

Chapter 4

Decreasing Greenhouse Gas Emissions of Meat Products Through Food Waste Reduction. A Framework for a Sustainability Assessment Approach

Thomas Winkler and Ralf Aschemann

Abstract The global food production industry is responsible for producing high levels of greenhouse gas (GHG) emissions. Along the entire food supply chain (FSC), potential for mitigation exists because approximately one-third of all food globally produced is wasted, equivalent to 1.3 billion tons per year. On a global scale, emissions from livestock production are about 4600–7100 Mt CO₂-eq/year when considered over the whole life cycle. These numbers represent roughly 9.4–14.5% of the total global GHG emissions. In Austria, the livestock sector was responsible for producing about 11.6% of the total GHG emissions in 2012 as a result of the production of about 909,000 t of meat. A high potential for mitigation of GHG emissions from livestock production exists, especially during the farming and production phases. A reduction in meat waste would, in the long-term, directly reduce GHG emissions stemming from livestock production. Two scenarios were considered to assess the GHG mitigation potential of waste from meat production: a business-as-usual (BAU) scenario and a reduction (RED) scenario (assuming a one-third reduction in waste from meat production in Austria). Because food waste is influenced by several phenomena along the FSC, taking an approach such as the life cycle assessment (LCA) offers only a partial solution. By using a Sustainability Impact Assessment (SIA) approach, researchers can consider social, economic and ecological impacts. It is possible to analyze and compare food waste reduction potentials through the use of such a tool, which can support GHG mitigation efforts in terms of their social, environmental and economic contribution to the livestock and meat processing sector. This approach allowed the identification of indicators that contribute to all sustainability dimensions and support the conclusion that preventing waste from meat processing would save at least 4.8 Mt CO₂-eq emissions per year in Austria, which represented 6% of Austria's total CO₂-eq emissions in 2012.

T. Winkler · R. Aschemann (✉)

Institute of Systems Sciences, Innovation and Sustainability Research,
University of Graz, Merangasse 18, 8010 Graz, Austria
e-mail: ralf.aschemann@uni-graz.at

Keywords Food supply chain · Food waste · Sustainability impact assessment · Greenhouse gas emissions · Austria

4.1 Introduction

The ‘*Loi Macron*’ is a French Act¹ (Senat 2015), which, inter alia, is banning supermarkets from wasting food, brought the discussion on food waste to the center of attention in the European Union in 2015. Italy soon picked up on the discussion and introduced the ‘*Spreco zero*’ (zero waste) campaign to its parliament (Partito Democratico 2015). Even though food waste is a topic of with a high level of importance globally, few studies have been conducted, and its media coverage has not been high in recent years. Considering how our society wastes food, particularly during the consumer phase, it is necessary to initiate programs that will prevent food waste entirely. About one-third of the total food produced in our world is being thrown away, representing about 1.3 billion tons yearly. Food waste and food losses are similarly high in both developed and developing countries (assessed by comparing the amount of food produced in a country or global region), but this waste and loss occurs at different stages of the food supply chain (FSC). Many different drivers result in food being wasted: the economic system, legislation, cultural issues, resource limitations and lack of infrastructure, to name a few (Parfitt et al. 2010). In developing countries, food loss often occurs during the first phases of the FSC-agriculture and food processing—due to lack of management skill and technical expertise in food production. In developed countries, in contrast, food is thrown away by members of the wholesale and retail sector as well as end-consumers (households, food services and restaurants). These processes coincide with increasing fragmentation of the global population and multiplication of issues about how food is grown and produced (FAO 2011; Parfitt et al. 2010).

Food waste is gaining increasing amounts of attention as a crucial waste management study area and is recognized more and more as a global problem. Using resources (along the FSC) in a more sustainable and efficient way can effectively decrease greenhouse gas emissions (GHG) and impact global climate change, as well as influence other economic and social factors (Papargyropoulou et al. 2014). In the European Union, it has been estimated that the food sector alone causes about 22% of all GHG emission. Thus, it ranks very high among life-cycle-wide impacts on resources and has a high environmental impact potential (European Commission 2006; Papargyropoulou et al. 2014). Food waste also has many social implications, which tend to involve ethical and moral issues (Salhofer et al. 2008). Interventions in the first stage of the FSC offer the best opportunities for mitigation; this specifically means influencing agricultural practices and preventing food waste at the consumer stage (Papargyropoulou et al. 2014).

¹The Act will enter into force by July 2016 (Moveforhunger 2016).

This contribution examines the effects of food waste, specifically waste from (national) meat production, on our (global) climate. When considering the entire FSC, food production is a main contributor to the total GHG emission level, erosion, water depletion and deforestation. The effects of food waste in Austria are in the focus of this study due to the rather unique absence of large industrial food production sites and importation of feed from other countries (USDA 2012), as well as the good availability of data. Food production and waste in Austria was quantified and connected to the primary emission sources. One of the largest contributors to emissions is meat production and consumption. The meat production industry in Austria produced about 909,000 t meat in 2013 (Statistik Austria 2013) and resulted in the slaughter of around 83 million animals (92% poultry) (Statistik Austria 2014b). A sustainability impact assessment (SIA) was conducted to evaluate the climate effectiveness of waste from meat production in Austria (in terms of CO₂-eq savings) and identify possible GHG reduction options. By using an SIA, it was possible not only to focus on the ecological implications of food and meat waste in Austria, but also examine social and economic factors.

First, an overview of food waste is given, providing definitions of and statistics for food waste in meat production and meat waste. Next, the SIA procedure, including two scenarios and system boundaries and six indicators, is described. Then, the results of an assessment of these indicators are given. Finally, a discussion is presented, and conclusions are drawn.

