvalley region and may be more optimally valorised according to the Moerman ladder. Along with a literature study, 41 different food processors within the Foodvalley region were approached, of which 11 were interviewed. In this interview details on the waste streams like outputs and quantities, but also drivers and bottlenecks of circularity were collected. In the evaluation, an impact assessment in terms of waste in kg, and CO_2 emission due to waste, was implemented for the identified companies. Next to the waste evaluation, an evaluation of the bottlenecks of circularity, the local connection to the region and the willingness to locally participate was implemented. The results stemming from this research were used to give elaborate advice to the commissioner to identify underutilised waste streams and increase local circularity in the Foodvalley region.

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1. Project description

Since 2010, a collaboration between eight municipalities (Figure 1) in the 'Gelderse Vallei' has existed under the name 'Foodvalley' - this region is represented by the organisation 'Living Lab Regio Foodvalley Circulair'. Foodvalley aims to improve the collaboration between local companies, knowledge institutions, and the government. They strive to reach these goals by improving the business climate for Agri-food organisations, promoting entrepreneurship, and strengthening the knowledge infrastructure in the Foodvalley region. By 2030 they strive to be a leading region regarding agriculture and nutrition, where the inhabitants are more healthy, happy to reside, entrepreneurial, and innovative, and where circularity is a no-brainer (Boezem et al., 2015; Foodvalley, 2020).

***Figure 1**: Location of the Foodvalley in the Netherlands.*

Now, Living Lab Regio Foodvalley Circulair, as commissioner, has asked a group of students from Wageningen University & Research (WUR) to conduct transdisciplinary research to trace food losses and underutilised waste streams, towards circular food chains in the Foodvalley region. Currently, there are many potential connections within the Foodvalley. However, the Foodvalley region has yet to discover what connections will have the most impact. Impact implicating, reducing food losses measured in weight (kg), decreasing the CO_2 footprint and the valorisation of food losses according to Moermans' ladder (Waarts et al., 2011). Brick-and-mortar stores and small enterprises (e.g., local butchers) in the Foodvalley are often willing to cooperate. However, they often do not have the scale or time to be impactful. Therefore, this project has mainly focussed on Business to Business (B2B), food processing companies and local entrepreneurs that were already invested in circular systems.

This project analysed under-researched areas and strives to reuse current waste streams in the Foodvalley. The project aimed to do this by interviewing local stakeholders, looking for synergies within existing structures and identifying possibilities for circular food systems. To identify where the most impact can be made, the existing waste streams and the magnitude of local waste streams were analysed.

The relevance of this project lies in improving local sustainability over the long term. This project aims to achieve this by creating a clearer overview of local resources used, where and how food losses can be lowered and how existing waste streams could be re-used to create new value. By connecting local stakeholders, new synergies by employing circularity could emerge. Circularity could also be seen to improve local independence as Foodvalley companies no longer rely on businesses outside the region. Regarding corporate stakeholders, this project aims to establish stronger connections between the corporate stakeholders and local businesses and to create more involvement from both sides.

2. Project problem statement

2.1. Multi-perspective problem analysis

As a part of Livithe ng Lab Regio Foodvalley Circulair group, the long-term goal of the commissioner is to create synergized ecosystems including various stakeholders to encourage vertical and horizontal integration within the Foodvalley region, to establish more circular food chains (Foodvalley, 2020). Establishing a network between different business units with clear communication channels will help in developing the circularity of their local supply chains, wherein the various food waste streams may be reduced, revalued, and reused.

The broad problem of the commissioner involves the multifaceted groups of stakeholders which must be addressed to introduce circular measures. The commissioner acts as an interface between the government, farmers, and businesses within the region, all of which have varying mentalities and motivations which causes difficulties when trying to increase connectivity and involvement. Besides this, a lack of communication, time or commitment of relevant stakeholders acts as a bottleneck in achieving progress. On a more practical note, the commissioner is further inhibited by a lack of data regarding the next steps; it is understood that progress must be made, but the locations of the highest impact in which to continue their research remain unknown. This project has accordingly been designed to target this very bottleneck, to gain an overview of the Foodvalley region and increase local circularity.

Possible problems for achieving the long-term goals may also be related to the closed attitudes of local companies, and a lack of awareness and interest among entrepreneurs in the Foodvalley region. Traditional supply chains may also find it difficult to alter their ways of working and might therefore prevent possible new circular systems from establishing, once connections have been indicated (Foodvalley, 2022). These two go hand in hand as a lack of public awareness gets a low demand, which in turn propagates a low financial motivation for companies, resulting in an ongoing cycle. Political bottlenecks also exist beyond the scope of the Foodvalley region (Mehmood et al., 2021). The Dutch government has placed the goal for 50% less carbon dioxide emissions by 2030, and 95% by 2050; despite this good news, issues are introduced in the forms of regulations placed to enact these goals. The Foodvalley region has been highly impacted by the nitrogen regulations, which positively impacts the environment, but simultaneously increases the pressure on farmers, thereby increasing tensions in the area (Rijksoverheid, 2022). Similarly, to the imposing regulations, legislations tied with containing the unknown risks of reintroducing wasted materials back into the food system provides a barrier to increasing circularity measures (Focker et al., 2022).

2.2. Project problem definition

Based on the current situation and the long-term goal of the commissioner, the project decided to address the key knowledge gaps regarding what waste streams are currently being underutilized, to what magnitude, and their location within the Foodvalley region. The information found by the project will make it possible to then map out and identify what waste streams have the most impact, and what could be addressed in order to reach a circular food supply chain.

There are multiple reasons for this problem addressed in the literature of (Robertson-Fall, 2021) Circular chains have environmental, economic, and social benefits. A circular supply chain implies that food loss and environmental impact are reduced since the magnitude of the final waste streams is lower. Also, a circular supply chain encourages interactions between stakeholders and increases the independence of the region. If the problem is not discussed and there is a lack of progress towards circularity, it sets a precedent for failure in the region and the potential for development is reduced. Competition amongst stakeholders would increase, leading to a higher dependency on external resources and therefore an increase in supply chain risks. A circular supply chain is beneficial for small businesses and entrepreneurs since the region would depend less on corporate firms. Therefore, the local economy and community also benefit from addressing this problem (Sehnem et al., 2019). A circular food supply chain would change the *status quo* by educating people about sustainable practices.

This project does not aim to involve the impact of consumers as this will make measuring the project too complex. Also, agricultural companies such as local farms as well as the HORECA companies are not interesting for the

commissioner in this project. Although their impact is among the highest, they are already being researched. Foodvalley region prioritizes researching new knowledge on local food processors and circularity. An overview of the food supply chain involved in this project is given in Figure 2. Brick-and-mortar stores (such as local butchers) in the Foodvalley are often willing to cooperate but are limited by a lack of time and scale, so they are excluded. International corporate firms tend to have lower rates of participation in the local economy (Foodvalley, 2022), but potentially provide significant waste streams. Therefore, this project will mainly focus on non-farm level B2B food intermediaries and corporate firms.

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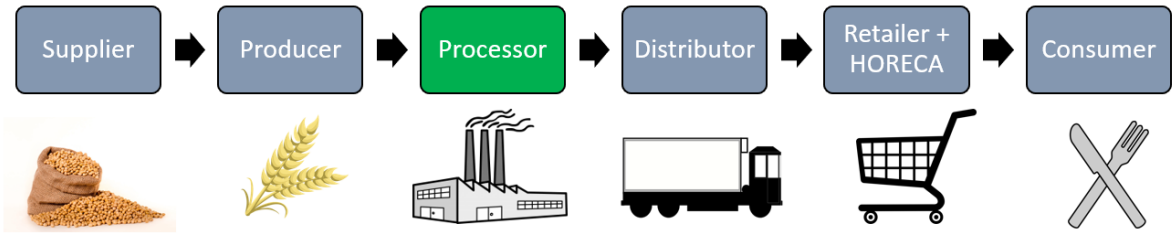

Figure 2: *Example of a food supply chain. The scope of this project is focused on non-farm level B2B food intermediaries and corporate firms, represented here as 'processors'.*

3. Research questions

3.1. Main Research Question

To address the problem statement described under the previous section the project aimed to answer the following main research question:

"What food waste streams are currently being underutilised in the Foodvalley region that may be more optimally valorised according to Moerman's ladder?"

3.2. Sub-Research Questions

Identification

- What food processors are in the region and what waste streams do they produce?
- Which of these are underutilized according to Moerman's ladder?

Evaluation

- What magnitude are the waste streams compared to one another?
- Which one has the highest impact in terms of kilograms and CO_2 footprint?
- What are the current bottlenecks preventing the valorisation of underutilized waste streams in the Foodvalley Region?

Advice

- How can existing waste management strategies from companies be improved in the Foodvalley region?

4. Key concept definitions

Bottlenecks: For this project, this term refers to the factor that limits/constrains the implementation of a circular food supply chain in the Foodvalley region. This factor can be related to a regulatory element, human behaviour or economic aspect amongst others.

Foodvalley region: Regional network organization in the Netherlands for agrifood involving eight municipalities (Barneveld, Ede, Nijkerk, Rhenen, Renswoude, Scherpenzeel, Veenendaal and Wageningen) within two provinces (Gelderland and Utrecht). The project is focused on this territory. Nevertheless, there may be relevant stakeholders from outside the region (i.e., Centraal Bureau voor de Statistiek as a source of information).

Food industry boundaries in the Foodvalley region: The project is focused on non-farm level B2B food intermediaries and corporate firms with facilities in the Foodvalley region. This implies that farms, HoReCa sector and brick-and-mortar stores are out of the scope of this project.

Food waste streams: Any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed. Inedible biomass is also included in this concept (e.g., residual pits or peels).

Impacts (society, economy and environment): How do food waste streams impact the society, economy and environment is explained in section 7.1.1 of the introduction. As a result, the kg and CO_2 emissions per food waste stream are given. These measurements will be used to asses the impact of the stream in the three dimensions.

Moerman's ladder: Model used to manage food waste and efficiently revalorise them. The top of the ladder consists of the uses of food waste that have the highest value possible. In this project it is used to valorise the identified food waste streams, i.e., identifying in what step of the ladder the waste streams are.

Underutilised food waste stream: Any food waste stream that could be shifted up Moerman's ladder. In other words, a waste stream that could have a use with higher value than the current use.

Waste management strategies: Management system of food waste streams within a specific company. Destiny, use and current circularity are aspects included within this concept.

5. Scientific relevance

This project aims to provide new data and insights about the B2B food waste networks in the Foodvalley region for future exploration since most of the current relevant research is focused on the downstream consuming stages of the food supply chain. Because of the UN environment programme's initiative to make more efforts in measuring food waste at retail and consumer level (Clementine. O, 2021). The food waste data in the Netherlands was primarily collected from the retail sector (European Commission, 2022). Furthermore, it is crucial for this study to establish a foundation for investigating the effects of the global food crisis and environmental issues (particularly CO_2 emissions) outside the consumption level.

6. Background Knowledge

6.1. Concept of food loss and food waste

In 2011, the Food and Agriculture Organization (FAO) defined food loss as the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption (FAO, 2011). It is then specified that food losses occur in the early stages of the food supply chains, production, post-harvest, and processing. On the other hand, food waste is defined as food loss that occurs at the end of the food chain, i.e., retail and consumers.

Later, the same organization defined in 2018 food loss as the food produced for human consumption that is not eaten by humans (Food and Agriculture Organization of the United Nations, 2018). It is stated that food waste is part of food loss and is understood as food intended for human consumption that is discarded or left to spoil because of a decision taken by an actor in the supply chain. The European Union defined in the Directive (EU) 2018/851 food waste as any food that is designated as waste. Waste is considered as any substance or object which the holder discards, intents to or is required to discard (Directive 2008/98/EC). There is no specific definition of food losses in the European legal acts. Considering the different definitions discussed, it has been concluded that there is no common definition amongst organizations. This leads to a lack of standardization and increases complexity when using the concepts.

Luo et al. (2021) addressed the issue regarding the concepts of food loss and waste (FLW), stating that there are multiple definitions used currently in the literature. Based on this, they review the existing definitions, and they suggest a classification for food losses and waste considering preventability, cost and value, and stage of the food supply chain. These researchers use the definition given by FAO (2011) as main reference since it sets a clear boundary between edible and non-edible parts of food, but it has limitations if it is used for FLW measurement. Their proposition consists of three criteria: preventability, activity cost & value, and the stage in the food supply chain (FSC). Upstream stages refer to production, post-harvest and processing. Downstream includes retail and consumers. Even if this proposition makes a very clear distinction between food loss and waste, it is complex, and a different framework is used in this project. Fusion EU definition of food waste is “any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed”, and food loss is not part of this framework (Fusion EU, 2016) . Since the commissioner operates with this framework, it is also used in this project.

6.1.1. Impact of food losses and causes

It is known that food losses and waste have impacts on an environmental, social and economic dimension (FAO, 2018; Luo et al., 2021). Food loss and waste has a twofold economic impact (FAO, 2018). First, the cost of the food lost or wasted is part of the final consumer price, and therefore the price of the final product is higher than it actually should be. This increase in price creates a barrier for people with limited economic resources. Additionally, food losses and waste represents an inflated demand that contributes to an increase in supply, resulting in an unsustainable food system.

From a social point of view, the amount of food that is being lost/wasted clashes with the current hunger worldwide (FAO, 2018). The reputation of the actors in the supply chain can be damaged if the food losses are known. Additionally, the current food losses and wastes make it more challenging to achieve a sustainable food production system, which is required for a growing global population (Luo et al., 2021a).

In 2013, FAO published a report analyzing the environmental impact of global food waste. They found that over 50% of waste occurs at the “upstream” stages, like production, technical handling and storage. And the rest occurs at the “downstream” stages like processing, distribution and consumption (FAO, 2013). As food is wasted further down the processing stream, the greater the environmental impact, as the energy and natural resources consumed during processing, transportation, storage and cooking must also be taken into account (Lewis, 2022).

