MITIGATION OF FOOD WASTAGE

SOCIETAL COSTS AND BENEFITS

Food and Agriculture Organization
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About this document

Food Wastage Footprint (FWF) is a project led by Nadia El-Hage Scialabba, Climate, Energy and Tenure Division. Phase I of the FWF project modeled the impacts of food loss and waste on climate, land, water and biodiversity. Phase II of the project, commissioned to the Research Institute for Organic Farming (FiBL), Switzerland, expanded the project to include modules on full-cost accounting of societal externalities of food wastage. This report is linked to three other publications: (i) Food Wastage Footprint: Impacts on Natural Resources (FAO 2013); (ii) Toolkit: Reducing the Food Wastage Footprint (FAO 2013); and Food Wastage Footprint: Full-Cost Accoounting (FAO 2014). This publication is aimed both toward consumers and their purchasing and consumption habits and to policy-makers who have the potential to set regulations and make investments that will lesson the burden of food wastage on society and our planet's natural resources.

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The FWF project products are available at: www.fao.org/nr/sustainability/food-loss-and-waste

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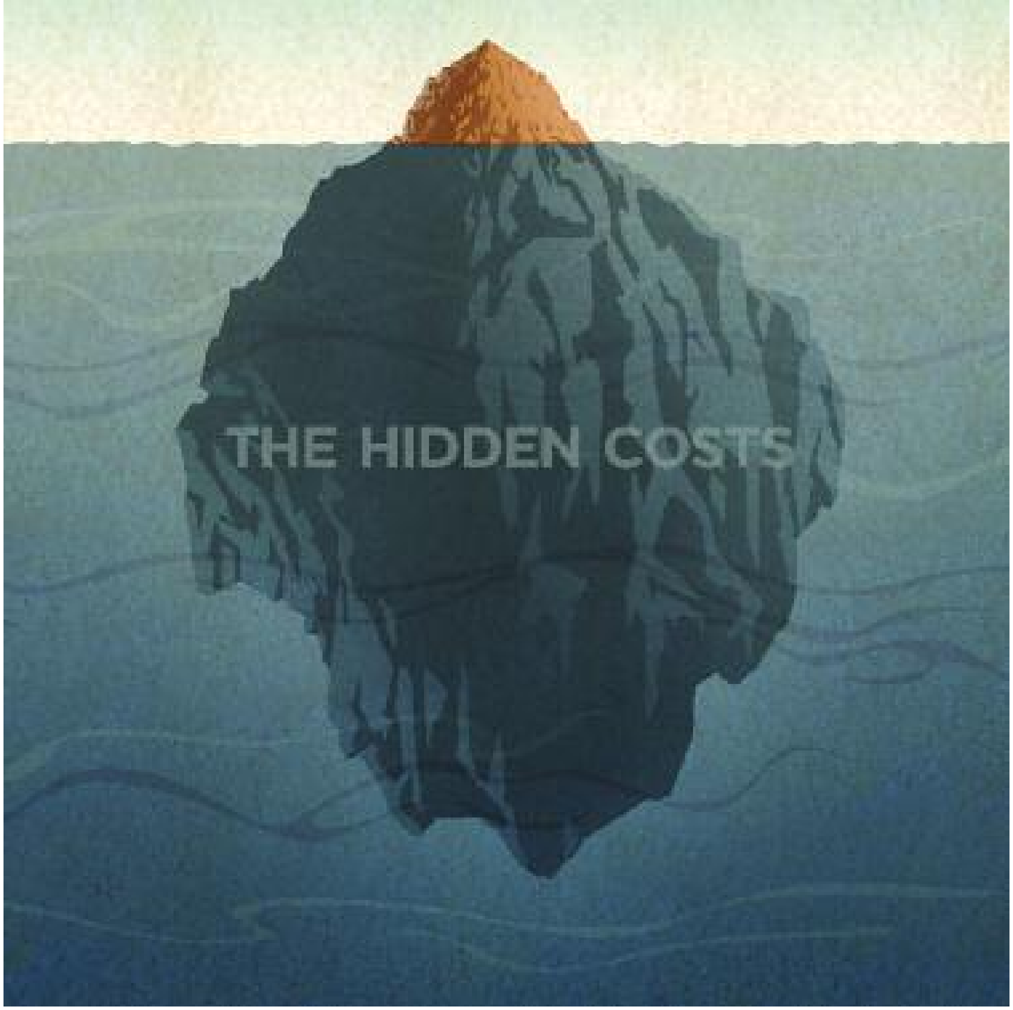
THE HIDDEN COSTS

Executive Summary

In recent years, progress has been made globally in establishing sustainable food production systems aimed at improving food and nutrition security and the judicial use of natural resources. Yet, all of those efforts are in vain when the food produced in those systems is lost or wasted and never consumed.

As food wastage increases in parallel with production increases, it becomes even more important to recognize that reducing food wastage must be part of any effort aimed at sustainable production and food security. In addition to this, there also are environmental repercussions, including all of the natural resources used and greenhouse gases emitted during the production or disposal of food that is not consumed.

Analysis of food wastage causalities suggests that it is economically rational to loose food as part of the costs are externalized, and incentives to producers and consumers along the supply chain further encourages not taking into account negative externalities such as environmental costs. However, food wastage has huge environmental impacts and corresponding societal costs that need to be dealt with. Mitigation of this wastage must become a priority for each actor along the food chain.

This paper presents a portfolio of potential food wastage mitigation measures, illustrating the gross and net economic, environmental and societal benefits of each. Adopting appropriate food wastage mitigation measures can offer corresponding huge environmental benefits, leading to associated net gains for societies in terms of reduced economic losses and external costs. The performance of measures aiming at avoiding food wastage tends to be higher than for reusing, recycling of food products and certainly higher than landfilling.

Assessments reveal different pictures, depending on the indicators used, such as GHG reduction per tonne of avoided food waste, GHG reduction per tonne of GHG emitted by the mitigation measure, or financial benefits per dollar invested. While for most measures, environmental benefits are unambiguously high, economic profitability can hinge on voluntary work, such as is often the case for food distribution to charities. With paid work, such measures can be less cost effective, even when accounting for avoided external costs. This highlights the importance of community commitment and engagement in food wastage reduction. Full-cost accounting informs about the direct and indirect cost-benefit potential of different options.

The highest aggregate impact reductions are clearly achieved with high volumes of wastage and high impact, so mitigation policies should first address commodities that have the highest environmental impact.