4.2 Scope and Statistical Overview of Food Waste

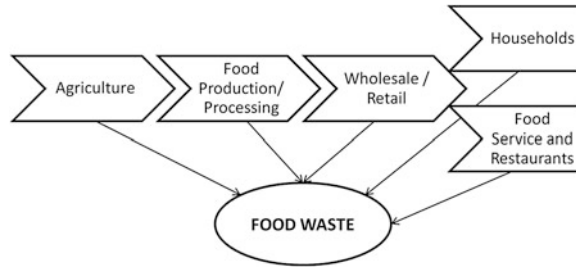
4.2.1 Definitions

Different studies use different definitions of food and food waste, and, equally importantly, set different system boundaries and/or consider different background information (e.g., inclusion of food processing sector, food service sector and restaurants). It is necessary to provide a clear definition of food and food waste in order to be able to reasonably interpret the results of the analysis.

The European Union (European Parliament 2002) defines food (or foodstuff) as ‘any substance or product, whether processed, partially processed or unprocessed [...] expected to be ingested by humans’. This broad definition also includes drinks, chewing gum and all additional materials that are intentionally included in food processing (including water).

In one of the deliverables of the EU-funded FP7-FUSIONS project (‘Food Use for Social Innovation by Optimising Waste Prevention Strategies’, 2012–16), food waste is defined as ‘... any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)’, cf. Fusions (2014).

Fig. 4.1 Food supply chain (FSC) and food waste (based on Kranert et al. 2012)



According to Kranert et al. (2012), food waste is (broadly) defined as waste from²:

- agricultural production
- food production and processing
- wholesale and retail markets
- food service and restaurants
- households
- (raw and processed food that is potentially edible).

Furthermore, food waste can be divided into avoidable, partly avoidable and unavoidable waste. Avoidable food waste includes edible food that is thrown away at some point along the FSC (please see Fig. 4.1), and food that would have been edible if it has been eaten before it spoiled. Unavoidable food waste is basically waste from food production that occurs somewhere along the FSC and is considered inedible under ‘normal’ circumstances (e.g., banana skins, bones, intestines). Defining partly avoidable food waste is rather difficult as this is quite often a subjective topic. In general, it can be argued that partly avoidable food waste includes food that is eaten by some and treated as waste by others (e.g., apple cores, bread crusts, potato skins); leftovers are also included in this category (Kranert et al. 2012; Monier et al. 2010; Quested and Johnson 2009). Due to this subjective classification of partly avoidable food waste, this study only categorized the food as avoidable or unavoidable food waste (e.g., leftovers were included in avoidable food waste). By-products in food processing are not defined as waste as long they are used for a different purpose later in the FSC (Kranert et al. 2012; European Parliament 2008).

Food waste and food loss are often treated synonymously. In most studies, the term ‘food loss’ refers to (food) waste that occurs:

- at the beginning of the FSC;
- during the agricultural stage;
- during food production
- during processing.

²Please see Fig. 2.1 for a graphical depiction.

The term *food waste* in the literature is associated with behavioral patterns observed during the retail and consumer (household) stages (Parfitt et al. 2010). This study addressed both food losses and food waste, but did not distinguish between these two terms. The term *food waste*, therefore, refers to both food losses and food waste.

4.2.2 Meat Production and Meat Waste

Globally, food production is responsible for about 9.4–14.5% of total GHG emissions (IPCC 2014; Steinfeld et al. 2006). About 52 billion animals were slaughtered in 2004 (not including marine animals) worldwide. Chicken represented about 90% of these animals, which were slaughtered for meat production (based on FAO statistics, Humanresearch 2015). In the European Union Member States, 15.6 million tons of animals were slaughtered in 2013, which represents—more or less—the livestock population for meat production in the EU (slightly higher numbers of imports of living animals were reported than exports) (Eurostat 2015). The maintenance of these animals (including their slaughter, but excluding all stages after the slaughterhouse) results in GHG emissions of 616–852 Mt CO₂-eq/year. In addition to these high levels of GHG emissions, livestock rearing contributes to erosion, eutrophication of water bodies and has a high water footprint.

In Austria, 200,000 cattle and calves, almost 500,000 pigs, 7700 goats and sheep and 125,000 poultry were slaughtered for national use in 2012 (Statistik Austria 2014b). These data do not include meat that is exported after slaughter out of Austria. Emissions from livestock production in Austria are approximately 9.3 Mt CO₂-eq/year, which represent roughly 11.6% of Austria's total GHG emissions in 2012.

In the EU, 35 million tons of animal and vegetal waste was produced by the food, beverage and tobacco processing sectors in 2008 (7.5 million tons of which were animal waste). Household waste amounts of animal and vegetal waste in the EU was estimated³ to be 23.8 million tons in 2008, which represents about 48 kg per capita and 10.8% of all household waste (European Union 2011).

It has been estimated that between 89 and 178.3 million tons of food waste accumulates each year in the EU, which will generate roughly 70–170 Mt CO₂-eq/year of emissions (Monier et al. 2010). Until 2020, it has been assumed that emissions from food waste will represent up to 240 Mt CO₂-eq per year (Monier et al. 2010). A large part of these emissions (21%) stems from animal and meat waste, although meat waste accounts for less than 5%, and vegetables for almost 25%, of total food waste (FAO 2013). This study assessed GHGs from food waste, and respectively waste produces as a result of food production, along the FSC.

³It is believed that these levels are underestimated (European Union 2011).

4.2.3 Food Waste in Austria

In terms of food waste per capita/year, Austria is not among the top 20 EU member states (Croatia not included). Eurostat data indicate a range from 4.51 kg/capita/year in Greece to 56.03 kg/capita/year of food waste in the Netherlands. The average for all EU-27 countries is 17.7 kg/capita/year of food waste (the official Eurostat data was used and complemented with data from various national sources that were provided by the EU member states, cf. Monier et al. 2010). Even though these data may not be trusted completely, it is obvious that Austria, at least in terms of food waste mitigation, is not among the leading countries (please see Table 4.1).

In Austria, slightly less than 1.5 million tons of animal and vegetal waste was produced by the processing industry, and 300,000 t came from food preparation. The amount of animal and vegetal waste as compared to total household waste in Austria is, at 18.7%, above the EU average (this value also includes food packaging material). In total, Austrians wasted 1,185,800–1,956,240 t of food in 2008, which is equal to about 21.7–22.8 kg of food wasted per person and year. 34–66% of the total food waste in Austria is produced by households, and another 30–48%, by food manufacturers (agriculture, food production, food processing). The remainder can be allocated to retail, wholesale and large-scale consumers such as restaurants and hospitals (European Union 2011; Monier et al. 2010; Selzer 2010). Unfortunately, no complete data set is available on avoidable food waste in Austria. Several studies have been conducted, each of which has focused on specific areas and/or stages of the FSC and/or waste categories (Bernhofer 2009; Obersteiner and Schneider 2006; Schneider and Lebersorger 2009; Selzer 2010).