The impact of food waste on the environment is visible in four main aspects: waste of natural resources, climate change, land degradation, loss of biodiversity. The first is the waste of natural resources. The Natural Resources

Defense Council (2013) has determined that food waste ends up wasting a quarter of the water supply in the form of uneaten food. In addition, large amounts of diesel, oil and other fossil fuels are being used according to global food transportation. The second impact is climate change. When discarded food is left to rot in landfills, it will produce methane, which is a greenhouse gas 25 times more potent than carbon dioxide (Moseman, 2021). It will heat up the atmosphere, leading to global warming and climate change. The third impact is land degradation. Around 11.5 million hectares of the global land surface is used for agriculture, and 900 million hectares of land is used for livestock. About 3.4 million acres are used to grow wasted food, approximately a third of the world's total agricultural land area (Lewis, 2022). These data show that people are putting too much pressure on food-producing land; if the losses are not cared for, the land will degrade and become less productive. The final impact is loss of biodiversity. The conversion of natural land to non-arable land and deforestation destroys existing ecosystems and species diversity. Besides, the population of marine life is declining and the capture of large quantities of fish can cause serious damage to marine ecosystems (Cattaneo et al., 2021)To conclude, tacking the issue with food waste will have a positive impact in multiple dimensions and aspects, which justifies the need to research this topic.

6.2. Food waste in Europe and the Netherlands

Nowadays, food waste makes up 6% of all human-related greenhouse gas emissions in Europe (Timmermans et al., 2015). To fan the flames, the climate change dilemma is being made worse by food loss and food waste. Both activities increase the emission of greenhouse gasses. Food-related activities such as the production, handling, and transportation of food emit large quantities of carbon dioxide, or when waste ends up in landfills, it releases methane. Methane is an even more potent greenhouse gas than CO_2 (Zhang et al., 2020). Prior research by Luo et al. (2021), Timmermans et al. (2016) and Wunder et al. (2018) have made estimations on the origin of European waste streams. The estimates by Timmermans et al. (2016) consists of a breakdown of food losses by sectors and an estimated amount within a 95% confidence interval (see Figure 3). According to Timmermans et al. (2016), the largest share of 53% all food waste comes from households (consumers), which accounts for an estimated total between 4 and 47 million tons of food waste every year. The processing of food was calculated at causing 19% of food waste in Europe, an estimated amount between 17 and 13 million tons of food waste every year. Other sectors that mainly contribute to food waste in Europe are the catering industry (12% of all food waste, av. 11 million tonnes), primary production (11% of all food waste, av. 9 million tonnes), and wholesalers and retailers (5% of all food waste, av. 5 million tonnes) (Timmermans et al., 2016).

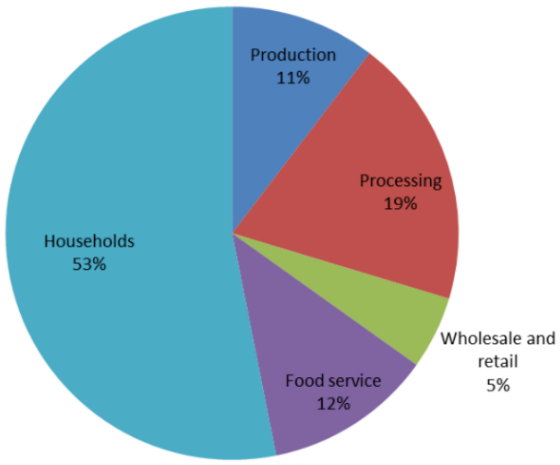

Figure 3: *Division of EU food waste including food and food related inedible parts (Timmermans et al., 2016).*

The total production of the Dutch food waste is approximately 200,000 tons per year, according to the Fusion reports of Timmermans et al. (2015). This annual food waste in the Netherlands leads to an emission of 600,000 tons of CO_2. When looking at exact amounts of food waste in the processing industry in the Netherlands there is no scientific data available. However, claim that 20% is wasted at food processors, 10% at farmers and growers, 5% at supermarkets and 45% on consumer level.

When investigating the food sector, the amount of waste depends per industry. The research by Rietveld, (2019) indicate that one of the most wasteful processes is the production of bread. Fresh bread and other bakery food items were wasted the most in 2020, with 7.8% never reaching consumers, compared to 7.7% in 2018. Followed by 2.4% of fresh meat and fish and 2.4% of fresh fruit and vegetables were wasted, compared to 2.9% and 2.7% in 2018. Finally, 1.2% of dairy, eggs, and refrigerated ready-to-eat products were wasted, compared to 1.4 percent in 2018. (Wageningen University & Research, 2022).

Based on the study by J.H. Welink, (2015) in North Holland, which measured leftover food scraps from 44 food processors, 80% to 90% was being composted digested to create biogas or processed into animal feed. These outcomes are based on data from, vegetables and fruit producers, cacao waste, fats, fat acids, bleaching soil, starch streams or sugars, coffee, whey, and animal by-products.

Current projects like 'Samen tegen Voedselverspilling' (Together against Food Waste), which tackle food waste by aiming to reduce food waste by 50% in the Netherlands between 2015 and 2030, which includes waste on food waste streams in all parts of the economic society. The goals set are based on the sustainable development goals (SDGs) from 2022, which aim to reduce global food waste according to the following goal description: "B*y 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses*" (FAO, 2021).

Besides national initiatives, there are also more local projects aimed at circularity and waste reduction. Since 2016, Gelderland has also promoted the circular economy by encouraging a more effective use of raw resources and the closing of material chains. The circular economy is a key goal of the environmental vision. Gelderland is working with the national government to achieve a significant decrease (50%) of the share of primary raw materials and eventually become a waste-free province. This policy will be implemented by the re-usage of materials in closed loops, reduce the number of products from primary sources and replace primary sources with more biobased sources (Jutte & Roos, 2019). Now, within the province of Gelderland (and Utrecht), the Foodvalley region has rolled up its sleeves to become the leading region regarding circularity (Foodvalley, 2022).

6.3. Foodvalley region

The Foodvalley region is a regional network organization in Netherlands for agrifood involving eight municipalities (Barneveld, Ede, Nijkerk, Rhenen, Renswoude, Scherpenzeel, Veenendaal and Wageningen) with two provinces (Gelderland and Utrecht), which includes 350,000 residents. Additionally, the Foodvalley region also collaborates with educational and research institutions as well as entrepreneurs in the region [1].

As the knowledge hub of the Foodvalley region, Wageningen University & Research (WUR) is one of the institutions that accommodates researchers and entrepreneurs from all over the world. The Foodvalley region is the location to WUR as well as a number of applied science universities, secondary vocational schools, and Rivers International School. Collaboration between local businesses and educational institutions is also supported and facilitated by the Foodvalley region. There are also some well-known research facilities in the region, including the World Food Center in Ede, the Friesland Campina R&D center, and as of 2019, the Unilever R&D Division[2]. However, as these companies do not have processing facilities in the region they were not included in this research.

By 2030, the Foodvalley region aspires to be a leading region in the field of agriculture and food, as well as a region where people are significantly healthier and like to live, conduct business, innovate, and implement circularity by default [3]. The Foodvalley region has now identified multiple challenges in their strategic agenda which is used to become a leading region. For instance, how could the region guarantee a healthy future for humans without damaging the environment, and how can they produce healthy, local food widely available for

[1] Over ons - https://www.regiofoodvalley.nl/over-ons

[2] About - https://www.regiofoodvalley.nl/en/home/about

[3] Strategic agenda themes - https://www.regiofoodvalley.nl/projecten/themas-strategische-agenda.

the inhabitants of the Foodvalley region (Foodvalley, 2020). To maximise the regions' impact while tackling these challenges, the Foodvalley region and its partners have developed seven themes. Such as "*Agriculture and vital countryside — Towards a sustainable agricultural system*", "*Nutrition for a healthy life — Healthy, sustainable and sufficient food*" and "*Innovation, cluster formation and circular economy*" (Foodvalley, 2020).

In terms of this consultancy project, the theme, '*Nutrition for a healthy life'*, is an important focus point. As the global population is growing quickly, this theme aims to provide healthy, sustainable, and sufficient food to feed the globe. In addition, increasing access to healthy nutrition for everyone is an important goal, also in the region. To reach this scenario, the project will concentrate on contributing to shorter food chains (more residents eat regionally produced food) and less food waste (50% reduction by 2050). By combining research, practical knowledge and entrepreneurship, the region aims to reach these goals and find ground-breaking innovations in the fields of agri-food, nutrition, and health (Foodvalley, 2020).

6.3.1. Business activities Gelderland and Foodvalley

As explained, Foodvalley region is partially located in the province of Gelderland. This research was able to find more detailed information on business activities in this province, and it was used to establish an impression of the local region. Jutte & Roos (2019) explained the food industries regarding the agrifood, livestock farming and related sectors in the province (Figure 4). Some of the largest identified flows were pasture grass and silage maize (together 4.3 million tonnes/year), animal feed (4 million tonnes/year), manure (12.640 million tonnes/year) and milk (2.2 million tonnes/year). The total flow of the food and feed industry is 7.6 million tonnes/year and a residual flow of 0.9 million tonnes/year. with the subsectors slaughterhouses & meat processing, potatoes, fruit and vegetables and vegetable and animal oils and fats have a large flow of materials. VGI disposal in Figure 4 stands for the approved disposal from the food and beverages industry.

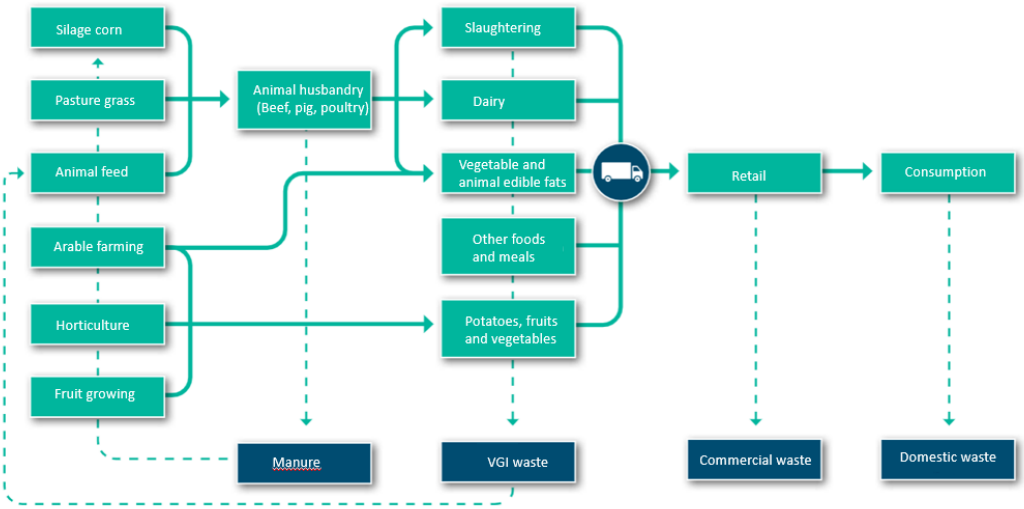

Figure 4: *Overview of food streams in Gelderland in terms of product use, translated from (Jutte & Roos, 2019).*

In the report of Circulair Atlas Gelderland by Jutte & Roos (2019), a map is drawn showing the main industries in the Foodvalley region. Since the report is on Gelderland this implies that Renswoude and Veenendaal are not represented on these maps. From these maps, the conclusions can be drawn that in the Foodvalley a lot of business activity related to meat cattle, pigs and poultry are present. In addition, it shows a high number of cattle feed producing companies (Appendix A). Furthermore, the number of food industries is also relatively high in the Foodvalley in relation to the other part of the province Gelderland, these concentrations are relatively high in Nijkerk, Barneveld and Ede (Appendix A). The companies identified in this report Circulair Atlas Gelderland might be appropriate for this research.

6.4. Circular economy

The circular economy (CE) is a closed-loop economic system that maintains the highest utility of raw materials, components, and products with minimal loss of value, uses renewable energy and takes system thinking as the core. An example of a circular food company is a British company called *Wasted Apple* which uses locally wasted apples as a key resource to produce food-grade drinks and beverages (Cullen & De Angelis, 2021). A more local example is that of *Bakkersgrondstof*, a company that collects locally wasted bread and processes these to become a primary resource for sourdough bread (Bakkersgrondstof, 2022). This primary resource is then sold to the companies the waste was initially collected at, closing a circular system. The CE has become an increasingly popular framework for systems solutions aimed at mitigating future resource scarcity and environmental challenges such as carbon dioxide emissions (MacArthur, 2013; Sarja et al., 2021). As a result, various stakeholders such as governments, companies and investors are incorporating the circular economy into their strategies to improve environmental sustainability and achieve climate goals. In practice, when a product reaches the end of its life, its materials remain in the economy as long as possible. These can be used effectively again and again, thus creating further value (European Parliament, 2022).

Reducing food waste can contribute to achieving the United Nations' Sustainable Development Goals and is also one of the most important tasks of the EU's Circular Economy package (FAO, 2021). The Dutch government aims to use 50% less primary raw materials in the Dutch economy by 2030 than today and to achieve a fully circular by 2050 (Rijksoverheid, 2022). Moving towards a more circular economy can bring lots of benefits such as increasing the security of the raw materials supply, improving competitiveness for the companies, reducing negative impacts on the environment, stimulating innovation, and promoting economic growth (European Parliament, 2022).

The application of circular economy principles can make the food supply chain more sustainable in a variety of ways. It is essential to find innovative ways to reduce food waste, gain value from underutilised waste and reduce unnecessary food packaging. In addition, achieving the vision of a circular food economy will bring economic, environmental, and social benefits, including 1) making a balance between health and ecosystems; 2) increasing food security; 3) empowering local communities; 4) contributing to positive GDP growth and job creation; and 5) promoting innovation (Bouroniko, 2021). The application of circular economy principles can make the food supply chain more sustainable in a variety of ways. It is essential to find innovative ways to reduce food waste, gain value from underutilised waste and reduce unnecessary food packaging. In addition, achieving the vision of a circular food economy will bring economic, environmental, and social benefits, including 1) making a balance between health and ecosystems; 2) increasing food security; 3) empowering local communities; 4) contributing to positive GDP growth and job creation; and 5) promoting innovation (Bouroniko, 2021). The circular economic seeks a model for global economic development that ultimately moves away from the consumption of finite resources. As the call for a new economic model grows, a favourable combination of today's technological and social factors can make the transition to a circular economy possible (MacArthur, 2013).