Getting more food to family meals requires innovative thinking and partnerships along the entire supply chain. However, the efforts also should extend beyond the food and agriculture sector, as several other sectors (such as energy) have a key role to play. With increasing natural resource scarcity and changing food and energy market prices, the need for food wastage mitigation programmes will become more obvious in terms of their potential beneficial in both societal and economic terms. As this happens, improvements – whether self-driven or government-calatyzed – will most likely increase.

Introduction

About one-third of all food produced today – some 1.7 billion tonnes – is lost or wasted along the food value chain[1]. In developing countries, this wastage occurs mainly in the post-harvest phase due to lack of adequate infrastructure while, in developed countries, wastage occurs mainly at the retail and consumption levels, due to overly constraining regulations and unsustainable consumption patterns (Gustavsson *et al.* 2011). It has been estimated that reducing food wastage by half by 2050 would provide one-quarter of the gap of food needs (Lipinski *et al.* 2013).

In 1974, FAO hosted the World Food Conference which called attention to the linkage between reduction of post-harvest losses and food security and as a follow-up, created a special action programme aimed at halving food losses. The fact that this objective has yet to be met indicates that market logic alone cannot trigger the needed change, especially when investments are required.

Today, thanks to concerted surveys commissioned by FAO in 2011 and 2013, we can quantify the total of global food loss and waste (referred to as food wastage), as well as how the impact of that loss and waste compounds through the accompanying waste of the natural resources used to produce it. As shown in Table 1, this impact can include GHGs emissions during production, unduly occupied land, unnecessary water usage and loss of biodiversity (see Table 1). In addition, a considerable amount of GHGs are emitted at a later stage in the supply chain, mainly due to methane emissions from food dumped in landfills or from carbon dioxide emitted by waste that is incinerated.

Table 1: Main global environmental impacts of food wastage

Environmental impacts	Unit	Global	OECD countries	Non-OECD countries
GHG emissions	Gt CO_2e	3.49	0.75	2.74
Land occupation	Million ha	0.90	0.21	0.70
Water use	km^3	306	24	282
Soil erosion	Gt soil lost	7.31	1.00	6.31
Deforestation	Million ha	1.82	0.16	1.66

Food wastage also means economic waste. Food produced that is not consumed has an annual bulk-trade value of USD 936 billion globally. But the cost goes beyond the financial value of lost food. Society also is left with indirect consequences of degraded environmental resources and loss of social wellbeing. For example, using water to irrigate crops that then go wasted not only results in the direct loss of the economic value of the water used, it can also compound water scarcity in the production region, leading to additional costs. Similarly, any food production may increase soil degradation, but if that food is wasted, it means that there was no benefit from the use of the soil and its nutrients and there will be corresponding social costs which may even contribute to sparking conflicts, due to increased scarcity of fertile land (see Table 2).

Table 2: Costs of societal impacts of food wastage (USD billion per year - 2012 value)

Costs	Global	OECD countries	Non-OECD countries
GHG emissions	394	85	309
Deforestation (as a proxy for land occupation)[a]	2.9	0.3	2.6
Water use	7.7	2.2	5.5
Water scarcity	164	14	150
Water pollution	24	13	11
Soil erosion	34.6	16.4	18.2
Biodiversity	9.5	4.4	5.2
Health (acute pesticide incidence costs)[b]	8	0.8	7.2
Livelihood (adults)[c]	228.6	7.8	230.8
Individual health (adults)[c]	102	2.8	99.2
Conflict (adults)	248.9	n.a.	n.a.
Total	**1 224.2**	**146.7[d]**	**838.7[d]**

Notes:

[a] As no land values are available, the costs of land use and land occupation due to food wastage cannot be determined directly. Thus, the costs of deforestation are used as a proxy for the costs of land occupation, as this strongly relates to the areas used for agricultural production.

[b] These represent public health expenditures only, including costs for medical treatment and the like. Individual costs, costs due to loss of labour force and other individual costs are not included.

[c] The conflict estimate is provided for global values only, due to small sample size for regional estimates; The difference between OECD and non-OECD numbers for livelihood and individual health are due to calculations based on per capita and year costs of one unit of environmental impact (soil erosion/toxicity) and the fact that these incidence levels are about six times higher in non-OECD than OECD, and that population in non-OECD is also about six times that of OECD. The OECD and non-OECD estimates do not sum to the global numbers, as they are based on three separate regressions leading to regionally different parameter estimates.

[d] Excluding conflicts, as these costs are provided on global level only.

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[1] This includes edible and non-edible parts, i.e. it is measured in "primary product equivalents", thus, for example, not counting "wheat flour" but "wheat grains" (which is about 30% more in weight due to byproducts (brans and germ) and processing losses. In total, the difference is about 20%, as "edible parts" would only account for about 1.3–1.4 billion tonnes.

Businesses and consumers are more likely to participate in preventing and reducing food wastage when mitigation measures are economically attractive or when they are required to comply with legally binding requirements. Hence, there is need for instruments that reflect the real cost of food wastage.

The urgency of food wastage mitigation becomes even more pressing when full societal costs are understood. But to give the full picture, any investment in mitigating food wastage needs to be broadly evaluated, in terms of potential environmental, social and economic costs and benefits. To date, there are gross estimates of the size of food wastage volumes and their environmental impacts, but almost no information on the related costs to society. Similarly, much is known about technical aspects of food wastage measures (Gustavsson *et al.* 2011), but the environmental and societal costs and aggregate reduction potential of food wastage measures are largely unknown. To fill this gap, FAO has engaged in work on cost accounting of food wastage to provide a basis for informed decision-making. Cost accounting makes the true societal costs of food wastage and its mitigation explicit and, in turn, allows a more encompassing and realistic assessment and understanding of the benefits of food wastage mitigation.

1. Methods

The FAO framework for full-cost accounting of food wastage describes the effects of food wastage and its mitigation in the context of the global economy, and suggests viable and easily managed methods for estimating specific parts of these costs. This includes global estimates on quantifiable environmental and social costs, and assessments of the costs and benefits of a range of concrete food wastage mitigation measures which, added together, illustrate the potential effects of food wastage mitigation.

It is important to note that food wastage and its mitigation have different outcomes, depending on where along the supply chain wastage occurs, or where the mitigation measure is implemented. For example, pre- and post-harvest losses result in costs for producers, due to lost income and wasted input costs. Ironically, losses at the processing, distribution or consumption stage can also be beneficial for producers, as they lead to scarcity and thus higher demand. Similarly, wastage at the retail level is costly to the retailer, but wastage at the consumer level can mean higher sales and revenues for retailers. Furthermore, the effectiveness of any food wastage measures will vary greatly depending on the type of intervention, with avoidance of wastage from the outset faring better than reuse or recovery of food wastage. When discussing food wastage, its mitigation and the related costs and benefits, it is thus crucial to address the distribution of costs and benefits, especially when there is need to make decisions on concrete mitigation measures.