4.3 Sustainability Impact Assessment (SIA) Procedure

No clear guidelines for how to assess food waste on a global and/or regional level have yet been created. Several international standards have been set and, frequently, life-cycle analysis (LCA) is used as a method to supplement household diaries, ‘waste-bin research’ and surveys. However, as Katajajuuri et al. (2014) mentioned, ‘no commonly approved standard or communication method for evaluating a foodstuff’s climate impacts are available’. Moreover, LCAs do not consider the social and economic impacts of food waste on the implications for climate change.

Therefore, different forms of Sustainability Impact Assessment (SIA) methodologies have been developed which address all three dimensions of sustainability, see OECD (2010) for example. Singh et al. (2012) reviewed many sustainability assessment methodologies, as “sustainability indicators simplify, quantify, analyze and communicate otherwise complex and complicated information”. Singh and his colleagues collected 61 different indices and ratings to assess the sustainability of various subjects such as development, products, cities, policies, industries and/or nations.

Table 4.1 Emissions stemming from all stages of the FSC—from the agricultural to the slaughterhouse stage—for livestock globally, in the EU and Austria (based on Winkler and Winiwarter 2015)

	Global	European union	Austria			
GHG emissions	Mt CO ₂ -eq/year 4600–7100	Share of total GHG emissions ≈9.4–14.5%	Mt CO ₂ -eq/year 616–852 ^b	Share of total GHG emissions ≈13.5–18.75%	Mt CO ₂ -eq/year 9.3	Share of total GHG emissions ≈11.6%
Sources	FAOSTAT (2015a, b, c, d) and Steinfield et al. (2006)	European Environment Agency (2014) (data for 2012), Lesschen et al. (2011) and Weiss and Leip (2012)	Leip et al. (2010) and Umweltbundesamt (2014a) (data for 2012)			

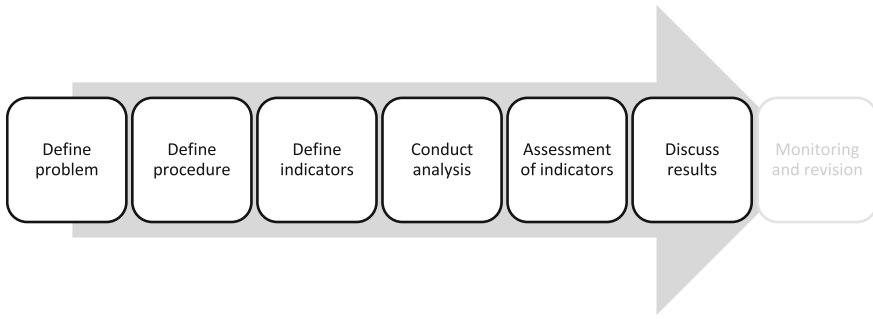


Fig. 4.2 Sustainability Impact Assessment (SIA) procedure followed during this study (based on ARE 2004)

Regarding the use indicators for SIAs, the authors referred to Ness et al. (2007), who distinguished between non-integrated (‘meaning they do not integrate nature-society parameters’) and integrated indicators (‘meaning the tools aggregate the different dimensions’). Referring to the latter, Pope et al. (2004) identified two options for the development of assessment for sustainability criteria, namely:

- a simultaneous achievement of a series of environmental, social, and economic goals or objectives;
- the development of assessment for sustainability criteria using a ‘top-down’ generation of criteria.

We began our study by focusing on overall sustainability goals in the context of food waste reduction and derived indicators from these. By transferring the integrated/non-integrated classification of Ness et al. (2007) to indicators for a food waste SIA, we were able to choose between developing and applying non-integrated indicators, integrated indicators or a combination of both. Both approaches resulted in advantages and disadvantages: when examining particular sustainability dimensions, we could compare their individual economic, social and environmental contributions and contrast these with each other, but not examine the contributions holistically. The approach of integrated indicators was eventually chosen in order to maintain that holistic dimension and avoid the disadvantages that resulted from the inclusion of non-integrated indicators (Fig. 4.2).

4.3.1 Scenarios

Two scenarios related to meat waste in Austria were created to illustrate how changes in behavior can lead to a decrease of waste and connected GHG emissions. One business-as-usual scenario (BAU) is compared to a reduction scenario (RED). In the BAU scenario, it was assumed that no behavioral changes occurred and that members of society produced meat waste as currently observed. In the RED

scenario, in contrast, the total meat waste was reduced by one-third, which is the amount of estimated avoidable meat waste in Germany (Kranert et al. 2012) and also seems to be realistic for Austria. It was assumed that less meat was wasted and, therefore, fewer animals were slaughtered for meat-consumption. Therefore, all parameters concerning meat production were decreased by one third. The reduction focused on aspects of meat production and did not consider the economic or environmental implications of by-product production. It is necessary to understand that these assumptions are purely a theoretical experiment. Even though, the potential mitigation of meat waste is one third it is not realistic (at the moment) that no meat is wasted at all. As no data was available about the type of meat that is generally wasted, an equal distribution over all types of meat was assumed. In terms of waste reduction, the RED scenario is considered to be the best case scenario.

4.3.2 System Boundaries

The food sector is a highly complex industrial branch and focusing on more details, such as of meat waste production, introduces still more complexity. It was not possible, therefore, to include all factors and elements of meat waste along the FSC in this study. Due to the interconnectivity of factors, multiplier effects were observed when considering the different ways to reduce food and meat waste. For example, if reducing meat waste results in fewer animals slaughtered, we assume that fewer livestock will be reared in total, and this will lead to a reduction in the production of animal by-products. As a potential side effect, this could mean that certain products would need to be fabricated using different materials, which could possibly have a higher global warming potential (which was not considered in this study).