6.4.1. Moerman's ladder

This project defines the degree of underutilisation of waste according to its placement on Moerman's ladder, shown in Figure 5. This model was designed to efficiently distribute the next processing steps of the food waste to lengthen the useful life cycles of the discarded biomass, with the rule of thumb being "the higher the ladder, the better" (Nederland Voedselland, 2018). Alongside the EU food waste hierarchy, the Moerman ladder is not the only framework developed in which to deal with waste; the manner in which to utilise different materials depends on the perspective that you take in viewing the 'waste'. As outlined by Muscat et al. (2019) in their review of the 'food-feed-fuel competition for biomass', the formation of various waste frameworks stems from the Sustainable Development Goals of the United Nations (United Nations, 2022). The treatment of food waste involves chiefly the second goal 'Zero Hunger', which highlights the need for "food security and improved nutrition", and the seventh goal for 'affordable and clean energy' (United Nations, 2022). Achieving clean energy in this case involves the growing of biomass for alternative and renewable energies such as biofuels, whereas nutrition and food security involve growing the biomass explicitly to feed humans, and to feed the animals necessary for a carnivorous diet (Muscat et al., 2020; Thornton, 2010). Therein, a discussion arises concerning

the perspective in which to distribute the resources to grow biomass, and whether it should prioritise food, feed, or fuel. This debate can be further broken down into feed versus food, and feed/food versus fuel, as the farmed biomass generally produces both edible and inedible components that may both be used for feed but not both for human food.

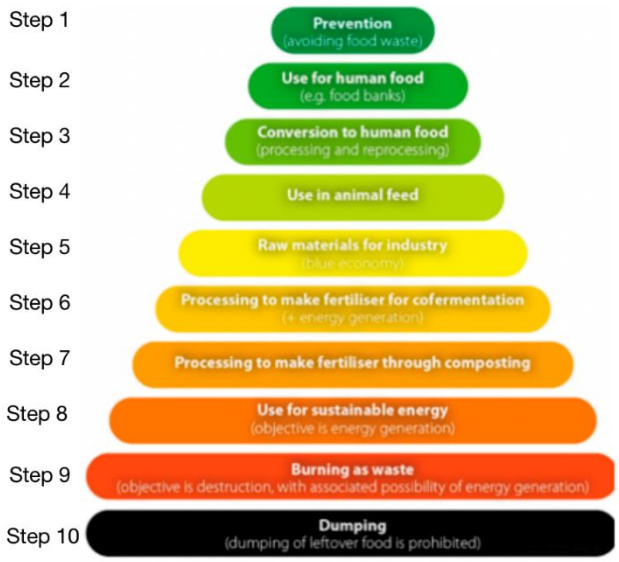

Figure 5: *Moerman's Ladder, which describes the food waste hierarchy (Eriksson et al., 2015).*

The Moerman's ladder uses a circular economy perspective, which emphasises the importance of conserving the value of the materials and lengthening their useful life cycles, particularly through the use of cascading. Alongside burning and dumping, the usage of biomass for energy is placed at the bottom of the pyramid (Figure 4) as this application inhibits further cascading of the material later on, thereby ending its useful life cycle. The materials needed for food (and then feed) are more particular in terms of nutritional content and food safety regulations, with the lower levels of the pyramid having fewer requirements in terms of content but rather a higher emphasis on quantity and bulk; the pyramid therefore prioritises the usage of waste according to its highest financial value. A study conducted by Melikoglu (2020) further demonstrated that certain 're-utilisation techniques' of food wastes such as anaerobic digestion, thermochemical conversion, and fermentation may not be financially beneficial due to the associated costs of handling waste products which may not derive sufficient energy to justify the costly process.

Besides prevention, the usage of food for human consumption is placed highest on the pyramid, directly above animal feed. With the original intention being feeding the worlds growing population, prioritising the feeding of animals which would be used to then feed humans is not as efficient as simply reusing it to feed to humans. Additionally, studies by Garnett (2009) have shown that using biomass directly for food versus feed is more efficient in the amount of land needed as well as in the emissions of carbon dioxide.

6.5. Regulations and Risks

When moving waste up the Moerman's ladder and using these new 'resources' as inputs in human food and animal feed processes, companies are likely to encounter regulations. A study by Bos-Brouwers, Kok and Snels (2020) has established a clear overview of relevant laws and regulations, and the formation of food waste within Dutch and European legislation and regulation. This study includes food waste legislation on foodstuffs that are no longer usable for human consumption, and the use of animal by-products and waste.

Regulation EG 654/2004 specifies the requirements for checking produce with animal origins destined for human consumption (Bos-Brouwers et al., 2020). New guidelines by the European Commission on using foodstuffs that are no longer fit for human consumption in animal feed, presumably prevent companies from engaging with waste streams. According to Bos-Brouwers et al. (2020), new guidelines could make companies feel obstructed

when planning to engage with using foodstuffs that are no longer fit for human consumption in animal feed. Companies that are labelled as 'foodstuffs- and animal feed company' will encounter multiple extra audits. Also, additional private certification is required when engaging with foodstuffs. Both factors may be intimidating to new entrants and therefore might prevent them from using the waste streams which are available to them. This increases food waste as biobased resources fit for animal feed now end up in low-value applications such as composting or biogas (Bos-Brouwers et al., 2020).

6.5.1. Regulations and Animal By-products.

Regulation EG 999/2001 predict the requirements concerning the prevention, control, and eradication of specific transmitted diseases. Animal by-products account for a significant amount of food waste in the EU (Wunder et al., 2018). These by-products can be categorized into three categories. Unlike categories 2 and 3, category 1 cannot be processed for anaerobic digestion plants as they might spread diseases and are only used for incineration, sometimes with energy recovery. Furthermore, Regulation EG 999/2001 states that currently the use of animal by-products is being curtailed, for example under regulation EG 999/2001. These regulations include several demands. One such example is that companies that use feed from animal origin (e.g., fishmeal and blood-related products), must register or ask for permission to do so (Bos-Brouwers et al., 2020; Wunder et al., 2018). The main goal of these regulations is to prevent cross-contamination between herbivores. Currently, this regulation prevents companies from using animal proteins, kitchen waste and food waste (Bos-Brouwers et al., 2020; Wunder et al., 2018). These streams might hold valuable animal by-products that could be used for human/animal consumption which are now either burned, composted or turned into biogas (Bos-Brouwers et al., 2020). *Regulation 142/2011* implementing *Regulation 1069/2009* specifies the way low-risk category 3 animal by-products, that have not been prohibited, need to be processed before using them as animal feed. An example is a raw milk, which needs to be heated to 72 degrees Celsius for at least 15 seconds (Wunder et al., 2018). Other examples to keep category 3 animal by-products in the supply chain are including the production of processed foods (e.g., making sausages), use by-products in specific animal feeds, or exporting organ meats to countries that traditionally consume those parts (Rao & Bast, 2021).

According to Wunder et al. (2018), *Regulation 183/2005* (laying down requirements for feed hygiene), requires UK and Dutch companies to register as 'Feed Business Operator' with competent authority for all food and feed businesses that produce, use, retail or market feed or ingredients for feed. This implies for example that whenever a bakery wants to supply a former foodstuffs operator, a company that uses former foodstuffs for feed, with leftover bread, the bakery has to go through full registration (Wunder et al., 2018).

6.5.2. Animal Meal from Pig and Poultry

Animal meal is an ingredient created by the processing of slaughterhouse waste (Silvis et al., 2021). Using animal meal as an ingredient for animal feed allows protein-rich animal waste streams to be used. Since 2001, because of an outbreak of the mad cow disease (BSE), the EU had banned the use of animal meal. However, over the past years the EU has reopened the case of animal meal and has been looking into ways to integrate animal meal from pigs and poultry. This implies either using pig meal in poultry feed or poultry meal in pig feed. As of August 17, 2021, under *Regulation (EU) 2021/1372*, it has been re-authorised to use:

- Processed animal proteins (PAP) derived from pigs and insects in poultry feed.
- Processed animal proteins (PAP) derived from poultry and insects in pig feed.
- Gelatine and collagen of ruminant origin in the feed of non-ruminant farmed animals.

This is re-authorised only under strict conditions in order to prevent cross-contamination, to ensure compliance with the prohibition of intra-species recycling (i.e., cannibalism), and in order to facilitate official control measures regarding animal feed (FEFAC, 2021). However, PAPs from ruminants (sheep, goats, cows etc.) are still banned for feed of all farmed animals due to the risks of spreading BSE and starting a new crisis (FEFAC, 2021; Silvis et al., 2021).

6.5.3. Risks of using food waste streams as input

Circular food supply chains imply the re-introduction of by-products to the process and/or new processing steps. From a food safety perspective, new or not well-known hazards can occur and accumulate in the supply chain due to the reuse of these by-products (Focker et al., 2022). The relevant food safety hazards are different for each main production domain: packaging, plant, animal, and aquaculture. In general, the hazards can be categorized into pathogenic bacteria, viruses, heavy metals, pharmaceuticals, dioxins, polychlorinated biphenyls (PCBs), perfluoroalkyl substances (PFAs), mycotoxins and prions (Focker et al., 2022).

It is a common practice in the EU to use food chain by-products for feed production (Fusion EU, 2016). Animal feed influences the quality and safety of the final food produced. The contaminants and toxins mentioned earlier can be transmitted to livestock through animal feed.

Once transmitted to the animal, the hazard is considered as a food safety risk in the case of its presence in the final food product. In fact, because of the scandals and food crises in the 1990s, the European Union adopted *Regulation 178/2002*, in which animal feed is raised to the same level as human food (Ustundag et al., 2016). Both food and feed processors must meet legal requirements in terms of safety and using waste streams as input is a potential source of hazards. Food safety scandals impact the companies involved in an economic and social dimension.

From a supply chain perspective, circular economy requires companies to make strategic long-term decisions. As stated by Govindan & Hasanagic (2018), circular food supply chains require a re-design of the product and process, which is a complex challenge. This clashes with the fact that customers often demand specific requirements and specific products. Mehmood et al. (2021) detail that other relevant barriers for circular chains are (1) low collection rate of waste (2) uncertainty about time and place of collection (3) failure in logistics transmitted to the entire supply chain (4) lack of reliable and affordable transport and communication between enterprises. To sum up, the required change in process and the current logistic uncertainty and lack of resources limit the implementation of circular food supply chains.

6.6. LCA and limitations

The life cycle assessment (LCA) is a tool designed to measure the environmental impact of a product system over its entire life cycle. This is accomplished by considering all processes, from resource extraction and production, transport, and consumption to waste treatment, which is commonly referred to as a "cradle-to-grave" analysis (van Hal et al., 2019). A simplified model is shown in Figure 6. The LCA considers numerous distinct environmental consequences, ranging from environmental impact categories (e.g., carbon footprints) to additional indicators such as waste types and output flows (Hillege, 2019). However, an LCA for managing food waste is still a complicated field which involves both technical and biological procedures. Food waste differs from many other waste fractions in that it is impacted by biological processes along the waste management chain. Both of these processes have adverse environmental impacts and limit the capacity to recover energy and nutrients through other waste management processes (Bernstad & La Cour Jansen, 2012). Local circumstances and timing are more significant and important than many other waste fractions since these biological activities can be highly reliant on variables including climate, rainfall, and soil profile (Bernstad & la Cour Jansen, 2012). Additionally, the effectiveness and validity of the LCA are determined by the quality of the available data.

Since the companies included in this report only provide incomplete and partially anonymous quantitative estimations, many assumptions were made. This has a negative impact on the precision and accuracy on the possible implementation of LCA. Although this tool is the most accurate and optimal to evaluate environmental impact, it will not be used due to the stated limitations.

***Figure 6**: The simplified steps included in life cycle assessments.*

7. Methodology

Data collection in the project was based on interviewing food processors in the Foodvalley region, with iterative rounds of literature reviews. The whole project was mainly carried out on the campus of Wageningen University & Research. When necessary, the interviews were conducted off-campus at the site of the food processors.

7.1. Identification

7.1.1. Municipality and waste management companies calls

The municipalities of Ede, Renswoude, Nijkerk, and Wageningen were contacted for this study to obtain information on the waste streams present in these areas. Halfway through calling the eight companies, the scope shifted. The search approach was changed to focus on calling local waste firms instead, as all four municipalities reiterated that said waste companies were responsible for the monitoring of waste, rather than the municipalities themselves. This was done with the intention of collecting regional data on waste types and quantities from the food industry. However, it was not possible to gather this information due to confidentiality issues. Therefore, this research focused on getting their opinion on current waste management. Contact was made with the two relevant waste companies in the Foodvalley region: Omgevingsdienst de Vallei and Omgevingsdienst regio Utrecht. From these two, it was only possible to interview Omgevingsdienst de Vallei, which covers five out of eight municipalities in the region.

7.1.2. List of company contacts and cold calling

The process to interview food processors in the area began by compiling a contact list (Appendix B) based on the list of companies available on the ORBIS database. This database managed and owned by Bureau van Dijk includes relevant information such as company name, type of industry, contact person and phone number. The filters applied limited the geographical scope to the eight municipalities within the Foodvalley region, and was further filtered to yield only ‘Manufacture of food products’ companies. The retrieved companies on the list were scanned to remove any companies which were not B2B, which is the intended scope.

From the list, each company was researched on whether the contact person found by ORBIS had the appropriate knowledge of company-specific waste streams. If necessary, LinkedIn and Google were used to find an employee on location with an operational function that could contribute to the interviews on the waste streams. The reason a decision was made to target operational people was based on the fact that operational functions involve streams of materials within companies (Parry et al., 2010). After confirming the contact person, every company on the contact list got at least one call from the team to make a 30-minute appointment for the interview. When the contact person was not available then, the question of whether there was another person in the related position who could participate in the interview was asked. Otherwise, an email was sent to the person that was aimed for the interview. As soon as the contact person agreed on an interview, an option was given to conduct the interview on location or via Microsoft teams.