It also should be noted that, no matter how efficient or beneficial, there are still costs involved in mitigation measures. Thus, from a societal perspective, “zero waste” cannot be a goal, as achieving it would require much higher mitigation costs. From an economic perspective, there is an optimal level of wastage in a society – a level considerably lower than the wastage level of today.

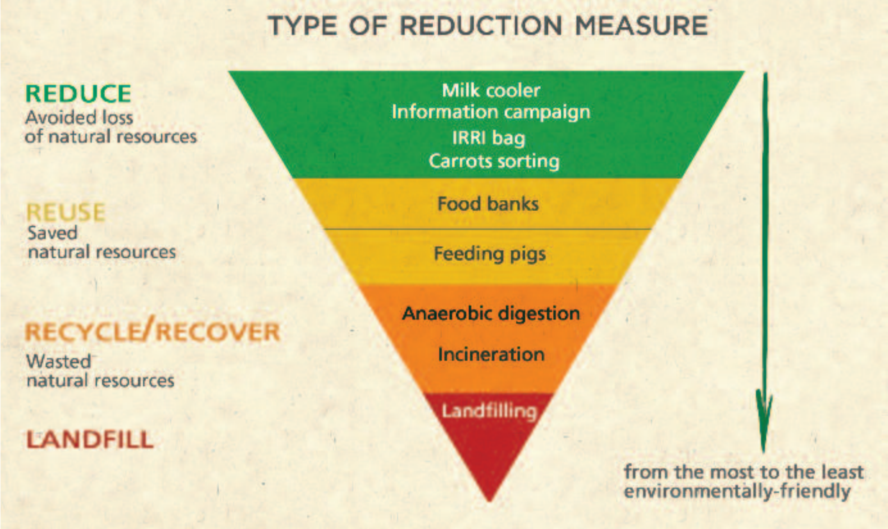
This document focuses on case studies of different food wastage mitigation measures in order to illustrate the full-cost accounting of food wastage in concrete cases and to inform decision-makers on the cost and benefits of different investment options[2]. The choice of the case studies was based on the desire to cover different commodities and food wastage hotspots, as well as types of interventions, namely those that reduce, reuse, recycle, recover and dispose of waste.

2. Case studies of mitigation measures

2.1. Overview of mitigation strategies

Mitigation measures have different levels of environmental efficiency along the food wastage pyramid. The FAO Food Wastage Footprint Toolkit (FAO 2013b) identified levels from reduction through re-use, recycle, recovery and, finally, to disposal which represents the continuum of the most-to-least environmentally friendly options. The case studies below have been chosen to illustrate all the different levels of the pyramid, as well as a large range of commodities and geographies. Figure 1 identifies the topics of the reduction measures that are featured in the case studies and how they rank in terms of environmental impact.

Figure 1: Case studies of food wastage mitigation along the pyramid



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[2] The full-cost accounting of food wastage, including the approach taken for the monetization of environmental and social impacts is described in (FAO 2014).

Some case studies have a more individual or business focus, such as the one featuring a carrot-sorting machine, while others, such as the one that looks at the contribution of food banks, have a society focus. The difference arises in how certain effects are judged as benefits or costs. Reducing labour, for example, is a benefit from a business perspective, as it reduces wage payments but, from a societal point of view, it can be problematic. Voluntary and unpaid work, on the other hand, can be of big value for society, while it would not have a place in a business operation.

Case Study 1:
Milk cooler (Kenya)

Commodity: Milk
Stage of the value chain: Production and post-harvest handling
Amount of annual milk loss in East Africa: 6% of total production is lost at production level and 11% is lost at post-harvest level, or 627 000 tonnes and 1 232 000 tonnes respectively, with a total of 889 593 tonnes in Kenya alone, of which 571 418 tonnes is at production level (FAOSTAT 2009).

Wastage impact on natural resources and the economy

Animal products, including milk, have a very high environmental footprint, as animal husbandry has a high level of impact on GHG emissions, water consumption and land use. Agricultural production and post-harvest losses account for the major part of the milk losses (over 60 percent), the other loss hotspot being the distribution (36 percent).

Table 3: Monetization of milk wastage in Kenya

Annual loss	Quantity	Metric unit	Value (USD)
ECONOMIC			
Lost milk sales to producers (USD 300/t) Wasted subsidies (if applicable)	571 418	tonne	171 425 400
Total economic costs			**171 425 400**
SOCIO-ENVIRONMENTAL			
GHG	4 923 791	t CO_2e	556 388 433
Water	79 287 564	m^3	378 036
Land[a]	Land occupation: 2 467 650	ha	
	Deforestation: 847		1 365 229
Water pollution[b]			14 149 394
Soil erosion	2 470 016	tonnes soil lost	10 900 214
Water scarcity			382 019
Biodiversity			2 477 838
Human health			453 989
Total socio-environmental costs			**586 495 152**
TOTAL VALUE OF LOSS			**757 920 552**

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation by using the costs of forest loss that correlates highly to agricultural areas as a proxy, and the corresponding value is reported. Therefore, total economic values (TEV) for forests are used and values for cropland ecosystem services are not accounted for. As Kenya does not report TEV values, the global average is used, which is USD 1 611/ha.

[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water. Some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff that are equal to USD 12 247 247.

Full-cost of wastage reduction measure

Description: Milk deteriorates fast at ambient temperature in Africa, which is a major cause of production and post-harvest milk losses. Installing milk cooling devices at the farmer cooperative level enables farmers to fight these losses.

Reference scenario: Farmers rarely have milk coolers, meaning the milk not sold immediately deteriorates quickly.

Scope of the measure: The cooling device considered by this case study is able to cool and store 1 000 litres of milk. Through the milk coolers, almost all of the 15 percent of production lost could be saved.

Life span: The average useful life of most dairy equipment is about 8 years.

System boundaries: Only the milk cooler itself has been studied, not the rest of the cold chain, nor the building in which the milk cooler should operate. The maintenance work for the milk cooler, as well as the socio-environmental costs of manufacturing the cooler have been also excluded from the calculation, as the running costs are usually much higher. Economically, only the sales of the "saved" milk have been included, though milk coolers are also often linked to improved milk production through higher yields and higher revenues for the famer.