The SIA presented has clear boundaries, and three input factors that were necessary for the whole FSC to function were considered: energy, water and feedstuff. The outputs of the FSC are the products themselves, including meat; certain emissions into the air, soil and water; by-products such as fat (i.e., products from livestock production that can be used afterwards); and food waste (see Fig. 4.3).

We applied the SIA to the output *meat* and *food waste* and showed how to achieve a potential reduction in CO₂-eq emissions through meat waste mitigation. This method can easily be extended and adapted to address more aspects and include other food products.

4.3.3 Indicators

The following indicators (Fig. 4.4) were chosen to represent inputs and outputs of meat production. However, it was not possible to consider every factor and every parameter, such as certain drug residues in the meat or the effect of less slaughtering on the production of by-products such as carcass meal. All indicators were chosen

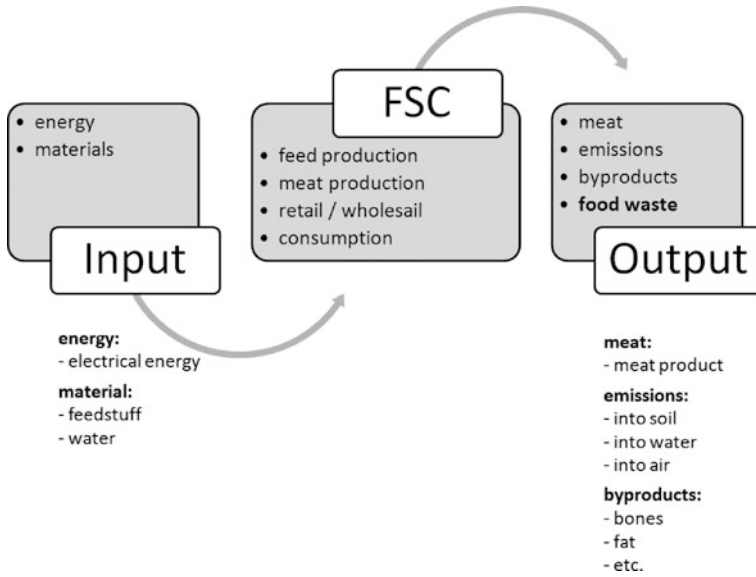


Fig. 4.3 System boundaries

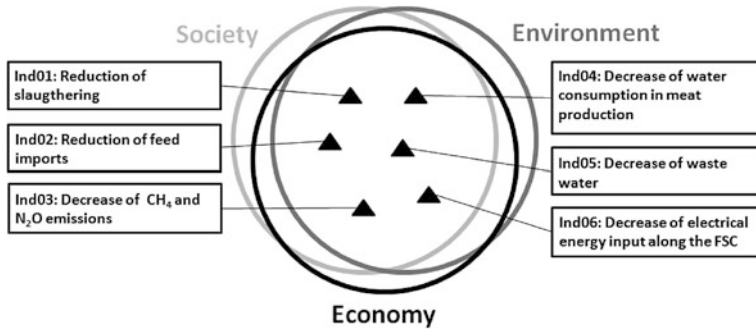


Fig. 4.4 Indicators of integrated SIA for meat waste in Austria

Table 4.2 National net consumption of meat in Austria (Statistik Austria 2013, 2014a)

	BAU	RED
	National net consumption (t)	National net consumption (t)
Cattle	201,452	134,302
Calves	6453	4302
Pigs	491,313	327,542
Sheep and goats	7454	4969
Poultry	121,515	81,010
Total	828,187	552,125

to represent meat production and its effects in Austria over one year (the locations of the triangles within the circles are random and do not indicate a connection with one of the three sustainability circles).

4.3.3.1 Reduction of Slaughtering (Ind01)

Food waste, and specifically meat waste, has many social, economic and ethical implications (Salhofer et al. 2008). In 2014, more than 83 million animals were slaughtered in Austria, the majority of which were poultry (77 million animals). From 2009 to 2013, the number of slaughtered cattle, which have the highest impact on the climate, decreased by $\sim 1\%$ (7414 animals) according to Statistik Austria (2014b). This 1% represents animals that have an individual average weight of 753 kg and carcass weight of about 452 kg (60%). Assuming an amount of 14.2 kg of CO₂-eq/kg of Austrian beef, this 1% reduction was equivalent to 48,000 t CO₂-eq/year (FAO n.d.; Leip et al. 2010). The net meat production in 2014 was roughly 909,000 t, and the national consumption approximately 828,200 t (see Table 4.2), respectively representing 97.7 kg per person and year (Statistik Austria 2013, 2014a). Almost 60% of the total meat consumption in Austria is pork, 25% is beef, 15% is poultry and the rest is goat and sheep (cf. Table 4.2). A reduction in meat waste would, consequently, lead to a reduction in slaughter numbers.

4.3.3.2 Reduction in Feed Importation (Ind02)

75% of the imported feed in Austrian comes from other European Union Member States, and about 10% are imported from MERCOSUR countries—mostly Southern American countries (Statistik Austria 2012). About 570,000 t of soy meal and 100,000 t of soybeans are fed to Austrian livestock. In 2011, about 104,000 t of soybeans were harvested in Austria and, thereof, 32,000 t (27%) were used for feed. Most of this soy meal and these soybeans come from South America. In total, it can be assumed that at least 500,000 t of soy meal is imported every year (Global 2000 n.d.), cf. Table 4.3. An LCA study of pork (Hinterberger et al. 2011) showed that 80% of the climate impact is caused by deforestation of rainforest areas. Changing feedstuff to local (soy) meal could reduce GHG emissions stemming from pig meat production by 50%. When examining the RED scenario, soy import was cut by one-third and the demand was met by national and European soy production.

Table 4.3 Austrian imports of soybeans and soy meal (Castanheira and Freire 2013; Global 2000 n.d.)