7.1.3. Company interviews

An interview script (Appendix C) was created based on the research questions of this project. The script included three parts: an introduction to the project and group, a confidentiality statement, and a question list. All the interviews with companies followed this script. A semi-structured interview was designed, to have flexibility in the interviews while always covering the important topics. All of the interviewees agreed on having the meeting recorded. It was used to obtain a transcript and an overview table.

The results of the transcriptions and recordings of the interviews were added in the table of appendix D. In this table the following are included: the company name, a company description, process inputs, process outputs (including waste), estimation of quantities, the current waste management, the current company circularity, the willingness to contribute to a local economy and the bottlenecks for a circular economy were added based on the results of the interviews. These results were further used to answer each of the research questions in this project.

7.1.4. Identification of industries and underutilized waste streams

To identify what type of food processors are present in the Foodvalley region, the companies were categorized into 9 categories. For each category, the number of companies is visualized in a diagram to clarify the number of companies per industry. To identify the types of waste streams, the results from the interviews were put into separate columns. The columns related to industry type, identified waste streams and waste management method were added to contribute to the research question: ‘What waste streams are in the region and what waste streams do they produce?’.

To gain knowledge on the utilization based on the Moerman ladder, the waste management of residual flows within the companies was used. Each of these waste management methods per company was categorized according to the different levels of the Moerman ladder (Eriksson et al., 2015). In this ladder, the differences in the number of steps on the Moerman ladder between the utilized core products and the waste streams was assessed to check to what extend the residual flows were underutilized.

7.2. Evaluation

7.2.1. Waste stream analysis

From the interview with the companies, the estimations of quantities for inputs and outputs were collected (Appendix D). This information was used to answer research questions three and four. The analysis and comparison were based on both amounts of the waste streams and the percentage of wasted inputs. It was not possible to obtain this information from all of the interviewed companies, due to confidentiality issues or lack of knowledge of the interviewed person.

For the comparison of the waste streams between different companies, a table and a bar chart were used to visualise the results. Since the units of the raw data were different from each other, the units were translated

into a consistent unit (kg/month). If the unit of data was collected weekly, the assumption was given by four weeks equal to a month. Moreover, if the unit was daily, then the assumption was based on thirty days per month.

To calculate the percentage of wasted inputs, the formula below was used:

$$P_{wasted\ input} = \frac{M_{waste}}{M_{input}} \times 100\%$$

$P_{wasted\ input}$ represents the percentage of wasted inputs (%); M_{waste} represents the amount of waste per month (kg); M_{input} represents the amount of the total inputs per month (kg).

7.2.2. CO_2 emission analysis

The CO_2 emission analysis of this project was based on the dataset which extracted from the database website named "AGRIBALYSE" and includes the data of environmental indicators (e.g, CO_2 emissions) of the 2,500 products in France in 2020. As this dataset provided the details of the main stage in the food supply chain, this dataset was applied to the Foodvalley region in the Netherlands (Colomb et al., 2015).

The dataset includes 6 stages: agriculture, processing, packaging, supermarket and distribution, and consumption. Since this project was only focused on B2B, the last two stages were not considered in the CO_2 footprint analysis (Colomb et al., 2015).

Once the data was fully collected, it was noticed that there is a trend to mix waste outputs in companies. The assumption is made for those mixed wastes to regard as one waste so that it will be straightforward to calculate the CO_2 emissions. Using the filters of the database, the corresponding big categories were searched, and the average equivalent CO_2 emission of the categories were calculated.

The amount of the CO_2 emissions of the companies were calculated by the following formula:

$$M_{CO_2\ emission} = M_{waste} \times C_{CO_2\ emission}$$

$M_{CO_2\ emission}$ represents the amount of CO_2 emission (kg); M_{waste} represents the amount of waste (kg); $C_{CO_2\ emission}$ represents the CO_2 emission per kilogram of the waste (eq CO_2 kg/kg of waste).

7.2.3. Bottlenecks, local connection and willingness.

The interview script included questions regarding the current local connection, willingness and bottlenecks of circularity in companies (Appendix C). In appendix C, it can be seen that there are specific columns for these aspects. Answers for each question (i.e., bottlenecks, local connection, willingness) were classified, in order to discuss quantitatively the results and answer research question five. For the bottlenecks, the classification is done based on the main factor. The local connection is classified based on the suppliers and customers of the company (are they within the Foodvalley region or not). Lastly, willingness is measured as interest on circular food supply chains, the region and similar projects.

To get another point of view about the current situation, Omgevingsdienst de Vallei was interviewed (responsible of the waste management in four municipalities in the region) and Hilke Bos-Brouwers (a senior scientist with expertise on circular food supply chains). These interviews were recorded and a transcript was obtained. Afterwards, a small summary was prepared to highlight the most important insights and topics. The information gathered from these sources was mostly related to the current situation and bottlenecks.

8. Results

8.1. What food processors are in the region and what waste streams do they produce?

An overview of all the firms discovered by ORBIS and the commissioner is provided in the table of appendix B. ORBIS initially generated a total of 201 enterprises. There were several business-to-consumer (B2C) enterprises on this list. These were eliminated by examining each company to see whether they directly delivered to the end customer since this was outside the scope of the study. Combining the relevant companies from the commissioner with the relevant companies from ORBIS, resulted in a total amount of 41 food companies with a total of 45 production facilities (some companies had multiple facilities in the Foodvalley region) that were approached for interviewing. The overview of the relevant facilities found present in the Foodvalley region is shown in figure 7. The grain industry is consisting out of bread companies, but also a breadcrumb company and other cookie or *savoury* grain snack companies. The category 'other' consist out of a nut processor, a herb company, and 2 other *start-ups*.

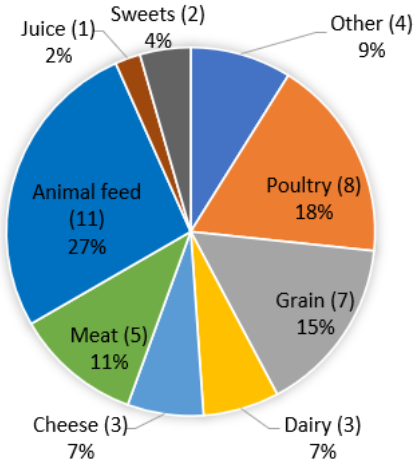

Figure 7: Number of process facilities per industry type.

A total of 11 businesses from the list of companies were interviewed either via teams or on location. No pertinent waste streams were found at the interviewed start-up, nor in that of the bread company. The waste stream management strategies for the remaining companies' interviews are laid out in table 1, excluding the 2 previously mentioned which did not produce any waste streams.

Table 1: *Identification of waste streams of 9 companies and the waste management of these companies. Note: between brackets, the number of the company is specified.*

Industry type	Identified waste streams	Waste management
Grain	Dough (16)	Sold to feed companies (16).
Feed	Little quantities of animal feed (1) Negligible quantities of animal feed (6)	If not suitable for animal feed, it will be used for energy production (1).
Meat	Silt (29), Bones with leftover meat (29) and Beef category 3 (7)	Send to recycling company a recycling company, which will be further used for Bio energy production.

Cheese	Cheese parts from slicing (10)	Animal feed company specialized re-usage of cheese waste. Some of the cheese will be used for melted cheese for human consumption.(10)
Sweets	Starch, water and sugar (23)	Sold to pig feed companies.
Juice	Waste juice with water (37)	Used by water treatment plants.
Other	Sugar and peanut mixture, spices, and herbs (30)	Sold to animal feed companies outside the region.

8.2. Which of these streams are underutilized according to Moerman's ladder?

It is feasible to assess where residuals end up based on the Moerman ladder using the results of the interviews. Table 2 shows by the length of the arrow the extent to which residual streams are underutilized. For example, residual streams with a relatively long arrow lose many steps on the Moerman ladder, which may cast doubt on the extent to which the residual streams are properly utilized.

Table 2: *Residual flow per industry type visualized on the Moerman ladder.*

Moerman ladder (industry) (number of companies)	Feed (2)	Grain (1)	Meat (2)	Cheese (1)	Sweets (1)	Juice (1)	Nuts (1)
1. Prevention							
2. Use for human food		Grain	Meat	Cheese	Sweets	Juice	Nuts
3. Conversion to human food		↓	↓	Grated cheese	↓ Dough	↓	↓
4. Use in animal feed	Feed	Dough	↓	Cheese waste	Starch, sugar	↓	Sugar, peanut, herbs
5. Raw materials for industry	↓		Bones with meat			↓	
6. Processing to make fertilizer for fermentation			↓			Water with sugar	
7. Processing to make fertilizer though composting	↓		↓				
8. Use for sustainable energy	Feed leftovers		Bones with meat				
9. Burning as waste							
10. Dumping							

The least desired outcome, food being burned as waste or dumped, never occurred in any of the companies. Some of the waste generated by feed businesses is converted into sustainable energy. Looking further into this with the Moerman ladder, there are three steps between the use of sustainable energy and animal feed. It should be considered to use animal feed residual flows to produce compost, create fertilizer or use as raw material (step 5, 6, and 7). The disparity between production and waste according to the Moerman ladder is less in the grain business as the waste that is not suitable for human consumption it ends up in the animal feed industry (only one step lower in the ladder).

Numerous animal products are reused in the meat business, which helps to reduce food waste. On the Moerman ladder, the parts that are not intended for human consumption, however, end up at a relatively low place and may consequently go unused. According to the Moerman ladder, the efficiency in the cheese business appears to be among the top levels. When cheese is left over after production, the leftovers are transferred to a firm

that repurposes them as food for humans or livestock (Table 2). This also applies in the sweets and nuts companies that were interviewed, which prioritised the prevention of waste by reusing and reintegrating the material back into the production process. The rest products that came from the Juice company, were used in water filtration systems as energy for bacteria in step 6 of the Moerman ladder (Eriksson et al., 2015).

8.3. What magnitude are the waste streams compared to one another and what is their impact?

8.3.1. Waste stream analysis

Table 3 has been divided into 2 main groups according to their priorities; the food companies that produce waste and intend to sell it, and the feed companies that are in turn able and/or willing to use the 'waste'. The food companies were generally unwilling to divulge the exact quantities of their inputs and outputs as a matter of confidentiality was involved. The feed companies generate less or even no waste and were able to reuse it by themselves, which explains the lack of data regarding the quantities of outputs in Table 3. Overall, the table demonstrates the diversity in the amount of waste created across the varying food processing companies, which could be attributed to a combination of factors such as the varying sizes of the different companies and the nature of the food being processed. Table 3 shows that companies 23, 30, and 37 producing sweets, nuts, and juice respectively were amongst the lowest producers of waste, with the highest producers being 29 (raw pork product) and 10 (cheese).

Table 3: *Quantities of waste, input and output monthly in different companies.*

Company	Category	Quantities of waste* (kg/month)	Quantities of input* (kg/month)	Quantities of output* (kg/month)
Waste producers				
30	Nuts	6,000.00	Unknown	104,000.00
16	Bread	8,333.33	Unknown	Unknown
29	Raw pork product	972,000.00	10,800,000.00	9,828,000.00
23	Sweets	12,000.00	Unknown	Unknown
7	Category 3 meat (beef)	10,000.00	26,000.00	Unknown
10	Cheese	125,000.00	Unknown	2,083,333.33
37	Juice	61,062.00	Unknown	Unknown
8	Protein	Unknown	Unknown	Unknown
Waste users				
6	Animal feed	None**	15,000,000.00	None
1	Animal feed	None	30,000,000.00	None
3	Bread	None	10,000.00	None

**Note: the quantities were all based on the estimations of the contact person instead of a realistic and reliable data.*

***Note: waste users use all the input (i.g., waste), so they do not have quantities of waste and output.*

Figure 8 compares the quantities of waste amongst the waste producer companies; the waste users and company 8 from the waste producers were excluded from this comparison due to a lack of usable data on the quantities of waste. According to this graph, the company 29 (meat) has the largest total amount of waste (972,000 kg/month) which is significantly higher than the other companies. The percentage of the wasted input of company 29 is 9%, which may be due to the large quantities of bones as compared to the little amount of meat resultant from the processed carcasses. Regarding company 10 (Cheese) and 37, the size of waste every month is 125,000 and 61,062 kg monthly respectively, which ranked highest after company 29. Besides these three mentioned companies, the waste sizes of other companies are relatively all small, varying between 6,000 to 12,000 kg per month.

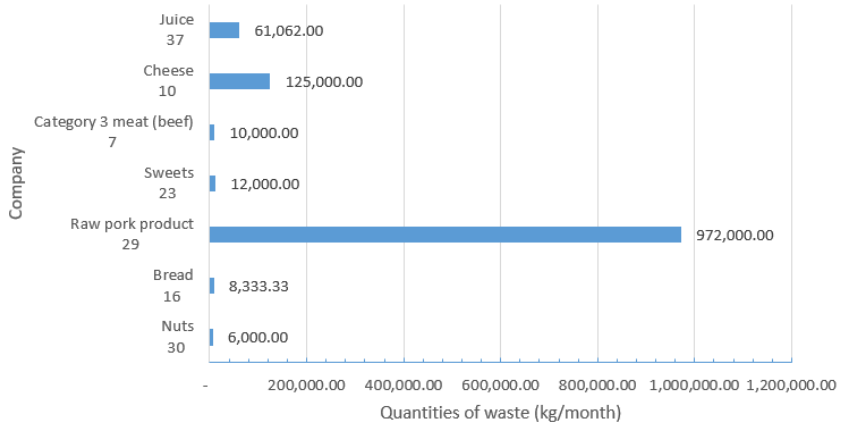

Figure 8: *Comparison of quantities of waste monthly in different companies.*

8.3.2. CO_2 emission analysis

The waste sources described in the interviews were often comprised of heterogenous mixtures of waste products, which were complicated to specify when analysing the CO_2 emissions. In order to make such calculations possible, each company's waste stream was assumed to be homogenous to one material, based on the material which was most present (Appendix E). It is assumed that the waste produced by the nuts company, which creates a mixture of sugar, herbs or nuts waste, falls under the nut category. For the meat company which produces bone waste from pig carcasses, it is assumed the waste belongs to the raw pork product because the bones are included in the processing of raw pork product, they have the same CO_2 emissions as the raw pork. For the sweet company which generates waste of marshmallows, starch and water with sugar, it is assumed the mainly waste falls into the sweet category. Moreover, for the juice company which generates waste of water, and sugar with mixed juice, it is assumed those wastes belong to the juice category.