Data sources: The year 2009 is the reference year. Data are based on FAOSTAT for milk prices, expert opinions for milk loss reduction potential, energy need and investment return and for energy costs (Bohm *et al.* 2013). For calculating the environmental impacts of the saved milk, FAOSTAT data was modelled.

Economic and socio-environmental cost-benefit analysis of the food wastage reduction measure

Economic cost of the measure: A 1 000-litre milk cooler costs around USD 7 000, with an associated 10 percent two-years micro-credit interest rate, and electricity running costs of USD 0.01/litre/day).

Economic benefit of the measure: Possibility to sell more milk at USD 0.3/litre (FAOSTAT).

Environmental cost of the measure: Production and powering of the milk cooler.

Environmental benefit of the measure: Milk loss reduction, saving 150 litres of milk per day for each 1 000-litre milk cooler (i.e. 54 750 litre/year).

Investment burden: The initial cost of the milk cooler is USD 7 000, also taking into account the 10 percent credit interest rate.

Investment breakeven point: Reached after two years.

Table 4: Economic and socio-environmental benefit analysis of milk coolers in Kenya

Economic		**Annual financial cost (USD)**		**Annual financial benefit (USD)**		**Annual financial net benefit (USD)**	
Mitigation measure: 1 000 litre milk cooler		4 708[a]		16 425		11 717	
Socio-environmental		**Annual socio-environmental cost**		**Annual socio-environmental benefit**		**Annual socio-environmental net benefit**	
Impact category	Metric unit	Quantity	Value (USD)	Quantity	Value (USD)	Quantity	Value (USD)
GHG	t CO_2e	12	1 356	472	53 336	460	51 980
Water	m^3			7 597	36	7 597	36
Land use[b]	ha			236	-	236	-
Deforestation	ha			0.1	131	0.1	131
Water pollution[c]	-			-	1 356	-	1 356
Soil erosion	t soil lost			237	1 044	237	1 044
Water scarcity	-			-	37	-	37
Biodiversity	-			-	237	-	237
Health costs	-			-	43	-	43
Total socio-environmental costs:			1 356		56 220		54 864
Annual net economic and socio-environmental benefit of a 1 000 litre milk cooler (USD):							
						66 581	

[a] Calculations are as follows: (7000 +700 + 770 + 8*3650)/8 = 4708; this is the average annual costs if the credit is paid back after two years and interest in the first year would also be financed by a 10% credit; this is for illustrative purposes – in reality, when paying back after 2 years, which is realistic from the calculations and due to expert information, no investment costs remain, only variable costs.

[b] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, and the corresponding value is reported. Thereby, total economic values (TEV) for forests are used and values for cropland ecosystem services are not accounted for; as Kenya does not report TEV values, we take the global average of USD 1 611/ha.

[c] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 1 173.

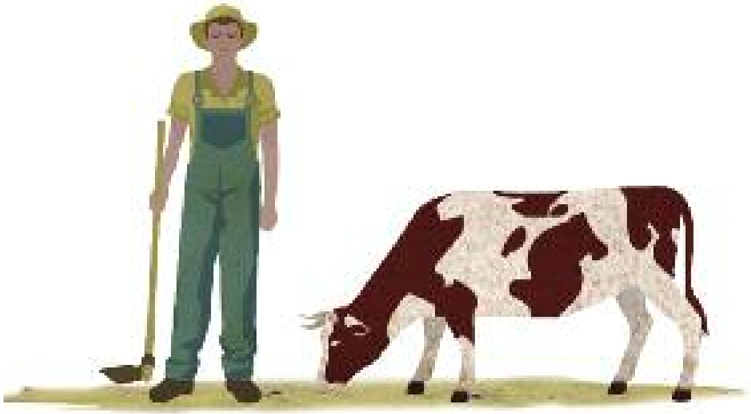
Potential of food wastage reduction measure

Opportunities: Milk cooler dissemination within farmer cooperatives that produce enough milk to run one or several 1000-litre milk coolers efficiently makes sense economically. Its environmental benefits make it a great way to reduce food losses. While the initial financial investment is costly, there is an apparent return on investment by the second year.

Constraints: The initial investment in the milk cooler is a major issue for farmer associations, as access to credit is difficult. Also, energy supply in Kenya is not reliable, and these calculations have been made on the basis of a functioning national grid. This means that the purchase of a generator and the costs of its fuel should be added to the costs. Calculations have been made on the GHG impacts of using a generator instead of the national grid and the emission are multiplied by a factor 2.5.

Further methodological annotations

- The energy needed to cool 12 litres of milk is 1 kWh/day.
- The GHG emissions are 0.395 kg CO_2/kWh using the average national grid emission factor in Kenya from the national grid. If the energy is coming from a diesel generator, the fuel consumption is estimated at 0.3 litres/kWh and the total GHG emission (direct + indirect) factor is 3.2413kg CO_2/litre which is 0.973 kg CO_2/kWh.
- This assumes there is a market for the cooled milk and the rest of the cold chain is in place.



Case Study 2:
Communication campaign: the Household Food Waste Prevention Programme of UK Waste and Resources Action Programme (WRAP)

Waste prevention

Key Areas

Waste prevention action

Resources for the retail and manufacturing sectors

Manufacturing and retail waste figures

Latest waste data for the UK food and drink supply chain

Waste Prevention Loan Fund

Cutting waste and increasing re-use in electricals, furniture and textiles

Courtauld Commitment

Grocery voluntary agreement

Commodity: Food and drink
Stage of the value chain: Consumption
Amount of annual household food and drink waste (UK):
5 421 873 tonnes in 2012, avoidable and possibly avoidable (WRAP 2013b).

Wastage impact on natural resources and the economy

Household food and drink waste (FDW) has the largest share in food wastage in industrialized countries. About 95 kg per capita is wasted each year by consumers in Europe (Gustavsson *et al.* 2011a). In the UK, nearly 90 kg of avoidable FDW per capita occurred at household level in 2007, which was reduced to about 70 kg in 2012 (WRAP 2013b).