BAU			RED		
Soy import (kg)	CO ₂ -eq min (kg)	CO ₂ -eq max (kg)	Soy import (kg)	CO ₂ -eq min (kg)	CO ₂ -eq max (kg)
1	0.3	17.8	1	0.3	17.8
500,000,000	150,000,000	8,900,000,000	333,333,333	100,000,000	5,933,333,333

It is difficult to get a clear picture of the environmental impact of Austrian soy imports from MERCOSUR countries. On one hand, no data on how much soybeans and soy meal is imported is available, and on the other hand, GHG emissions from soy production in South America mainly depend on emissions from land-use change and vary greatly depending on where the soy is planted. Castanheira and Freire (2013), in an LCA study on soy-bean production in Brazil and Argentina, showed that GHG emission per kg of product varied between 0.3 and 17.8 kg CO₂-eq (including emissions from cultivation, land-use change and transport). Due to missing data for Austria, the emissions from soy production from Argentina and Brazil were used to calculate the impact on the environment by imports.

4.3.3.3 Reductions of CH₄- and N₂O-Emissions (Ind03)

The main sources of methane (CH₄) and nitrous oxides (N₂O) are agricultural processes and emissions from waste systems. Manure from livestock emits CH₄ and N₂O, but the manure characteristics vary according to the animal species and feedstuff. These two climate gases have a global warming potential that is several times higher than CO₂: CH₄ is 34 times higher and N₂O is 298 times higher (IPCC 2014).

In Austria, emissions from enteric fermentation, manure management, animal manure applied to agricultural soil, and pasture, range and paddock manures are responsible for producing 4.5 Mt CO₂-eq/year,⁴ which represents 5.6% of the total GHG emissions for Austria. Enteric fermentation from ruminants is responsible for the majority of the emissions in this sector.

According to the official emission inventory data for Austria (Umweltbundesamt 2014a, data from 2012), cattle farming is responsible for the majority of CH₄ and N₂O emissions produced in this sector, cf. Table 4.4. In addition, emissions from animal manure applied to agricultural soil (inventory subsector 4D1.2) and pasture, range and paddock manures (inventory subsector 4D2)⁵ need to be considered. The N₂O emissions from these areas are 2150 and 300 t per year, respectively, which represent an amount of 730,100 t CO₂-eq/year.

Landfills are one of the largest sources of methane emissions (Nguyen 2012), and these include biodegradable waster (i.e., biowaste). Although landfilling is probably the worst waste management strategy to use when dealing with biowaste, it is still the method most frequently used (30–40%) in the EU (European Commission 2008). Biowaste is, in general, defined as any waste that can be anaerobically or aerobically digested such as vegetal material, kitchen waste and paper (European Parliament 1999).

⁴Using the global warming (GWP) potential as calculated in the IPCC Second Assessment Report achieves consistency with the Austrian inventory report; however, using GWP values from AR5 increases national livestock emissions by approx. 2 Mt CO₂-eq/year.

⁵Subsectors defined as in UNFCCC (2006).

Table 4.4 CH₄ and N₂O emissions from livestock in Austria (Umweltbundesamt 2014a)

	BAU			RED		
	CH ₄ ent. ferm. (t)	CH ₄ man. mgmt. (t)	N ₂ O man. mgmt. (t)	CH ₄ ent. ferm. (t)	CH ₄ man. mgmt. (t)	N ₂ O man. mgmt. (t)
Cattle	79,890	5880	1290	53,260	3920	860
Pigs	4470	3500	180	2980	2333	120
Sheep and goats	2920	70	80	1947	47	53
Poultry	280	1050	230	187	700	153

In total, approximately 76.5–102 million tons of green and food waste is produced annually in the EU, while another 37 million tons of waste produced by the food and drink industry are categorized as biowaste (European Commission 2008). It has been estimated that up to 29,000,000 t CO₂-eq emissions could be saved by preventing the production of bio-waste (European Union 2011).

In Austria, separate bio-waste collection is supported by a waste management system initiated by the government. In 2014, almost 80,000 t of biowaste (including food) were collected in the city of Vienna. About 21% of the food waste in Austria's capital is treated through anaerobic digestion (biogas production) and about 77% is sent to a biological treatment plant to be transformed to compost (MA 48 2014). Unfortunately, little data on food waste in the Austrian biowaste collection system exists. Therefore, emissions from this sector were not included.

4.3.3.4 Reductions of Water Consumption in Meat Production (Ind04)

In general, agriculture accounts for about 92% of the total global water footprint and about one-third of this is related to livestock production (Gerbens-Leenes et al. 2013). In 2005, the average global water footprint of meat production was 2422 Gm³/year, whereas the majority of this water was needed for feedstuff production (Mekonnen and Hoekstra 2012). The values for the average water footprint of a live animal measured at the end of its lifetime, and the average annual water footprint of one animal are presented in Table 4.5.

Mekonnen and Hoekstra (2012) assessed the water footprints of several food products in their study. These data included water from feed production, drinking water and service water (e.g., for cleaning), but not water from processing (processing water is included in Ind05). Beef had the highest water footprint measured: about 15.4 million l per ton of product.

Ridoutt et al. (2011) argued that Mekonnen and Hoekstra's estimations are rather high because they included water produced as a result of evapotranspiration from crops and pasture grasses, which enhanced the footprint. Thus, only the grey and blue water footprint has been considered for calculating the water footprint of Austrian meat. By combining those footprint data with the Austrian net

Table 4.5 Average annual water footprint of on animal from 1996–2005 (Mekonnen and Hoekstra 2012)

Animal category	Average water footprint of a live animal at the end of its lifetime (m ³ /ton)	Average annual water footprint of one animal (m ³ /year/animal)	Annual water footprint of animal category (Gm ³ /year)
Cattle	7477	630	798
Pigs	3831	520	458
Sheep	4519	68	71
Goats	3079	32	24
Broiler, layer chickens	3364	59	422
Total (excluding water footprint from horses and dairy cattle)			1773

Table 4.6 Water footprint of Austrian meat products (Mekonnen and Hoekstra 2012; Statistik Austria 2013, 2014a)

Meat product	BAU		RED
	Water footprint per ton (m ³ /ton)	National water footprint (m ³) of meat	National water footprint (m ³) of meat
Beef	15,415	208,112,905	138,742,604
Pig meat	5988	531,109,353	354,072,902
Sheep/goat meat	8763	3,801,540	2,534,190
Chicken meat	4325	94,781,700	63,187,800
Total		837,805,498	558,537,496

consumption of meat, the national water consumption caused by meat production equals 838 million m³ (or 838 billion liter), please see Table 4.6.