Figure 9 details the equivalents of kg of CO_2 emitted per kg of product, which demonstrates the absolute impact of the product itself, irrespective of the size of the company. According to Figure 9, category 3 meat (beef) belonging to company 7 has the largest CO_2 emission per kilogram (30.17 kg CO_2 eq/kg) among the six categories. While the bread and the juice generate the least amount of CO_2 (respectively 0.63 and 1.17 kg CO_2 eq/kg). In addition, cheese, raw pork products and nuts produce a similar level of CO_2 emissions.

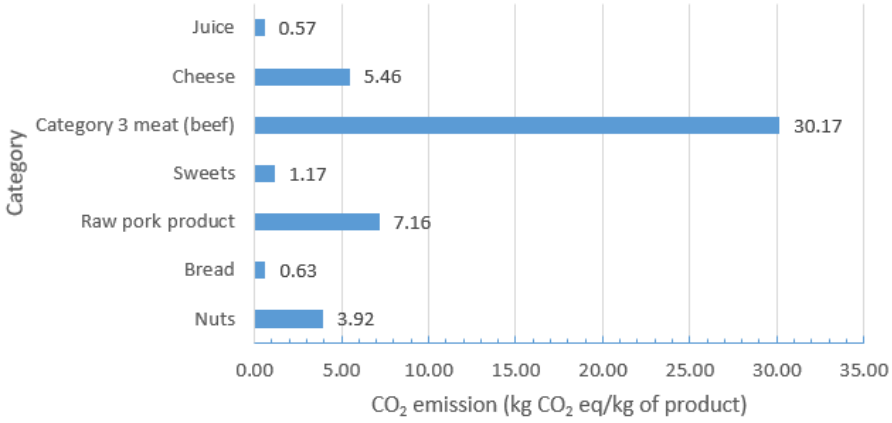

Figure 9: *Comparison of CO_2 emission (kg CO_2 eq/kg of product) of different categories.*

According to Figure 10, company 29 produces the highest CO_2 emission (6961777.4 kg) because of the highest waste generation. Figure 10 shows that the waste released from company 29 exhibits the highest CO_2 emission compared to the other companies; even though it was shown to be relatively conservative in CO_2 emissions compared to company 7 in Figure 9, it remains the most impactful due to the huge disparities in the amount

produced between both companies (Figure 8). That being said, the once seemingly insignificant company 7 (according to its tiny presence in Figure 8) has gained a significant increase to the third place in Figure 10, due to the huge amount of CO_2 emitted per kg of its product (beef). Keeping in line with the findings from Figure 8, company 10 remains the second place in Figure 10, as it was consistent in both having high amounts of waste with high amounts of CO_2 emitted per kg of product. The remaining companies in Figure 10, namely 37 (juice), 23 (sweets), 16 (bread), and 30 (nuts), ultimately presented much smaller presences due to either having a low amount of waste produced, or a low equivalent of CO_2 emission per their product, or both. Therefore, Figure 10 appropriately describes the relative magnitudes of each companies' waste streams, and demonstrates that company 29 (pork) has the highest CO_2 impact.

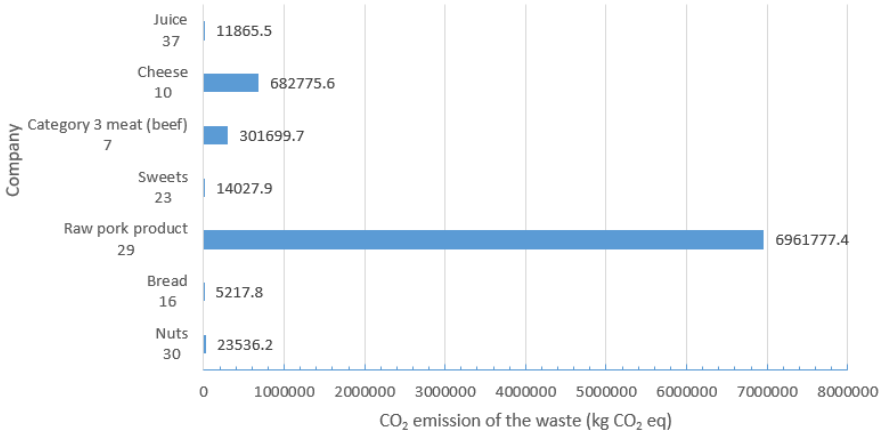

Figure 10: *Comparison of CO_2 emission of the waste (kg CO_2 eq) of different companies.*

8.4. What are the current bottlenecks preventing the valorisation of underutilized waste streams in the Foodvalley region?

As stated in the interview script (Appendix C), the companies were asked about the bottlenecks regarding the implementation of circularity in their processes. In Figure 11, the most important bottlenecks per company are represented.

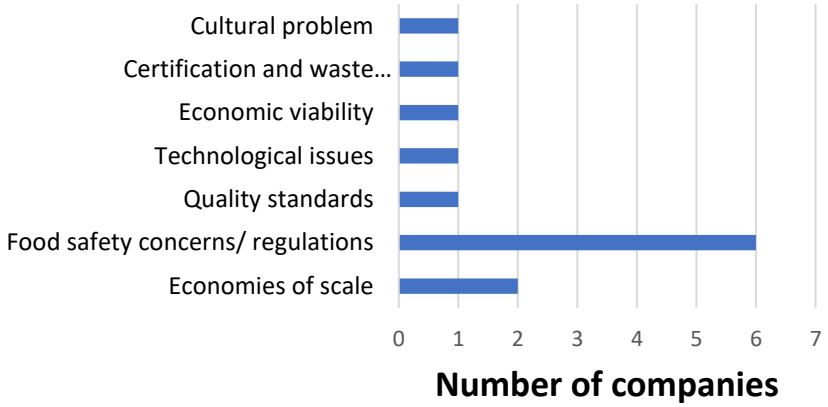

Figure 11: *Main bottlenecks of circular food and feed processing according to companies.*

Food safety concerns and regulations are the main bottlenecks for the interviewed companies (Figure 11). Economies of scale is another relevant bottleneck and refers to the size difference between companies and streams. Quality standards are not legal regulations and therefore voluntary, but they are desired by customers and consumers. Economic viability takes transportation and refrigeration costs into account if required. The cultural problem refers in this case to food processors not willing to share their waste streams with feed

companies. Food waste streams in companies require a management system and in some cases certifications. Implementing these systems and obtaining the certification requires time and resources, and it can limit circularity in some companies.

The results regarding local connection and willingness are presented in Figure 12. As seen in the figure, the number of companies with very low local connection is higher than the companies with very low willingness. On the other hand, the number of companies with high or very high local connection is lower than the companies with high or very high willingness. It is important to note that one of the contacts did not know what the company's opinion was. Therefore, this company is not included in Figure 12.

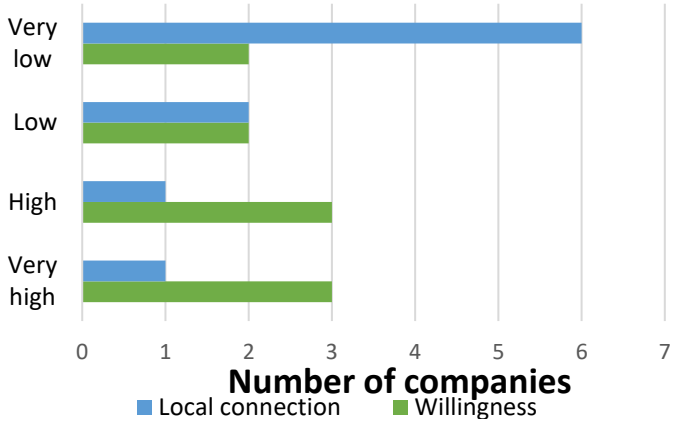

Figure 12: *Current local connection and willingness to participate in circular food supply chains of the interviewed companies. A scale from very low to very high is used.*

Expert interview – Omgevingsdienst de Vallei

Omgevingsdienst (Environmental service) 'de Vallei' is responsible for waste management in the municipalities of Barneveld, Ede, Nijkerk, Scherpenzeel and Wageningen. They are responsible for the regulations around waste management, building permits and permits regarding environmental regulations towards waste disposal. They will do periodic and unexpected checks with companies in the region to check whether the permits the companies own are still valid. If not, the environmental service is allowed to fine them as they are a governmental organisation. Furthermore, Omgevingsdienst checks whether inputs by companies are also accounted in the outputs. By means of sampling they aim to prevent companies dumping their waste.

No local waste processors

The main conclusion that can be derived from the interview with Omgevingsdienst de Vallei is that currently all big waste streams from the region are taken care of by companies who are not located in the Foodvalley region. According to Omgevingsdienst, the Foodvalley region currently does not include any industrial digestion installations or waste burning facilities. The closest installations that can reuse waste for energy are around Arnhem (ARN, Weust). Other than that, most waste is reused for animal feed according to Omgevingsdienst.

Indicating waste streams

Another problem for indicating food waste streams in the Foodvalley region according to Omgevingsdienst is that companies sometimes do not recognize waste as such themselves. Omgevingsdienst does acknowledge that current food processing companies in the region are very efficient in their resource usage and thus might not have large and consistent waste streams.

However, when regarding present waste streams by taking the meat industry as an example, Omgevingsdienst recalls that future projects might want to focus on indirect waste streams – for example, water used for cleaning the meat or frying oils needed to process the carcasses in meat factories. These fluids might hold sludge that could be used as fertilizer. Olthuis, a firm located outside the region, is currently responsible for processing these kinds of waste (e.g., frying oils, grease, fats).

Expert interview – Dr Hilke Bos-Brouwers

Senior scientist in sustainable chains for food and biobased resources at Wageningen Food & Biobased Research. She has participated in European projects related to food waste, such as FUSIONS and REFRESH. Her expertise includes environmental management, food waste, circular economy and supply chains.

Involving food processors in circular food supply chains

In order to involve food processors in circular economy, two problems must be faced. It is essential to deeply analyse their inputs and products. Inconsistencies in waste streams are generally caused by the complexity of the process and/or combined streams. This fluctuation of waste streams makes further valorisation harder. The combination and heterogenous mixing of streams is typically seen in animal and vegetable products.

Additionally, food processors typically do not see their waste streams as waste because they have a settled purpose. For example, if the stream is used for animal feed, aerobic digestion or composting no further valorisation is considered. This leads to companies stating that the generated waste is not a relevant stream. Raising awareness about food waste and the importance of valorisation would be helpful, but solving this situation would require a strategy to financially motivate the companies to do so.

Regulation and operation problems

There are technological ways to safely introduce animal by-products in food processing. Therefore, if the relevant regulations are lifted, new possibilities would be viable. A relevant limiting regulation was lifted recently, and it was related to the use of chicken waste within the pork industry and vice versa. The review of the regulations showed that the requirements for food and feed are almost analogous, so materials that are used for animal feed is may more than often also be considered human food grade. Despite this, the trends displayed in Table 2 demonstrate that the wasted biomass is more likely to be diverted towards animal feed rather than being valorised to human food.

The underlying issue thereby does not lie solely in the food safety regulations as a bottleneck, but rather the need to provide a product with an attractive nutritional content. Furthermore, the system is currently catered towards animal feed as this option is relatively cheap and easy. The underutilisation of these food wastes is thereby more of an operational issue.

In order to introduce a by-product in the processing, food processors need to change recipes and operational parameters. For example, waste streams tend to have a high content of ash, which affects not only the nutritional content, but the taste. It is still possible to obtain an edible product out of it, but it requires many operational changes. The situation is stuck mainly due to processing and money, rather than the technical properties of the stream. This processing barrier is less relevant in the feed industry, where by-products can be implemented more easily.

Is the Foodvalley region big enough to truly achieve circularity?

If the goal is to include all parties, then the consumer's diet should be circular. The Foodvalley region is not big enough to achieve a circular diet, because there not all of the input needed can be produced here. It is important to make the local processing as efficient as possible, by minimizing the total waste streams of the region.

9. Discussion

9.1. Meat industry

Considering the processing of meat, 9% of the inputs of meat processors ends up as waste. Considering all of the results, the meat industry has the highest amount of waste and CO_2 emission in comparison to the other industries analysed. However, it must be taken into account that bones are the most important by-product of this industry and thus not only meat. The waste ends up within the energy (step 8) and raw material production (step 5). This is relatively a large number of steps lower on the Moerman ladder in comparison to the initial step of human meat consumption.

The interviewed companies were open to better valorisation of their waste, but not to use by-products as input due to food safety. Currently, regulations and food safety are large barriers for circularity according to the interviewed company employees within the meat industry. There has recently been a development in which regulations on by-products in the food industry have been loosened, as stated by Dr Hilke Bos-Brouwers during the expert interview; additionally, the expert indicated that it is possible to use animal by-products safely. This change in regulation brings flexibility and opportunities for more circularity within the meat industry. Considering the industry's willingness to work locally, the current situation could be improved. As the scope of meat companies flows lays on a European level, the local region is more easily ignored.

9.2. Animal feed industry

In terms of the animal feed, these companies are not considered large waste generators, but rather waste users. Circularity is already included in animal feed business models, as such companies encourage the use of waste streams as an input. Nevertheless, minor waste streams are generated during their processing. As a result, this waste from food companies will continue cascading down the Moerman's ladder, as any food waste that can no longer be reutilised within the animal feed industry may no longer be valorised to the food level. For example, some waste from the animal feed companies is used for bioenergy production, which is much lower in Moerman's ladder. However, the amount of waste is not large enough to be considered as an impactful improvement, which is why they are not classified as waste generators.

From the results of the interviews, company 1 uses the largest input (30,000,000 kg/month) to produce animal feed. Company 6 (feed) used about half as much input as the former company (15,000,000 kg/month). These input sizes indicate that a huge contribution to the valorisation of waste streams is possible. Valorising food waste for animal feed is not the most desired use, according to the Moerman ladder. Nevertheless, feed companies can have a huge impact on a circular food supply chain, by collecting big food waste streams that cannot be used for human food production.