Table 5: Monetization of household food and drink waste in the UK

Annual loss	Quantity	Metric unit	Value (USD)
ECONOMIC			
Food and drink waste (FDW)	5 421 873	tonne	4 295 462 769
Wasted subsidies (if applicable)			937 457 447
Total economic costs			5 232 920 216
ENVIRONMENTAL			
GHG emissions	9 676 462	t CO_2e	1 093 440 172
Water use	120 450 791	m^3	12 045 079
Land[a]	1 450 272	ha	
Water pollution[b]			257 248 337
Soil erosion	2 445 272	t soil lost	38 840 371
Water scarcity			11 994 992
Biodiversity			44 099 724
Human health			261 951
Total socio-environmental costs			1 457 930 626
TOTAL VALUE OF LOSS			**6 690 850 842**

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, but this parameter does not play a role in the UK.

[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 194 741 222.

Full-cost of wastage reduction measure

Description: The Household Food Waste Prevention Programme (HFWPP), one of WRAP's nine main programmes, is funded by the UK Department for Environment, Food and Rural Affairs (DEFRA), the Scottish Government, the Welsh Government, the Northern Ireland Executive and EU projects. It aims "to reduce the amount of food and drink waste from homes by changing attitudes and behaviours of consumers, and by changing packaging, products and the way food and drink are sold, such as through an increase of re-sealable packaging (WRAP 2011). It includes the "Love Food Hate Waste" (LFHW) campaign, launched in 2007 and parts of the Courtauld Commitment, launched in 2005. The LFHW campaign aims to prevent food waste in households by addressing consumers through direct communication (e.g. cooking classes, stands on the street), advertisements in magazines and newspapers, its website and social media. Household food waste is reduced by designing smaller packages (WRAP 2013a).

Reference scenario: For analysing the environmental effectiveness and economic efficiency of WRAP, we assumed a reference scenario where WRAP did not exist. Econometric analyses showing how consumer behaviour was affected by WRAP were taken as a data source for modelling the reference scenario (WRAP 2014). It estimated that 60 percent of the household food and drink waste reduction between 2007 and 2012 was due to the HFWPP from WRAP, equalling savings of about 273 000 tonnes of primary food production per year.

Scope: WRAP addresses all households in the UK.

System boundaries: The costs and benefits of the entire Household Food Waste Prevention Programme (HFWPP) were included in the calculation. Direct costs consisted of expenditures for direct consumer engagement (information campaign for consumers), partner support (services to partner companies) and research. Indirect economic costs were the loss of revenues for retailers.

Environmental costs were restricted to costs due to GHG emissions, consisting of emissions due to transport fuel, electricity and natural gas. Environmental costs due to water use, land use and biodiversity loss were assumed to be negligible in comparison with the high ecological footprint of FDW. The economic benefits included consumers' savings on food and drink. Furthermore, consumers benefited from paying less disposal costs.

Environmental benefits were composed of various factors due to less agricultural production and industrial processing (e.g. less GHG emissions and land use). Calculations included avoidable and possibly avoidable food and drink waste. Unavoidable food and drink waste was excluded.

Benefits not included are the economic and environmental value of reduced packaging waste and indirect environmental benefits such as decrease in poverty, famine and conflicts due to climate change. Costs which are not included were: the value of volunteer working hours, loss of jobs due to less production and waste, health costs due to consumption of spoiled food, and packaging waste

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[3] The Courtauld Commitment is a voluntary agreement between WRAP and various companies in the UK mainly aimed at improving resource efficiency and reducing the carbon impact of the UK grocery sector.

due to smaller packaging. The programme was assumed to have major impact on food markets, as the demand for food was reduced. Price reactions have not been considered.

Data sources: WRAP provided documentation and reports, shared internal data on the economic value of wasted food and drink, and made rounded figures available (WRAP 2013c). Environmental benefits due to saved food were calculated with a model based on FAOSTAT data and a study conducted by Gustavsson *et al.* (2011). Environmental costs of the HFWPP were calculated back from electricity and gas costs by taking year-specific average prices offered by the UK Department of Energy and Climate (DECC 2013) and conversion factors offered by DEFRA (2012). Environmental (costs due to fuel use were based on miles driven by car, train and flight and also converted on basis of data from DEFRA (2012).

Economic and environmental cost-benefit analysis of food waste reduction measure

Economic cost of the measure: Expenditure for direct consumer engagement, partner support and research, as well as decrease in revenues of retailers.

Economic benefits of the measure: Consumer savings.

Environmental cost of the measure: Energy costs (fuel, gas, electricity) and resulting social costs of carbon (SCC).

Environmental benefits of the measure: Saved food.

Investment burden: N/A.

Investment breakeven point: N/A.

Table 6: Economic and socio-environmental benefit analysis of the Household Food Waste Prevention Programme in the UK

Economic		**Annual financial cost (USD)**		**Annual financial benefit (USD)**		**Annual financial net benefit (USD)**	
Mitigation measure: information campaign		854 950 576		934 372 657		79 422 080	
Socio-environmental		**Annual socio-environmental cost**		**Annual socio-environmental benefit**		**Annual socio-environmental net benefit**	
Impact category	Metric unit	Quantity	Value (USD)	Quantity	Value (USD)	Quantity	Value (USD)
GHG	t CO_2e	16.77	1 895	614 770	69 468 967	614 753	69 467 072
Water	m^3			9 783 277	978 328	9 783 277	978 328
Land use[a]	ha			75 995	-	75 995	-
Water pollution[b]	-			-	13 287 125	-	13 287 125
Soil erosion	t soil lost			170 813	2 713 167	170 813	2 713 167
Water scarcity	-			-	974 260	-	974 260
Biodiversity	-			-	2 290 747	-	2 290 747
Health costs	-			-	12 119	-	12 119
Total socio-environmental costs:			1 895		89 724 713		89 722 818
Annual net economic and socio-environmental benefit of the HFWPP information campaign (USD):							
						66 581	

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, but this factor does not play a role in the UK.

[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 10 204 483.

Potential of food wastage reduction measure

Opportunities: Conducting a programme such as the HFWPP makes sense economically and environmentally. The cost-benefit analysis revealed a huge benefit, in particular due to saving of GHG emissions.

Constraints: Reaching all/enough people through such campaigns might be difficult. The mitigation opportunity of food and drink wastage in the UK is declining (WRAP 2013a), thus the potential of such campaigns might become exhausted in a few years. Nevertheless, information campaigns can play an important part in a portfolio of different food waste mitigation measures.

Case Study 3:
IRRI Rice Super Bags (Philippines)

Commodity: Rice
Stage of the value chain: Post-harvest storage
Amount of annual rice loss in the Philippines: 10% of total domestic production (FAOSTAT 2009) or 1 803 242 tonnes.

Wastage impact on natural resources and the economy

Cereals have the most loss and waste of any commodity in South and Southeast Asia. Among cereals, rice production has a particularly important water and carbon footprint, due to agricultural practices in paddies. Most rice wastage occurs in the post-harvest phase of the value chain.