However, when considering the RED scenario, approximately 279 billion liter of water could be saved (Mekonnen and Hoekstra 2012; Statistik Austria 2013, 2014a). Due to the lack of data for Austria, the footprint data Mekonnen and Hoekstra (2012) had to be used in the analysis.

4.3.3.5 Reduction of Waste Water from Slaughterhouses (Ind05)

Food production generally has a large influence on bodies of water. Water run-off from farming and rearing livestock leads to eutrophication and leaches fertilizers into the environment, causing an increase in nutrient levels and algal blooms in larger bodies of water. As a direct consequence, water quality can be jeopardized and hypoxia of the lifeforms in the water bodies might occur (Chislock et al. 2013).

Waste water is primarily produced during the slaughterhouse stage of the production chain. A European Commission (2005) report assumed that the production of one chicken as delivered to the supermarket results in the production of 70–130 L

Table 4.7 Waste water from slaughterhouses (European Commission 2005; Statistik Austria 2014a)

Animal	BAU		RED
	Waste water (l per t of carcass)	Waste water (l per total animal prod.)	Waste water (l per total animal prod.)
Cattle	1623–9000	658,944,872–3,654,038,106	439,296,581–2,436,025,404
Pig	1600–6000	1,047,294,301–3,927,353,628	698,196,201–2,618,235,752
Sheep	5556–8333	78,513,225–117,755,706	52,342,150–78,503,804
Poultry	5070–67,400	858,344,916–11,410,739,120	572,229,944–7,607,159,413
Total		2,643,097,230– 19,109,886,560	1,762,064,876– 12,739,924,373

of waste water by the slaughterhouse. The waste water from poultry production carries a high microbial load and increases the risks of microbial infections (e.g., Salmonella). The RED scenario data in Table 4.7 show that the amount of waste water created by the meat industry in Austria can be reduced by one-third. The total potential reduction of waste water from slaughterhouses in Austria, as a result of reducing meat production and, thus, meat waste, ranges from 881 million to 6.37 billion liters (European Commission 2005; Statistik Austria 2014a).

4.3.3.6 Reduction of Energy Input Along the FSC (Ind06)

In addition to water and various materials, energy represents another input factor in food production. De Vries and de Boer (2010) compared several LCA studies of animal products and the energy intensity of pork, beef and chicken meat. 18–34 MJ of energy are needed to produce 1 kg of pork; 34–52 MJ, for 1 kg of beef; and 15–29 MJ, for 1 kg of chicken meat. These high values are derived from wide system boundaries. De Vries and de Boer (2010) also included the energetic input from feed production, for example. Winkler et al. (2016) examined Austrian pork production more narrowly, considering only the energy input on-farm, and calculated an energetic input of 1.75 kWh/kg of pork (~6.3 MJ) for electricity, heat and mechanical energy.

This study focused on the entire life cycle of meat, and the cradle to gate-data from de Vries and de Boer (2010) was used to calculate the energy input of the Austrian meat processing industry, see Table 4.8. The RED scenario data show that a reduction of about 8.13 million MJ (or 2.26 GWh) per year (calculated for all meat products, but excluding sheep and goat) can be achieved (de Vries and de Boer 2010; Statistik Austria 2014a). Due to a lack of data, the energy input of sheep was not included, but is considered to be negligible as sheep represent only 0.8% of the total Austrian meat industry.

Table 4.8 Energy input for meat production (de Vries and de Boer 2010; Statistik Austria 2014a)

	BAU		RED
	MJ per t (av. value)	MJ of total meat prod.	MJ of total meat prod.
Beef	43,000	8,939,915,000	5,959,929,000
Pork	26,000	12,774,138,000	8,516,092,000
Chicken meat	22,000	2,673,330,000	1782.220,000

4.4 Assessment of Indicators

Data gathered from the evaluation of the indicators was converted into CO₂-eq emission, and the two scenarios were compared and evaluated (for detailed results, please see Annex). In the RED scenario, Ind01 shows a decrease in animals slaughtered of more than 26 million animals per year (most are chicken) and of 2.13 million t CO₂-eq/year (Leip et al. 2010; Statistik Austria 2014b).

Data from Castanheira and Freire (2013) showed that emissions from feed imports (Ind02) had an extremely high range and that their variability was mainly due to the effects of land-use change. In the RED scenario, it was assumed that one-third less soy (beans and meal) would need to be imported and that this amount could be substituted by soy and other high-energy crops sourced from Europe (a substitution was not calculated in this study). In total, a decrease in feed imports from South America was estimated to reduce GHG emissions by 50,000–2,966,667 t CO₂-eq/year (Castanheira and Freire 2013; WWF 2014). Our analysis did not consider emissions that occurred as a result of possible substitutions, but solely took the consequences of decreases in imports into account.

Ind03 shows that emissions from enteric fermentation and manure management were one of the biggest contributors to GHG emissions from food production. Data for this indicator included CH₄ emissions from enteric fermentation and manure management as well as N₂O emissions from manure management, animal manure applied to agricultural soil and pasture, range and paddock manure. In total, the reductions in the CH₄ and N₂O emissions in the RED scenario led to total emission reductions of 1,531,527 t CO₂-eq/year (Umweltbundesamt 2014a). Due to missing data, emissions from sheep and goats were not included.

Ind04 shows a potential water reduction in the RED scenario of 279 million m³ (Mekonnen and Hoekstra 2012; Statistik Austria 2013, 2014a). On the basis of data gathered in Germany, a calculation of the average emissions of water production with 0.82 g CO₂/l of fresh water (Stadtwerke Karlsruhe 2014) indicated a possible reduction of approximately 229,000 t CO₂-eq/year in the RED scenario.