It is relevant to highlight that animal feed production is still higher than other valorisations, and they are open to inconsistent streams as long as the bulk quantity is high enough. This flexibility is explained by Dr Hilke Bos-Brouwers. Even while the food and feed safety requirements are alike, feed companies face fewer operational challenges when introducing a new by-product. Food processors would have to adapt the recipe and the operational parameters in order to introduce a by-product. Additionally, food processors face a moral issue: should the consumer be informed about the use of by-products? This question does not come up in the feed industry.

9.3. Waste streams are leaving the region

There is already a relevant circular system between the waste producer companies and waste user companies. Most of the food companies interviewed have had the foresight to increase profits by selling their waste streams for further processing (e.g., feed companies), rather than burning or dumping the waste. Nevertheless, their decision on how waste is managed is heavily driven by the price companies receive for selling their waste products.

All the identified waste streams in this project are going outside of the Foodvalley region or even outside the Netherlands to be reused. There are two main reasons why: financial interest and lack of relation with local companies. The feed companies that were interviewed are open to any relevant food waste, and they aim to source more from the region. Therefore, it is viable to achieve the same valorisation within the Foodvalley region to improve the local circularity and connections.

9.4. General situation

Economies of scale was brought up as a main bottleneck by two companies with high export of products. These companies believe that the Foodvalley region is too small, and would therefore not attempt to interact with local stakeholders. The big companies in the region imported inputs and exported products outside of the region and the Netherlands. As stated before, many companies already send their waste to external stakeholders; due to globalisation, many of these companies consider transactions within Europe as local. Dr Hilke Bos-Brouwers

also acknowledged that the region needs inputs from outside the region. Both Dr Hilke Bos-Brouwers and Omgevingsdienst de Vallei mentioned that not all the waste streams are known, due to the lack of awareness and lacking a local waste processor. Identifying and monitoring the waste streams from the entire region would make the region more attractive to big companies since the identification of potential inputs would be higher.

As shown in Figure 12, the general willingness is higher than the general current local connection. This implies that most companies are open to becoming more local in the future, and some stated their aim to become local and/or circular in the future years. The current landscape stands demonstrate a general understanding of the beneficial aspects of circularity, paired with an aversion towards the risk in being a first-mover, resulting a lack of change.

Ultimately, the evaluation of bottlenecks, local connection and willingness suggests that there is a clash of conflict between the stakeholders involved. In other words, each stakeholder holds different values concerning waste streams and circularity: (1) food processors are most attentive about food safety (which can cause economic consequences) and economic viability, (2) policymakers such as the Dutch government and the European Union are concerned about food security and safety, (3) Living Lab Regio Foodvalley Circulair wants to improve the local economy and decrease the environmental impact, and (4) the feed industry wants a local supply of input, but their valorisation is less desired. These varying interests have not been managed and integrated, resulting in a lack of local connections. This project has information that proves that all interests can be potentially satisfied, but changes have to be made.

9.5. Underutilised waste streams and their valorisation

The goal of this research was to answer the research question: “What food waste streams are currently being underutilised in the Foodvalley region that may be more optimally valorised according to Moerman’s ladder?”. The researchers find that this knowledge gap has been sufficiently addressed and successfully answered, within the confines of the scope and limitation of the research (discussed later in section 11). The findings explained in the results and discussion section displayed above demonstrated that, indeed, there are waste present that are being underutilised according to the Moerman’s ladder which may be further valorised. The nature of the food processing companies dictates that every measure be taken to save costs, which in many cases, includes re-introducing the waste products back into their own processes. This extends to further valorising their waste by selling it to feed companies. The smaller companies that do not have constant quantities and contents of waste were unable to participate in this form of further valorisation.

To conclude on the earlier sentiment, although a theoretical perspective dictates that the research was able to find examples of underutilised waste streams that could be pushed further up on the ladder, a practical approach disagrees. Increasing the circularity of food companies in the region involves reducing costs by reusing waste products, and increasing the locality of the product cycles, both of which inherently imply a reduction of cost. Considering that all companies within the scope are driven by finances, all companies, by proxy, aim for the same motivation as the circular economy, indicating that the intentions of the company is not the main issue, but rather the infrastructure of the market as a whole. As of which, any advice given or taken to improve the circularity of the economy must include a system’s perspective to keep in mind the system as a whole, rather than each company as an individual unit.

10. Advice

10.1. Short-term

For the existing food processing companies, the main advice derived from the report is to direct their current waste streams towards local animal feed companies. The advice is derived from the fact that the local feed companies have emphasized their interest in using local waste streams when available. To tackle the bottleneck of inconsistent and mixed-up waste streams caused by efficiency measures, local food/feed processing

companies could establish a common database or local waste collecting network in which multiple streams (with sufficient nutritional values) could be collected to be sent to animal feed producers.

Furthermore, a general lack of knowledge was identified during the interviews, related to the concept of food waste. This results in less waste being recognized by the companies, and therefore less useable waste is being recognized. To change this, an awareness campaign about food waste and Moerman's ladder could be done. Explaining the impact of food waste would result in higher willingness, commitment, and participation in the region. Another relevant topic to explain to companies is the current state of regulations and possible future changes. Legal requirements are moving towards making circularity easier and making this clear to the companies would result in higher willingness. To sum up, it is advised to have an awareness campaign regarding the concept of food waste, it is impact and relevant regulations.

As a result of this project, some practical examples of connections between industries were found. Meat processors in the region work with big streams. The generated waste is relevant, and constant in terms of amount and composition. The wasted food cannot be consumed by humans due to legislation on animal by-products, but it can likely be used for animal feed. The local animal feed industry is looking for streams with high content of protein, like meat. Furthermore, the high willingness of the animal feed industry implies that animal feed should be considered the lowest step on the Moerman ladder, excluding cases in which feed safety is compromised. It is also recommended to explore the poultry sector of the region. It has big streams of input and output, and due to the new regulations, poultry has new possibilities. Due to the limited time available for this project, the first contact with the industry was made, but it was not possible to explore it.

Additionally, it was noticed that companies are not aware of the possibilities of using specific waste streams which might be available in other local companies. This is due to a lack of communication between them. To change this, it is again advised to connect companies through a common database or social networks. Making companies aware of available local waste streams would result on them thinking more locally.

10.2. Long-term

Start-ups can be an example of circularity, and inspire bigger companies that are not open to participate in local supply chains. Due to their innovative ideas, new products and technology they can easily contribute to the valorisation of local waste streams. Also, they are familiar with the importance of the Moerman ladder and circularity, because they are heavily related to WUR. If their valorisation of waste streams results successful, other companies would see it as a new opportunity to work on. Because of this, the long-term advice is to start implementing the circular food supply chain by promoting the participation of start-ups.

It was also noticed that most of the waste streams generated in the Foodvalley region are currently being sent outside of it. The advice given regarding this situation is to keep it in the region. Even if the same valorisation is done, the region would benefit if it occurs within it. In order to promote local valorisation, making companies aware of the environmental benefits would be needed. It is also advised to align the sustainability goals of local companies with regard to waste (SDGs). Having common SDGs would facilitate connecting companies and building strong business relations.

The interviews revealed that the activity level of larger food processors is at a higher level than just the Food valley. Based on this fact, it is recommended that larger players should be approached at a higher level. In this case, consider that possible cooperation on at least a provincial level will have to be sought here. For instance, more cooperation in the field of larger processors could be sought with a collaboration with similar parties that are displayed in Figure 13. These parties are 'Biobased economy de Groene Hub', 'Lerende regio Arnhem-Nijmegen' (purple), 'Agenda Cleantech Regio' (yellow), 'Achterhoekse thema tafel Circulaire economie and Energie transitie' (blue). Combining data between the regions may lead to better options for circularity that might be more economically viable for larger firms. Furthermore, Cluster Circles Oost-Nederland focuses on sharing information among companies in the field of circularity. Data may be shared with this party to find more collaborations on a higher scale which increases circularity.

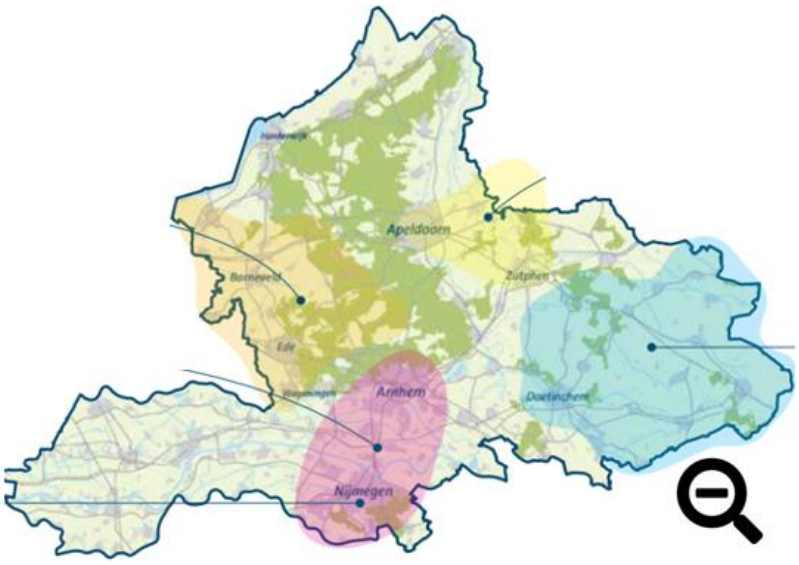

Figure 13: *Local initiatives aiming at circularity and efficiency (Jutte et al., 2019)*

11. Limitations, Reliability & Validity

Company search

The initial company search was done through ORBIS. The limitation of ORBIS is that it excludes any businesses in the region that are not publicly listed. Due to the lack of time and resources, it was impossible to obtain a more exhaustive list of the food processing companies that fit the scope of the research, thereby making limiting the ability to truly answer the first sub-research question. The commissioner aided this search by providing a list of potential stakeholders to interview; this list was limited by the constraints of human memory and attention span and remains an unreliable method of data collection. Under regular circumstances, this would render the study inimitable, as future replications of the study would reveal a different set of companies given, depending on the commissioner available and their memory and experiences with companies. As it happens, none of the companies ultimately interviewed came from the commissioner's recommended list, so the reliability of the results remains intact.

For the visualization of the number of companies, no underpinned industry categorization was used, but rather were segmented based on the industries observed. This may have had a downside on mis-categorizing the distribution of companies found through ORBIS, as well as potentially lacking key industries which are comprised solely of private unlisted companies. Furthermore, the time restrictions placed both on the researchers and the responding companies limited the amount of interviews possible, thereby limiting the validity of the data set. Furthermore, only one company was measured per industry present, which further reduces the validity of the results, as an industry may not be generalized and defined by one company alone.

Interviews

Interviews were appointed by approaching companies over the phone, in either Dutch or English according to the caller's preference and abilities. A lack of expertise in cold calling, and the fact that the majority of the researchers were non-Dutch speaking acted as a limiting factor, in that not all companies were able or willing to speak in English, nor have the patience or time to spare the inexperienced researchers. Despite this, a considerable number of companies accepted the request to be interviewed. It was seen throughout the process that such companies were not convinced to do so, but rather, were already willing to work with students on such projects. This introduces a bias into the research which reduces negatively affects the research's validity, as willingness to talk to students and exchange ideas with such other stakeholders indicates an inherent openness to the idea of flexibility, which circularity demands. In doing so, the remainder of the companies which

were not willing to cooperate on this same basis may very well be the companies which must be addressed in this issue.

A semi-structured approach was applied in the interviews, and was always held by at least 2 people, although the participants holding the position of interviewer varied to allow every group member to gain experience in this research skill. The choice of interviewer group may have introduced a bias in the procedure in the willingness to respond from the interviewee – as an example, some might have been more comfortable when talking in Dutch, and therefore more willing to divulge information and provide a more descriptive overview. Limitations of the semi-structured interview process involves the time-consuming nature to conduct, transcribe, and then summarise every individual interview; alongside this, the majority of the researchers lacked sufficient professional training in the skill, which may have led to the incorrect or inefficient conduction of an interview.

Due to the confidentiality issue, many of the responses received from the interviews were based on estimations, and the identification of the bottlenecks relied on the person's perspective. A lack of official raw data, and having interviewed only one perspective from each company introduces a large bias in the data, as the data is experience and memory based, neither of which is necessarily valid nor reliable on its own. Future attempts to improve such research should include a multi-perspective approach when talking discussing bottlenecks.

Evaluation

The limitations of the evaluation can be divided into three parts. One is for the waste stream analysis part, the second one for the CO_2 emissions analysis and the final part for the analysis of bottlenecks of circularity and local connection. One of the main limitations involved the interviewee's willingness to share the relevant data. Of the companies that were willing to participate in an interview, only a portion of them was willing to reveal any data concerning their actual output streams, as well as the quantities of their input streams. Those that were willing in any case only resulted in estimations, which further affected the precision and reliability of the data. In terms of the waste stream analysis, this lack of precision or data, or lack of data, added a significant limitation in the extent to which the data could be analysed. Especially in the proportion of waste relative to the total input, since any data concerning the input of materials was often not shared.

In terms of CO_2 impact analysis, the calculations were based on the emissions of the production process of the products. It was regarded that there will be no more CO_2 produced if the waste can be better reused. However, the reality is that when the waste is recycled, more CO_2 is produced in the process. Moreover, the CO_2 emissions of the products are from the dataset AGRIBALYSE, the reliability of the dataset will have a significant influence on the results of the CO_2 impact analysis. Also, the dataset contains data from France, it may be questioned in this project to what extent this data is also applicable to the Foodvalley region. Additionally, the analysis was limited as a lot of assumptions were made since the data could not be found, or a lack of resources restricted access to data. For instance, the waste streams are not consistent, and the components were not analysed and calculated one by one, and a huge assumption that the wastes from one company are considered as a same product. Therefore, the results of CO_2 impact analysis may have a huge computational error.