Table 7: Monetization of rice wastage in the Philippines

Annual loss	Quantity	Metric unit	Value (USD)
ECONOMIC			
Lost rice sales to producers (USD 350.3/t)	1 803 242	tonne	631 675 743
Wasted subsidies (if applicable)			
Total economic costs			631 675 743
SOCIO-ENVIRONMENTAL			
GHG	3 458 069	t CO_2e	390 761 816
Water	100 226 201	m^3	1 171 434
Land[a]	489 094	ha	
Water pollution[b]			746 815
Soil erosion[c]		tonnes soil lost	
Water scarcity			4 184 469
Biodiversity			1 477 901
Human health			7 210 163
Total socio-environmental costs			405 552 598
TOTAL VALUE OF LOSS			**1 037 238 341**

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, but as no deforestation data is reported for the Philippines in FAOSTAT, there is no value assigned.
[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 341 895.
[c] No soil erosion values is reported for rice.

Full-cost of wastage reduction measure

Description: The Super Bag (SB), an ultra-hermetic bag that provides a water-resistant and gastight storage solution, is used as an inner liner for jute bags and ordinary sacks. It is made of multilayer polyethylene and protects rice from moisture, pest infestation and fungal growth. It was developed by the International Rice Research Institute (IRRI).

Reference scenario: Under regular storage conditions (without the SB), 10 percent of stored rice can be lost due to rodents or fungus.

Scope of the measure: The 50 kg SB contributes to avoiding the 10 percent of rice lost due to fungus and rodents.

Life span: The SB can be reused effectively for an average of 5 years.

System boundaries: This case study looks specifically at the impact of the bag itself. It does not include processes that happen before or after bagging, such as drying. It also does not incude transportation of the basic material for bag production to the production unit or the impact of the transportation of the bag from the production to the retailing site.

Data sources: The year 2009 is the reference year. Data on SB production are based on personal communication with IRRI. Ecoinvent 2.2 database has been used for calculating the environmental impacts, and FAOSTAT has been modeled to calculate the environmental impacts of the saved rice. Rice prices have been estimated using FAOSTAT 2009 producer prices, but it is important to note that the price of the rice is highly dependent on quality grade and local economic situations.

Economic and socio-environmental cost-benefit analysis of the food wastage reduction measure

Economic costs of the measure: Super Bag price (no recurrent cost), estimated at USD 2.5 per bag, but the price can vary depending on the marketing channel.

Economic benefits of the measure: Sales of the rice saved from loss, as well as premium prices received if rice conserved in the bags is sold out of season. Rice prices can be up to 20 percent higher when sold out of the main season.

Socio-environmental cost of the measure: SB production (no recurrent cost). To calculate the environmental impact of the SB, it was assumed that the bag is made of multilayer plastic film, usually consisting of two polyethylene (PE) layers of 78 µm thickness with an oxygen barrier in between and weighing around 250 g.

Socio-environmental benefits of the measure: Rice saved from being lost.

Investment burden: The investment is USD 2.5 per SB. Each bag can be used for an average of 5 years, so an annual cost of USD 0.5 is used in the calculations below.

Investment breakeven point: The return on investment is apparent by the second year.

National investment requirements: Saving 1 803 242 tonnes of rice that is currently lost in the Philippines would require 36 065 SBs, or an investment of USD 90 162 – amounting to USD 18 032 per year for the 5-year life of the bag.

Table 8: Economic and socio-environmental benefit analysis of Rice Super Bags in the Philippines

Economic		**Annual financial cost (USD)**		**Annual financial benefit (USD)**		**Annual financial net benefit (USD)**	
Mitigation measure: 1 Rice Super Bag		0.5		In-season sales: 1.715 Out-of-season: 2.1		In-season sales: 1.215 Out-of-season: 1.6	
Socio-environmental		**Annual socio-environmental cost**		**Annual socio-environmental benefit**		**Annual socio-environmental net benefit**	
Impact category	Metric unit	Quantity	Value (USD)	Quantity	Value (USD)	Quantity	Value (USD)
GHG	kg CO_2e	0.168	0.019	9.6	1.08	9.432	1.06
Water	litre	0.6	negligible	278	0.003	277	0.003
Land use[a]	ha			0.0014	-	0.0014	-
Water pollution[b]	-			-	0.002	-	0.002
Soil erosion[c]	t soil lost			-	-	-	-
Water scarcity	-			-	0.012	-	0.012
Biodiversity	-			-	0.005	-	0.005
Health costs	-			-	0.02	-	0.02
Total socio-environmental costs:			0.019		1.122		1.102
Annual net economic and socio-environmental benefit of 1 Rice Super Bag (USD):							
						In-season sales: 2.32 Out-of-season: 2.7	

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, but as no deforestation data is reported for the Philippines in FAOSTAT, there is no value assigned.

[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 0.001.

[c] No soil erosion values reported for rice.

For 1 803 242 tonnes of rice in the Philippines, 36 065 SB would be needed, or an investment of USD 90 162. For illustration, the per-bag assessment is also scaled to national level, for saving all rice wastage.

Table 9: Rice Super Bag benefit analysis scaled to national level in the Philippines

Economic	Annual financial cost (USD)	Annual financial benefit (USD)	Annual financial net benefit (USD)
Mitigation measure: 36 065 Rice Super Bags	18 032	In-season sales: 61 852 Out-of-season: 75 737	In-season sales: 43 819 Out-of-season: 57 704
Economic	**Annual socio-environmental cost**	**Annual socio-environmental benefit**	**Annual socio-environmental net benefit**
Total socio-environmental costs:	685	40 465	39 780
Annual net economic and socio-environmental benefit of 36 065 Rice Super Bags (USD):			
			In-season sales: 83 599 **Out-of-season: 97 484**

Potential of food wastage reduction measure

Opportunities: SB dissemination makes sense economically and accompanying socio-environmental benefits make it a great way to reduce food losses. While the financial investment may be costly in the first year, the investment break-even point is reached by the second year.

Constraints: Farmers have indicated that the initial investment in the SB is an obstacle to its wider dissemination. In countries such as Bangladesh, the fact that the bags are made from plastic is a problem, as they can only be sold if there is a recycling chain in place.

Case Study 4:
Improved carrot sorting (Switzerland)

Commodity: Carrots
Stage of the value chain: Post-harvest handling
Amount of annual carrot loss: 60 214 tonnes of carrots are produced in Switzerland annually but about 30% production is lost during processing (Kreft 2013).