Ind05 describes the waste water produced as a result of meat production in the slaughterhouse phase. Waste water per ton of carcass was combined with the total slaughter numbers in Austria and emissions from waste water production. The amount of waste water needed during slaughter depends on the animal and ranges from 1600 to 67,400 l per t of carcass. The highest amount of water is needed during poultry production because of the risk of microbial infection (e.g., Salmonella)

Table 4.9 Savings of RED scenario

Indicator	Savings in RED scenario (t CO ₂ -eq)		% of Austrian CO ₂ -eq emissions 2012
	Min	Max	Min max
Ind01—reduction of slaughtering	2,129,355		2.7
Ind02—reduction of feed imports	50,000	2,966,667	0.06 3.7
Ind03—decrease of CH ₄ and N ₂ O emissions	1,531,527		1.9
Ind04—decrease of water consumption	228,998		0.3
Ind05—decrease of waste water	2973		0.004
Ind06—decrease of energy input along the FSC	826,463		1.03
Total savings (Mt CO ₂ -eq)	4.8	7.7	6.0 9.6

(European Commission 2005). In total, the reduction in waste water by decreasing meat waste was calculated to lead to GHG savings of 2973 t CO₂-eq/year (Stadtwerke Karlsruhe 2014).

Ind06 describes the potential reduction in energy input as a result of reducing meat waste. Using data from de Vries and de Boer (2010), who estimated the necessary energy input of meat production to be 0.366 kg CO₂-eq/kWh (Umweltbundesamt 2014b), a possible reduction of approximately 0.83 Mt CO₂-eq per year could be achieved in the RED scenario. Due to missing data, Ind06 did not consider sheep and goats.

Table 4.9 shows the summary of all indicators and the total savings achieved through the application of the RED scenario, ranging from 4.8 to 7.7 Mt CO₂-eq/year, as compared to the BAU scenario, which is equivalent to minimal 6.0% or maximal 9.6% of Austria's total CO₂-eq emissions in 2012.

4.5 Discussion

The assessment of indicators conducted in this study highlights the potential impacts of food waste reduction on social, economic and environmental factors. The environmental impact on the climate is discussed in more detail than economic and social impacts. It was difficult to clearly assess the social and ethical impacts, because this would have required us to assess or place a price on life itself, which has considerable moral and ethical implications. Even though the animals (and their products) are subject to continual “pricing”, it is on conviction that an appropriate price can never be determined. Our study indicates that the social and ethical

impacts of a reduction in food waste, and particularly meat waste, can result in a reduction in the numbers of slaughtered animals. When considering the system boundaries of this study, the decrease in Austrian feed imports could indirectly help indigenous people living in or near rainforest areas in South America, who might be affected by enlargements in agricultural areas.

The economic impact of decreasing food waste is obvious because the production of less meat waste, as estimated in this scenario, would directly lead to less meat production and, consequently, lower income levels in the agriculture (e.g., for farmers), meat processing and retail sectors. Assessing the overall cost of food waste is an extremely complex task. The FAO (2013) attempted to price each impact from food waste (including social aspects) on a global scale and arrived at total costs of 2.625 billion US-\$. The highest costs arise from production of food (which is subsequently wasted), social factors such as loss of livelihoods and the increasing risk of conflicts and from GHG emissions. Many of these values can be easily contested and, therefore, this assessment focused on the environmental impact of meat waste and, specifically, the impact on our climate. Nevertheless, the important components of the meat supply chain, namely energy, feedstuff and water, were fully taken into account and treated within the system boundaries of the SIA.

However, some restrictions of this study should be considered. Not all indicators cover all three sustainability dimensions, although none of these is an indicator that focuses only on environmental impact. One of the indicators selected did not cover the whole supply chain, because Ind05 only considered waste water produced during the slaughterhouse stage. For this indicator, it was not possible to calculate CO₂-eq emissions and, instead, an average value extracted from the literature was used. Due to missing data, the emissions from landfills in Austria could not be considered, but it is verifiable that a certain amount of food waste is landfilled. For Ind02, a high degree of uncertainty had to be accepted, because only LCA data on soybean production in Brazil and Argentina could be used, which ranged from 0.3–17.8 kg CO₂-eq per kg feedstuff. Data from dairy cows were included because it was not possible to exclude them. The average soy use for beef in the OECD represents less than 1% of the total use of soy as feed due to high numbers of pigs and chicken (WWF 2014), but because only approximately one-fourth of all cattle in Austria are dairy cows, this minor error was not considered to have an impact on the overall results. Ind04 was based on water footprint data for livestock reported in Mekonnen and Hoekstra (2012). The critique of Ridoutt et al. (2011) was considered, as they have argued that Mekonnen and Hoekstra's estimations are rather high because they included water produced as a result of evapotranspiration from crops and pasture grasses, which enhanced the footprint. Therefore, only the blue and grey fraction of the water footprint was taken into account, resulting in a lower mitigation potential of the BAU scenario regarding water consumption, when compared to the entire water footprint.

Despite these restrictions, uncertainties and missing data, the SIA presented can provide researchers with a rough picture, revealing the huge potential for GHG emissions savings that would exist if the total meat waste in Austria were reduced by one-third. The largest factors that could contribute to this potential are reducing feed imports (e.g., particularly soybeans and meal), reducing the number of animals slaughtered and decreasing CH₄ and N₂O emissions. Our study demonstrated that by decreasing the energy input and the water consumption, GHGs emissions could be reduced further, whereas waste water decreases were negligible.

Future research could focus on modifying the SIA to address the restrictions listed above, to gain a more precise and accurate forecast for GHG emissions resulting from food waste (as well as the impact of food waste reductions). In this context, it might be of interest to examine the situation in other countries and/or for other food products and gather more data. Moreover, including a greater variety of indicators would allow researchers to test the reliability of these results. For this purpose, including approaches used in other fields such as technology assessment could be supportive [cf. e.g., the study to determine the requirements for a sustainability product label, which was developed by the Office of Technology Assessment in the German Parliament (TAB 2015)].

4.6 Conclusion

This paper addresses a topic with high societal relevance. The reduction in food waste is a sub-goal of one of the United Nations ‘Sustainable Development Goals’ (SDGs), which have been adopted by the United Nations Sustainable Development Summit (25–27 September 2015). According to SDG 12 (‘Ensure sustainable consumption and production patterns’), EU member nations are required to ‘By 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’ (United Nations 2015).