In addition, the waste streams differ a lot between different industries, so the comparisons of the quantities may not be valid. For example, differences in sizes between different processors exist. Furthermore, the meat industry has a large amount of waste, mainly bones with some meat. The evaluation of local connection was based on the location of suppliers and customers. Due to confidentiality, the companies did not want to reveal all the information. Therefore, it is possible that not all connections were mentioned in the meeting, and that the evaluation is incomplete. The classification of local connection and willingness is simple and may not capture small differences between companies.

12. Conclusion

This project focuses on the research and analysis of valorising the current underutilized waste stream in the Foodvalley region according to Moerman's ladder, while giving recommendations and achievable solutions according to the current bottlenecks, and highlighting areas with potential improvement. As a first step to

starting research, literature review and term identifications provided a comprehensive understanding for the project and the knowledge gap. Identifying the relevant stakeholders and cold calling was the second step, which resulted in a valuable contact list for the commissioner. Interviewing was the third step to find out the underutilized waste streams and obtain relevant data. The data analysis was divided in two parts: kilograms and CO_2 emissions. It was illustrated in both tables and figures using a visual way to find out the waste stream with the highest impact.

In terms of waste producers, most companies send their waste to animal feed companies. In other cases, it is used for energy production, and rarely for human consumption. Most of the waste is on the relatively lower positions on the Moerman ladder (i.e., not human consumption), which is not desired in a circular economy. Even though companies are looking for new inventions for a circular economy, there is no implementation due to regulation related to food safety and quality. It was noticed that there is no communication between local companies, which is a major constraint for circularity. Additionally, the general willingness towards circularity is higher than the current local connection, which indicates that most companies are open to becoming more local and circular. The companies tagged as waste users have circularity included in their models, as they are open to using many kinds of waste streams as input. Their willingness can have a relevant impact on the circular food supply chain.

There are limitations which have a negative impact on the reliability and validity of the research. Some of the literature used focuses on the EU, which does not necessarily apply to the Foodvalley region. The initial company search was done with ORBIS which does not include some local businesses. Additionally, only one company per industry was interviewed due to the limited time. The interview excludes random sampling and the contact people have different backgrounds, which could have lead to biased opinions and conclusions. Due to confidentiality, companies only provide the data based on estimation. Additionally, many assumptions were made because of the mixed waste streams and unavailable data.

The advise given considers the short and long term. In the short term, it is essential to build a local waste-collecting network among local food/feed companies in order to promote the connections between companies and the local region. On the other hand, an awareness campaign regarding food waste can be carried out to increase local willingness and participation. In the long term, it would be optimal to promote the participation of start-ups in the circular food supply chain, because of their open-minded attitude and innovations. Additionally, approaching the issue from a provincial level can result in better communication and cooperation.

Most of the companies in the region are not participating in a circular food supply chain because of the associated risks, even if the benefits are known. It is important to understand and address these concerns by taking action in the short and long term. Further research on regulations, the role of start-ups and an efficient common network is recommended, since the benefits are many.

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Appendices

Appendix A: food industry map

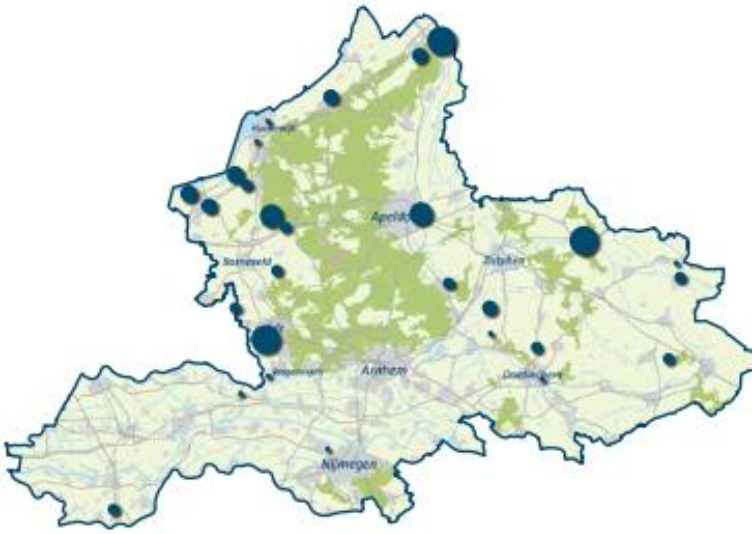

Figure A1: *Animal feed production in province of Gelderland* (Jutte & Roos, 2019).

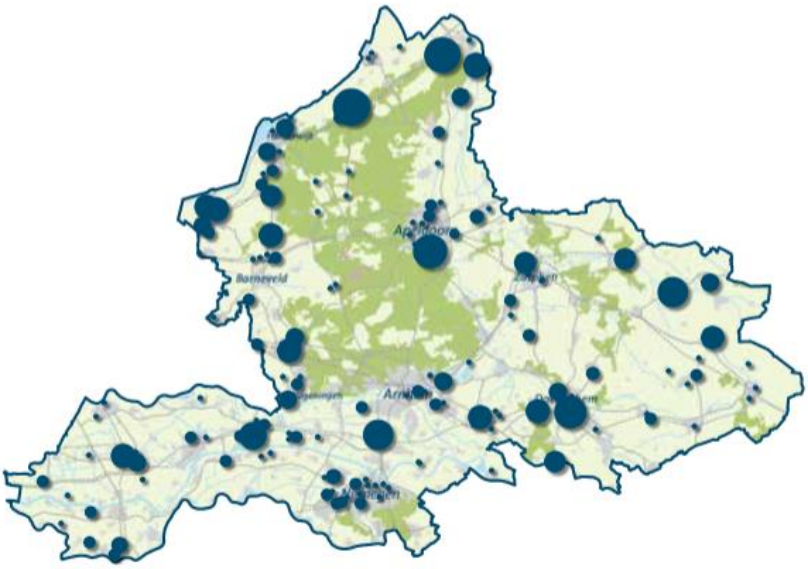

Figure A2: *Map on the food industry activity based on amount of labour, and revenue* (Jutte & Roos, 2019).

Appendix B: contact list

Company	industry	Description	Location
1	Feed	Animal feed poultry.	Barneveld
1	Feed	Animal feed pigs.	Wageningen
2	Dairy	Dairy products.	Nijkerk
3	Grain	Bakery.	Wageningen
4	Feed	Animal feed.	Nijkerk
5	Feed	Animal feed.	Nijkerk
6	Feed	Young Animal feed production.	Barneveld
7	Meat	Producer of meat and substitutes.	Veenendaal
8	Other	Microbial ingredients.	Wageningen
9	Grain	Bread and spaghetti producer.	Nijkerk
10	Cheese	Cheese processor.	Barneveld
11	Herbs	Spices, sauces and seasoning.	Nijkerk
12	Meat	Meat processor (halal).	Rhenen
13	Dairy	Processor of dairy products & logistics.	Barneveld
14	Grain	Cookie producer.	Barneveld
15	Poultry	Processing and packaging chicken	Veenendaal
16	Grain	Breadcrumbs production.	Barneveld
16	Grain	Breadcrumb production.	Barneveld
17	Poultry	Chicken processor	Barneveld
18	Poultry	Chicken processor (cutting marinate and packaging)	Nijkerk
19	Cheese	Cheese processor.	Wageningen
20	Grain	Rice, Corn and Grain waffle processing.	Veenendaal
21	Sweets	Sweet decoration.	Barneveld
22	Meat	Slaughterhouse & meat processor	Veenendaal
23	Sweets	Salmiac processor.	Nijkerk
24	Grain	Bakery.	Veenendaal
25	Other	Regain oil production from seeds.	Wageningen
26	Poultry	Poulty slaughterhouse.	Nijkerk
27	Feed	Animal feed	Veenendaal
28	Cheese	Bouillon and cheese maker	Ede
29	Meat	Meat processor.	Scherpenzeel
30	Other	Nut processing	Rhenen
31	Dairy	Dairy processing.	Barneveld
32	Poultry	Chicken meat processing	Nijkerk
32	Poultry		Nijkerk
32	Poultry		Barneveld
33	Feed	Processor of dairy products & logistics	Veenendaal
34	Feed	Animal feed	Ede
35	Meat	Meat processor.	Barneveld
36	Feed	Petfood	Barneveld
37	Juice	Fruit juice company	Ede
38	Feed	Fishfeed	Renswoude
39	Feed	Petfood.	Renswoude
40	Poultry	Chicken processor	Nijkerk
41	Feed	Insects as petfeed.	Barneveld

Appendix C: interview script

Key points

- Current waste streams in the company
    - Are they underutilized
    - Kind of waste
    - Size of streams
- Circularity within the company currently
    - Situation in the supply chain
    - Any examples
- Willingness
    - Motivation/interest to participate
    - Why

Small introduction paragraph

We are a group of six students from Wageningen University, working as consultants on a project. Our goal is to identify and evaluate food waste streams in the Foodvalleyregion. In the end, we will advise on potential connections between companies to increase the circularity of the supply chain. There are multiple reasons to increase circularity:

- Economic benefit:
    - Value of waste streams increases
    - Waste streams are cheap input
    - Circularity market will increase, participating now would give you an advantageous position
    - The supply chain becomes more independent, less risk from external events
- Environmental benefit:
    - Lower food loss (1/3 of the total food production is wasted at some point in the food supply chain)
    - Lower environmental impact
- Social benefit:
    - It is a future trend, consumers will appreciate it
    - The local community becomes stronger
    - Good reputation

Confidentiality statement

Your data is kept confidential and will not be shared with other companies. Our intention is to share with Regio Food Valley:

- Type and size of waste streams
- Name of the company that generated them
- Current waste management
- Input streams

Their goal is to connect companies in the region to make the supply chain more circular.

If you have a problem with us sharing the data with our commissioner, let us know and we will take it into account. We would like to at least share what the waste streams per company are.

The data will be kept in our Microsoft Team, which is managed by Wageningen University and Research. Only the team members and coach have access to the data.

Questions:

(Sub-research question: What food industries are in the region and what waste streams do they produce?)

- What are the inputs and what are the outputs?
    - What are your products?
    - What resources are used (maybe from third parties / external & internal).
- What waste streams does your company currently have?
    - What is the approximate size of the waste streams?
    - What percentage of initial resources is wasted?
    - Why is it wasted?

(Sub-research question: Which of these are underutilized according to the Moerman's ladder?)

- How are these waste streams managed? (Where is the waste going?)
    - Do you have a designated waste manager or anyone responsible for this?
    - What costs are related to your current waste streams?
- How is circularity included in the current company model?
    - Are you currently sharing streams (e.g., resources, output) with other companies in the FoodvalleyRegion?
    - Can it be improved in your opinion? If so, how?

(Sub-research question: Are the current bottlenecks preventing the valorisation of underutilitized waste streams in the Foodvalley region?)

- What is your opinion about using waste streams as input in your company?
    - Why?
    - What are the bottlenecks to your being more circular in your food production system?
- To what extent do you feel connected to the economy in the local region?
    - Are you interested in participating in a circular food supply chain in the Foodvalleyregion? Why?
- What companies or players would you include when establishing a more circular ecosystem including waste streams of local food processing companies?
    - Would you be willing to connect us with relevant stakeholders?

Thanks for your participation and time. It was a pleasure to meet with you. If needed, we can contact each other through email.

Appendix D: overview table of interview result

Company	Background	Input	Output	Estimation of quantities	Waste management	Current circularity	Local connection / Willingness	Bottlenecks
30	Nut processor.	Nuts, spices, sugar, herbs.	200,000 types of products, a mixture of sugar, peanuts or nuts, small pieces of nuts, spices and herbs. Not consistent residual stream.	104,000 kg (in June) and 6,000kg of waste were generated in this month. Varies per month.	Animal feed, since they can work with inconsistent streams (Outside the region).	They can not use second-hand cashews for example to produce new products because of food safety/quality. Until now they are not looking for new inventions regarding circularity product.	Limited connection, because products are 80% exported, and 20% stay in the Netherlands. Never involved in the Foodvalley region projects. They would like to connect with local stakeholders if there are customers. Sales to wholesalers.	A bottleneck for them to connect to the local region is mainly based on economies of scale.
16	Produces a range of varieties, sizes, and colours of breadcrumbs for different industries.	Flour, starch, herbs, spices, and additives.	Breadcrumbs are their main output. They are distributed to packaging companies. The failed dough is the main waste stream.	It depends on the production; therefore, it is not consistent. In case of failure, waste is 100,000+ kg a year.	Failed dough sold to the highest bidder (feed company Switzerland).	The circularity is mostly based on animal feed or energy. The costs of waste management and transportation are the responsibility of the feed companies.	This is the first time that they know about the region Foodvalleyunder the project of making it more circular (very low / very low).	They do not use waste streams as inputs or resources from other companies because of food safety concerns.
29	A processor of pig carcasses.	Pig carcasses.	Bones with meat rest to a recycling company.	Daily input 360,000kg of carcasses, of which 32,400kg+- are bones. These are cooked out for rest over meat and sent to the recycling company.	Waste is picked up by a recycling company. (energy producer) (contains meat leftovers)	All products are used. The silk might be a further opportunity	No big local connections except for helping Ukrainian refugees get work (very low/low).	The meat industry has high food safety and quality standards, because of legal regulations and customer demand.