Wastage impact on natural resources and the economy

Carrots are the most consumed and produced vegetable in Switzerland, where carrot loss can vary according to value chain. At agricultural level, the main reason for loss is bad planning of production quantity, leading to oversupply. However, this over-production is often necessary in order for producers to supply the quantities guaranteed to retailers and processors. At processing level, which often takes place at carrot-producing farms, carrot losses are mainly due to damages to the carrots (scratched or broken), inefficient sorting and overly stringent quality standards (Kreft 2013).

Table 10: Monetization of carrot wastage in Switzerland

Annual loss	Quantity	Metric unit	Value (USD)
ECONOMIC			
Lost carrot sales to producers (USD /tonne)	18 064	tonne	18 306 058
Wasted subsidies (if applicable)			793 403
Total economic costs			19 099 461
SOCIO-ENVIRONMENTAL			
GHG emissions	2 259	t CO_2e	191 424
Water use	190 147	m^3	27 090
Land[a]	472	ha	
Water pollution[b]			80 306
Soil erosion	411	tonnes soil lost	9 295
Biodiversity			18 215
Human health			163
Total socio-environmental costs			326 466
TOTAL VALUE OF LOSS			**19 425 927**

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, but this does not play a role in Switzerland.

[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 43 476.

Full-cost of wastage reduction measure

Description: Carrot losses at sorting stage can be reduced from 27 to 30 percent with a modern and appropriate carrot-sorting machine. A typical sorting machine can handle 2 to 6 tonnes of carrots per hour. This case study included 2 carrot-sorting machines, as this represents a typical sorting capacity for Switzerland.
Reference scenario: When carrots are sorted by hand, 30 percent of the produce is discarded.
Life span: The average lifespan of the carrot-sorting machine is 5 years.
System boundaries: To calculate the environmental costs, both the production and the use phases of the two machines were considered. The other environmental costs listed in the tables were found to be negligible for the carrot-sorting machines. Furthermore, the impacts of producing the carrots that can be substituted through the machines were accounted for. Transport of carrots was not considered in the model. The calculations refer to"Class A" quality carrots.
Data sources: The main data sources for this case study are the reports from Kreft (2013) and Agridea (2010). FAOSTAT data have been modelled for calculating the environmental impacts of the saved carrots. Technical features of the carrot-sorting machine and hand-sorting were based on information from Visar Sorting (2014) and Kreft (2013). Total costs of carrot losses in Switzerland were based on information by BLW/SBV (2008), Agridea (2010) and Kreft (2013).

Economic and socio-environmental cost-benefit analysis of food waste reduction measure

Economic cost of the measure: Purchase and use of the machines, including maintenance, cleaning, labour, energy and interest for financial capital. The average costs represent the annual cost if the machine is depreciated linearly, i.e. by the same amount each year over its entire lifetime.
Economic benefits of the measure: Extra benefit from the sale of the carrots saved and saving on manpower.
Socio-environmental cost of the measure: Environmental impacts of the production and use of the two carrot-sorting machines.
Socio-environmental benefits of the measure: 375 tonnes of carrots saved from loss annually, meaning fewer carrots have to be produced. The environmental impacts of this saving can be attributed to the carrot-sorting machines.
Investment burden: The cost of the two carrot-sorting machines is USD 191 314. The machines can be used for about 5 years and the savings in annual labour costs are higher than this investment, bringing the average annual net benefit to USD 427 283.
Investment breakeven point: The return on investment is apparent by the second year.

Table 11: Economic and socio-environmental benefit analysis of carrot-sorting machines in Switzerland

Economic		**Annual financial cost (USD)**		**Annual financial benefit (USD)**		**Annual financial net benefit (USD)**	
Mitigation measure: 2 carrot-sorting machines		- 47 258[a]		380 025		427 283	
Socio-environmental		**Annual socio-environmental cost**		**Annual socio-environmental benefit**		**Annual socio-environmental net benefit**	
Impact category	Metric unit	Quantity	Value (USD)	Quantity	Value (USD)	Quantity	Value (USD)
GHG	kg CO_2e	1 180	133	46 889	5 298	45 709	5 165
Water	m^3			3 947	562	3 947	562
Land use[x]	ha			10	-	10	-
Water pollution[c]	-			-	1 667	-	1 667
Soil erosion	t soil lost			9	193	9	193
Biodiversity	-			-	505	-	505
Health costs	-			-	5	-	5
Total socio-environmental costs:			133		8 230		8 097
Annual net economic and socio-environmental benefit of 2 carrot-sorting machines (USD):							
						435 380	

[a] Savings in labour costs are that high that they overcompensate initial investments into carrot-sorting machines, thus leading to profits (i.e. negative costs) from this measure, making it profitable from the beginning.

[b] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, but this does not play a role in Switzerland.

[c] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 903.

Potential of food wastage reduction measure

Opportunities: The carrot-sorting machine is economically and environmentally beneficial. If the environmental costs are considered, the relation between costs and benefits is even better as the savings in environmental costs from saving carrots are by far higher than the environmental costs for building and using a carrot-sorting machine.

Constraints: Farmers indicate the initial investment in the carrot-sorting machine is an obstacle to the wider dissemination of its use. Furthermore, replacing human labour with machines can lead to unemployment if there are not enough alternative jobs – which can lead to social problems.

Case Study 5:
Food banks: the German Tafel (Germany)

Commodity: Mixed food and drink
Stage of the value chain: Distribution
Amount of annual food waste (Germany): 10 970 000 tonnes/year for the total value chain; at the processing and distribution levels, it totals 2 400 000 tonnes/year (Kranert *et al.* 2012).

Wastage impact on natural resources and the economy

In Germany, about 22 percent of food and drink wastage (FDW) occurs at the processing and distribution levels, amounting to 2 400 000 tonnes per year (Kranert *et al.* 2012).

Table 12: Monetization of food and drink waste in Germany

Annual loss	Quantity	Metric unit	Value (USD)
ECONOMIC			
Food and drink waste	10 970 000	tonnes	6 606 032 379
Wasted subsidies (if applicable)			910 922 963
Total economic costs			7 516 955 342
SOCIO-ENVIRONMENTAL			
GHG emissions	13 043 743	t CO_2e	1 473 942 949
Water	141 370 352	m^3	15 568 441
Land[a]	Land occupation: 1 371 758	ha	
	Deforestation: 224		360 819
Water pollution[b]			73 788 250
Soil erosion	1 908 569	tonnes soil lost	33 384 954
Water scarcity			87 163 535
Biodiversity			42 613 768
Human health			294 320
Total socio-environmental costs			326 466
TOTAL VALUE OF LOSS			**19 425 927**

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, and the corresponding value is reported. Thereby, total economic values (TEV) for forests are used and values for cropland ecosystem services are not accounted for. Deforestation does not play a role in Germany and the values used are based on world average impacts on deforestation of the different crops and livestock activities. This results in a very gross proxy for this impact only, as there is no information on the share of imported goods and on their source countries available for the wastage quantities addressed here.