In many European countries, food waste is a topic of active discussion. One of the goals of this study was to gain a clear picture, how food waste in Austria—and in particular meat waste—is affecting the climate. Our data indicated that, by making ‘simple’ changes in behavior, Austria could potentially save at least 4.8 Mt CO₂-eq emissions per year (i.e., 6% of Austria’s total CO₂-eq emissions in 2012), without considering making any improvements in meat production or taking into account a growing number of Austrians that switch to vegetarianism or veganism. By combining all these factors, a significant reduction in Austrian (and global) GHG emissions could be achieved, and a step towards the goal to keep the rise in global average temperature below 2 centigrades compared to pre-industrial times by 2100 could be taken.

Annex: Overview of SIA Indicators and Their Values for BAU and RED Scenarios

	BAU scenario	RED scenario	Sheep (& goat)	Poultry	Beef/cattle	Pork/pig	Sheep (& goat)	Poultry	Beef/cattle	Pork/pig	Sheep (& goat)	Poultry
Ind01 ^a	Beef/cattle											
	Net national consumption (t)	207,905	491,313	7454	121,515	138,603	4969	81,010		327,542	4969	81,010
	kg CO ₂ -eq/kg meat	14.2	6.0	8.4	3.5	14.2	6.0	3.5		6.0	8.4	3.5
	kg CO ₂ -eq of net consumption	2,952,251,000	2,947,878,000	62,613,600	425,302,500	1,968,162,600	1,965,252,000	41,739,600	283,535,000		1,965,252,000	41,739,600
Ind02 ^b	Sum (t CO ₂ -eq)				6,388,045							4,258,690
	Soy import (kg)	Soy import (kg)	CO ₂ -eq max (kg/kg of soy product)		Soy import (kg)	CO ₂ -eq min (kg/kg of soy product)			Soy import (kg)	CO ₂ -eq min (kg/kg of soy product)	CO ₂ -eq max (kg/kg of soy product)	
	500,000,000	500,000,000	17.8		333,333,333	0.3			333,333,333	0.3	17.8	
	Total soy (meal) feed = 530,000 t (30,000 t from Austria)											
Ind03 ^c	Sum (t CO ₂ -eq)											
	Beef/cattle	Beef/cattle	CO ₂ -eq max (kg/kg of soy product)		Beef/cattle	CO ₂ -eq min (kg/kg of soy product)			Beef/cattle	CO ₂ -eq min (kg/kg of soy product)	CO ₂ -eq max (kg/kg of soy product)	
	79,890	79,890	8,900,000,000		53,260	100,000,000			53,260	100,000,000	5,933,333,333	
	5880	5880	8,900,000		3920	100,000			3920	100,000	5,933,333	
	CH ₄ emissions from enteric fermentation (t)	4470	2920		280	2980	1947		187	1947	187	
	CH ₄ emissions from manure management (t)	3500	70		1050	2333	47		700	47	700	

(continued)

(continued)		BAU scenario	RED scenario	80	230	860	120	53	153
Ind04 ^d	N ₂ O emissions from manure management (t)	1290	180	80					
	CO ₂ -eq (t)	3,300,600	324,620	125,500	113,760	2,200,400	216,413	83,667	75,840
	Addit. N ₂ O em. (t) to agric. soil	2150				1.433			
	Addit. N ₂ O em. (t) to pasture, manures	300				200			
	CO ₂ -eq (t)	730,100				486,733			
	Sum (t CO ₂ -eq)				4,594,580				3,063,053
		Beef/cattle	Pork/pig	Sheep (& goat)	Poultry	Beef/cattle	Pork/pig	Sheep (& goat)	Poultry
Ind05 ^{e, s}	Estimated Austrian water footprint (m ³)	208,112,905	531,109,353	3,801,540	94,781,700	138,742,604	354,072,902	2,534,190	63,187,800
	CO ₂ -eq (t)	170,652	435,509	3117	77,721	113,769	290,340	2078	51,814
	Sum (t CO ₂ -eq)				686,999				458,001
		Beef/cattle	Pork/pig	Sheep (& goat)	Poultry	Beef/cattle	Pork/pig	Sheep (& goat)	Poultry
	Average total waste water (l)	2,156,491,489	2,487,323,964	98,134,466	6,134,542,018	1,437,660,993	1,658,215,976	65,422,977	4,089,694,679
CO ₂ -eq (t)	1768	2040	80	5030	1179	1360	54	3354	
Sum (t CO ₂ -eq)				8919				5946	

(continued)

(continued)

	BAU scenario	RED scenario	Poultry		Sheep (& goat)	Pork/pig	Beef/cattle	Sheep (& goat)	Poultry	Beef/cattle	Pork/pig	Sheep (& goat)	Poultry
Ind06 ^f	Beef/cattle	Pork/pig											
	MJ of total meat production (average value)	8,939,915,000	12,774,138,000	No data		2,673,330,000	5,959,929,000	No data	2,673,330,000	8,516,092,000	No data	1782.220,0000	
	kWh	2,483,309,722	3,548,371,667	No data		742,591,667	1,655,535,833	No data	742,591,667	2,365,581,111	No data	495,061,111	
	CO ₂ -eq (t)	908,891	1,298,704	No data		271,789	605,926	No data	271,789	865,803	No data	181,192	
	Sum (t CO ₂ -eq)					2,479,384			2,479,384			1,652,921.79	

^aLeip et al. (2010) and Statistik Austria (2013, 2014a)^bCastanheira and Freire (2013), Global 2000 (n.d.) and WWF (2014)^cUmweltbundesamt (2014a)^dMekonnen and Hoekstra (2012), Stadtwerke Karlsruhe (2014) and Statistik Austria (2013, 2014a)^eEuropean Commission (2005), Stadtwerke Karlsruhe (2014) and Statistik Austria (2014a)^fde Vries and de Boer (2010), Statistik Austria (2014a) and Umweltbundesamt (2014b)^gEutrophication potential included in Ind01

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