Company	Background	Input	Output	Estimation of quantities	Waste management	Current circularity	Local connection / Willingness	Bottlenecks
8	Microbial ingredients startup	Brewer's yeast	Proteins and fibers food.	This information was not shared due to confidentiality.	No relevant waste is generated.	The company is about sustainability and focus on human food.	Needs yeast as an input. They are planning on building a facility for themselves, could be within Foodvalleyregion.	As a startup, so far, they have only faced technological issues.
23	They are a sweet producer	As raw materials, they mainly use sugar syrup, gelatin and starch. No circular input.	They produce marshmallows, gums and candy mainly. As a waste, they generate marshmallow waste, starch and water with sugar.	The composition and size of the waste streams are consistent and have not changed in years. The approximate size per month is 12000 kg starch and 15000 L slurry.	They reuse part of the waste. The remaining waste is sold to the Pig feed company. They make a slurry using the wastewater with the highest amount of sugar. The company does not pay for transport.	They reuse the waste if possible, and the remaining part is sold to an animal feed company. This company is outside of the Foodvalley region.	No link to the local economy, export is about 60%. The sugar they use may come from NL, but they have no combinations. It all depends on the cost, if the cost and safety are OK, they may switch to any other sugar company in the world. In the past, they had sugar from England, but problematic. The price was almost the same. They did not want to take the risks for those few cents. Not interested in joining the FV circular supply chain as they have secrets.	They cannot use waste for input because of food safety/regulations. If the laws allow using waste, it will be possible, which is the only bottleneck.
7	Process and package meat. Recently they have started a new production line of vegan products to substitute meat.	Pork, poultry, and beef carcasses, vegan ingredients.	Packaged meat and vegan products can be refrigerated or frozen.	Their main waste is category 3 meat, mostly the beef constant amount of 2500kg of category 3 meat waste.	Waste is stored in containers in the factory. They pay a recycling company to collect it and take it away. They would like to find a more sustainable way	They work with specific inputs, and therefore they are not open to using waste streams as input. Food safety is also a big concern for them. They want to find a better	Limited local connection. The suppliers are mostly international, and they sell products mainly to big retailers and distributors in the Netherlands. They occasionally sell directly to consumers	Bottlenecks of circularity are food safety and money. Food safety requirements certification) are important for food processors because the products cannot be sold if the requirements are not met. Money is also

Company	Background	Input	Output	Estimation of quantities	Waste management	Current circularity	Local connection / Willingness	Bottlenecks
					to manage waste.	use for their waste, for example, animal feed.	if they want a specific cut of meat. As a big company, they feel like the Foodvalley region is too small for them, and they consider the Netherlands as local. They want to find a use for the category 3 waste.	crucial for companies since they need it to be viable. This company is worried about transportation and energy costs.
10	A company cutting, slicing and then packing cheese in two factories. The old factory proceeds with the small batches, and the new factory have large orders.	All different kinds of cheese	Sliced cheese is packaged and transported to various destinations. Waste is generated mainly during the shaving and slicing steps.	Waste is dependent on sliced wheels. The generated waste depending on the process can range between 7 and 30% of the production. In general, they hope to slice this year more than 25 million kilos of cheese. In that case, 6% would be wasted.	Most of the waste is sent to an animal feed company in Zevenhuizen. They process the waste to produce grated cheese for example. The remaining waste is managed by themselves.	They send their waste to a company to produce food for human consumption. They are not focusing on cheese but more on the packaging. They are looking for packaging substitutes.	Have a close connection with local people. Everything they do, they try to do it with the local people here. Participation in local activities. They just do it in this neighbourhood because they want to support them. They want to make the change to be more local and circular. Transport costs and packages are not very good for the environment so keep an open attitude for participating in a singular supply chain in this region.	In the economy of scale, they need to interact with big companies with similar stream sizes.
6	A corporate firm with multiple business units, related to animal feed and ingredients	Inputs cereals, vegetables, and animal products, including waste streams	Animal feed and ingredients. In Voorthuizen, they produce feed for cows, pigs, and lambs. They also	15 million kg of raw material is used monthly in this facility.	They do not generate any relevant waste	Usage of by-products from other companies as input. These companies can be national or	The company is becoming more international in the last few months, due to the local market's instability. Right now,	The cultural problem is highlighted as a problem since managers from food companies do not want to give their

Company	Background	Input	Output	Estimation of quantities	Waste management	Current circularity	Local connection / Willingness	Bottlenecks
		from other companies.	trade with ingredients. The company is limited to animal feed			international. The company is interested in using streams with high protein and/or fat content.	they consider Europe as local. Their connection with companies nearby are very limited (very low / very high).	streams to feed producers.
1	The agricultural and horticultural cooperative that produces animal feed. They have facilities in Barneveld and Wageningen	More than 300 inputs from food producers, mainly cereals but also meat.	Animal feed for poultry (Barneveld), Pork in Wageningen.	In Barneveld, the total weekly input is 5 million kg. In Wageningen, it is 2.5 million kg.	If there is waste in the process, they manage it themselves. Most of the time they can reuse it for animal feed. If it is not possible, they use it for energy production.	They want to become as circular as possible within 15 years. Their concept of local refers to Europe, they cannot depend exclusively on the region.	Very high willingness, they are open to any relevant waste stream in the region. Customers are local farmers, but they have international suppliers, for example, Brazil and Canada (high / very high).	Legal regulations are a constraint in their opinion, especially because it limits what.
37	Produces fruit drink, appelsientje taxi , in ede karton verpakkingen.	concentrates flavourings, water, (spring water wells) , chemicals detergents, disinfections. Nitrogen carbon dioxide.	Water discharged into the sewer. Packs of juice become.	One company picked up 412304 kg of juice annually. A waste company picked up 180900kg of juice annually. A bio digestion company picked up 139540 kg of juice waste annually.	The juice is good but the packs are rejected, fermentation, to treatment plants that use it for water treatment plants.	The director has connections with food valley, the interviewed employer has no information on this.	The contact was not aware of the company's point of view.	Because of labour circumstances, rules for labour people could not use fallen packs of fruitdrink (ARBO), The regulations for cattle feed are too strict to reuse the product.
3	Bread company	They use bread from the smaller companies as input.	60% of the input is used to produce sourdough. Bread with allergens (e.g., nuts) is separated and used for chicken feed. The eggs from the chicken	The weekly input is 2.5 tons of bread.	They throw away the bread that has meat, but it is not a relevant waste stream. There is no other waste.	The design and strategy of the company is all about circularity.	Extremely high local connection and willingness to participate in circular food supply chains. They have local suppliers and customers, and they depend on these	Food safety related to allergens.

Company	Background	Input	Output	Estimation of quantities	Waste management	Current circularity	Local connection / Willingness	Bottlenecks
			go back to the initial bakery and are used to produce bread.				streams (very high / very high).	

Appendix E: raw data of data analysis

Table E1: *Detailed CO_2 emission (kg CO_2 eq/kg of product) of different categories of four stages (Colomb et al., 2015).*

Category	Food group	Food sub-group	LCI Name	Climate change (kg CO_2 eq/kg of product)				
				Agriculture	Processing	Packaging	Transport	Average
Nuts	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Alfalfa seeds, sprouted, raw	2.48	-	0.54	0.26	3.92
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Almond paste or marzipan, prepacked	3.05	0.26	0.29	0.25	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Almond, (with peel)	5.05	0.07	0.27	0.34	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Almond, grilled, salted	5.05	0.07	0.27	0.34	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Almond, peeled, unpeeled or blanched	5.05	0.07	0.27	0.34	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Alphalfa seeds, raw	2.48	-	0.54	0.26	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Brazil nut	6.70	0.07	0.27	0.71	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Cashew nut, grilled, salted	6.30	0.14	0.54	0.99	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Chestnut cream	0.83	0.32	0.22	0.14	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Chestnut cream, vanilla flavoured, canned	0.83	0.32	0.22	0.14	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Chestnut flour	1.66	0.02	0.27	0.25	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Chestnut, boiled/cooked in water	1.40	-	0.56	0.21	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Chestnut, canned	0.87	0.09	0.20	0.14	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Chestnut, grilled	1.40	-	0.30	0.16	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Chestnut, raw	1.40	-	-	0.15	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Coconut, immature kernel, fresh	1.38	-	0.54	0.51	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Coconut, kernel, dried	1.38	-	0.54	0.51	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Coconut, ripe kernel, fresh	1.38	-	0.54	0.51	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Cucurbitacea, seed	2.48	-	0.54	0.26	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Flaxseed	2.48	-	0.54	0.27	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Flaxseed, brown	2.48	-	0.54	0.27	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Hazelnut	4.15	0.07	-	0.26	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Hazelnut, grilled	4.15	0.07	0.27	0.27	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Hazelnut, grilled, salted	4.15	0.07	0.27	0.27	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Macadamia nut	2.51	0.07	0.27	0.16	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Macadamia nut, grilled, salted	2.51	0.07	0.27	0.16	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Mix of salted grains/nuts and raisins	2.25	0.36	0.29	0.25	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Mix of unsalted grains/nuts and dried fruit	2.25	0.36	0.29	0.25	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Mix of unsalted grains/nuts and raisins	2.25	0.36	0.29	0.25	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Peanut	4.15	0.07	0.27	0.16	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Peanut butter or peanut paste	2.13	0.10	0.37	0.24	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Peanut, boiled/cooked in water, w salt	8.29	0.14	0.54	0.32	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Peanut, grilled	4.15	0.07	0.27	0.16	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Peanut, grilled, salted	4.15	0.07	0.27	0.16	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Pecan nut	2.51	0.07	0.27	0.16	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Pecan nut, salted	2.51	0.07	0.27	0.16	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Pine nuts	4.15	0.07	0.27	0.16	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Pistachio nut, grilled	6.31	-	0.54	0.62	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Pistachio nut, grilled, salted	6.31	-	0.54	0.62	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Seeds, chia, dried	2.48	-	0.54	0.26	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Sesame seed	4.50	-	0.54	0.55	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Sesame seed, grilled, husked	4.50	-	0.54	0.55	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Sesame seed, husked	4.50	-	0.54	0.55	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Soybean, whole grain	3.31	-	0.27	0.27	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Sunflower seed	1.71	-	0.54	0.26	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Sunflower seed, grilled, salted	1.71	-	0.54	0.26	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Tahini (sesame paste)	2.29	0.17	0.29	0.26	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Walnut, dried, husked	2.51	-	0.54	0.26	
	Fruits, vegetables, legumes and oilseeds	Nuts and oilseeds	Walnut, fresh	2.51	-	0.54	0.26	
Bread	Cereals products	Breads and pastries	Bread, wholemeal or integral bread (made with flour type 150)	0.25	0.15	0.10	0.13	0.63
Raw pork product	Meat, eggs, fish	Other meat products	Pork on skewer, raw	1.30	0.08	0.29	0.19	7.16
	Meat, eggs, fish	Raw meats	Brain, pork, raw	1.30	0.08	0.29	0.19	
	Meat, eggs, fish	Raw meats	Heart, pork, raw	1.30	0.08	0.29	0.19	
	Meat, eggs, fish	Raw meats	Liver, pork, raw	1.30	0.08	0.29	0.19	
	Meat, eggs, fish	Raw meats	Tongue, pork, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, back fat, rindless, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, rack, raw	4.91	0.57	0.56	0.24	
	Meat, eggs, fish	Raw meats	Pork, chop, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, rind, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, loin, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, shoulder, raw	1.02	0.04	0.29	0.19	
	Meat, eggs, fish	Raw meats	Pork, ham escalope, raw	4.92	0.22	0.29	0.20	
	Meat, eggs, fish	Raw meats	Pork filet mignon, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork tenderloin, lean, raw	7.71	0.89	0.51	0.26	
	Meat, eggs, fish	Raw meats	Pork, jowl, rindless, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, shoulder lower half, without rind, fat and bone, raw	4.92	0.22	0.29	0.20	
	Meat, eggs, fish	Raw meats	Pork, way leg, without rind, fat and bone, raw	7.71	0.89	0.51	0.26	
	Meat, eggs, fish	Raw meats	Pork, knuckle oh ham, without rind, fat and bone, raw	7.71	0.89	0.51	0.26	
	Meat, eggs, fish	Raw meats	Pork, knuckle or shank, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork loin, raw	7.71	0.89	0.51	0.26	
	Meat, eggs, fish	Raw meats	Pork, 80/20 trimming, raw	1.02	0.04	0.29	0.19	
	Meat, eggs, fish	Raw meats	Pork, 90/10 trimming, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, shoulder upper half, without rind, fat and bone, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, belly, flank removed, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, belly, raw	7.71	0.91	0.49	0.21	
	Meat, eggs, fish	Raw meats	Pork, roast, raw	6.17	0.71	0.41	0.20	
	Meat, eggs, fish	Raw meats	Pork, round steak, raw	7.71	0.89	0.51	0.26	
	Meat, eggs, fish	Raw meats	Pork, spare-ribs, raw	9.64	1.13	0.62	0.26	
	Meat, eggs, fish	Raw meats	Kidney, pork, raw	1.30	0.08	0.29	0.19	
Sweets	Sweet products	Non-chocolate confectionery	Candies, marshmallows	0.48	0.29	0.28	0.13	1.17
Category 3 (beef)	Meat, eggs, fish	Raw meats	Beef, knuckle, raw	33.20	0.06	0.36	0.25	30.17
	Meat, eggs, fish	Raw meats	Blood, beef, raw	32.80	0.06	0.26	0.25	
	Meat, eggs, fish	Raw meats	Heart, beef, raw	26.24	0.05	0.29	0.20	
	Meat, eggs, fish	Raw meats	Kidney, beef, raw	26.24	0.05	0.29	0.20	
	Meat, eggs, fish	Raw meats	Tongue, beef, raw	26.24	0.05	0.29	0.20	
	Meat, eggs, fish	Raw meats	Tripe, beef, raw	32.80	0.06	0.36	0.25	
Cheese	Milk and dairy products	Cheeses	Processed cheese, in slices	4.71	0.22	0.27	0.26	5.46
Juice	Drinks	Soft drinks	Fruit soft drink, still (10-50% of fruit juice), reduced sugar	0.10	0.06	0.22	0.19	0.57
	Drinks	Soft drinks	Fruit soft drink, still (10-50% of fruit juice), with sugar	0.10	0.06	0.22	0.19	
	Drinks	Soft drinks	Fruit soft drink, still (less than 10% of fruit juice), with sugar	0.10	0.06	0.22	0.19	

Table B2: *Simplified CO_2 emission (kg CO_2 eq/kg of product) of different categories.*

Category	CO_2 emission (kg CO_2 eq/kg of product)
Nuts	3.92
Bread	0.63
Raw pork product	7.16
Sweets	1.17
Category 3 meat (beef)	30.17
Cheese	5.46
Juice	0.57

Table B3: *CO_2 emission of the waste (kg CO_2 eq) of different companies.*

Company	Category	CO_2 emission of the waste (kg CO_2 eq/month)
30	Nuts	23536.2
16	Bread	5217.8
29	Raw pork product	6961777.4
23	Sweets	14027.9
7	Category 3 meat (beef)	301699.7
10	Cheese	682775.6
37	Juice	11865.5