[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 29 336 984.

Full-cost of wastage reduction measure

Description: Food banks, such as those operated by the German NGO "Deutsche Tafel" (referred to hereafter as "German Tafel" or "GT") enable people in need to access surplus high-quality food at little or no cost. In addition, by participating in food banks, food processors and retailers can save money by reducing what they pay for waste disposal (FAGT 2014). GT established its first food bank in Berlin and, subseqently, initiated and runs food banks all over Germany.

Reference scenario: If the food bank were not active, the food it distributes would have been wasted, and the needy consumers who accessed that food would have had to buy it at regular supermarket prices.

Scope of the measure: The GT in Berlin distributes food for the symbolic price of Euro 1–2 per person. The food is collected by the GT in Berlin from 74 supermarkets, companies, hotels and bakeries, and redistributed at 45 distribution points to over 300 social institutions where about 125 000 persons benefit from it each month.

Life span: The GT in Berlin has worked continously since its founding in 1993.

System boundaries: Societal boundaries included all economic costs and benefits from the GT, including fixed and variable costs of the food bank, costs borne by supermarkets due to fewer sales, and the symbolic price that the customers of the food bank have to pay. Economic benefits considered consumer savings on cost of food, and company savings on cost of diposal. What was not considered was the value of volunteer workers, potential loss of jobs due to less production, sale and waste, and reduced packaging waste due to a reduction in sales. Indirect benefits not considered included decrease of poverty, because poor people have access to cheap food, and health benefits due to enhanced possibilities for a healthy diet for the customers of the GT. On the environmental cost side, water use, land use and biodiversity loss due to activities of the GT were not considered, as they were assumed to be negligible in comparison to the high ecological footprint of food and drink wastage.

Data sources: A survey of several German food banks was conducted, for which datasets from the GT in Berlin were the most complete. Data about food and drink redistribution were available for 2011 and 2013. Figures in the table above are the mean values of these years. Additional data was taken by Kranert *et al.* (2012). Environmental benefits due to saved food were calculated by modelling FAOSTAT data and Gustavsson *et al.* (2011).

Economic and environmental cost-benefit analysis of food waste reduction measure

Economic costs of the measure: The analysis included factors such as potential for reduced sales by supermarkets (main cost), personnel costs and rent for the GT building. Direct economic costs included fixed costs, such as costs for buildings, variable costs such as personnel and energy, and indirect economic costs, including the decrease in revenues for retailers and the symbolic price paid by beneficiaries to the GT.

Economic benefits of the measure: Economic benefits consisted of savings to companies due to fewer disposal costs, savings to beneficiaries, and the revenue from the symbolic payments consumers make when purchasing food from GT.

Socio-environmental costs of the measure: Transportation.

Socio-environmental benefits of the measure: 8 060 tonnes of food and drink saved from wastage annually (in primary product equivalents).

Investment burden: Most of the equipment and infrastructure was rented, meaning the initial private investment was small.

National investment requirements: It cost USD 381 to save 1 tonne of food and drink from wastage.

Break even point: N/A.

Table 13: Economic and socio-environmental benefit analysis of the German Tafel in Berlin

Economic		**Annual financial cost (USD)**		**Annual financial benefit (USD)**		**Annual financial net benefit (USD)**	
Mitigation measure: 1 food bank (Berlin)		23 318 661		23 875 334		556 673	
Socio-environmental		**Annual socio-environmental cost**		**Annual socio-environmental benefit**		**Annual socio-environmental net benefit**	
Impact category	Metric unit	Quantity	Value (USD)	Quantity	Value (USD)	Quantity	Value (USD)
GHG	t CO_2e	164.77	18 619	14 352	1 621 801	14 187	1 603 182
Water	m^3			718 394	79 113	718 394	79 113
Land use[a]	ha			1 652	-	1 652	-
Deforestation	ha			2.4	3 842	2.4	3 842
Water pollution[b]	-			-	72 118	-	72 118
Soil erosion	t soil lost			6 831	119 497	6 831	119 497
Water scarcity	-			-	442 934	-	442 934
Biodiversity	-			-	49 329	-	49 329
Health costs	-			-	215	-	215
Total socio-environmental costs:			18 619		2 388 849		2 370 230
Annual net economic and socio-environmental benefit of the German Tafel in Berlin (USD):							
						2 926 903	

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, and the corresponding value is reported. Thereby, total economic values (TEV) for forests are used and values for cropland ecosystem services are not accounted for. Deforestation does not play a role in Germany and the values used are based on world average impacts on deforestation of the different crops and livestock activities. This results in a very gross proxy for this impact only, as there is no information on the share of imported goods and on their source countries available for the wastage quantities addressed here.

[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 35 330.

Potential of food wastage reduction measure

Opportunities: The GT distributes food to poor people that would be wasted otherwise. Thus, less food has to be bought, and both environmental and social benefits are generated for society. The total benefits exceed the costs as shown above.
Constraints: The activities of the GT lead to reduced sales by supermarkets. The GT food distribution system does not make sense from a business perspective in the current economic framework. The GT is dependent on monetary donations and volunteer workers. In addition, about one-third of the fruits and vegetables donated by companies is still wasted due to low quality (estimation of the GT). Food and drink that pass the best-before date are not allowed to be redistributed and have to be discarded, even though they would have been edible.

Further methodological annotations

- The GT may impact the market prices of foodstuffs. These were not considered.
- Environmental costs of the GT were calculated back from fuel costs by taking USD 1.93 per litre diesel (ADAC 2014). The Berliner Tafel uses electricity from renewable sources, and thus CO_2e emissions were not part of the equation.
- The economic value of wasted food and drink was calculated on basis of data from Kranert *et al.* (2012).
- Saved disposal costs to companies donating food and drink were calculated by using the USD 163.39 per tonne gate-fee charges of landfills in Berlin (BSR 2013). Environmental impacts of the disposal of the food in the reference scenario were not considered.
- On the basis of the estimation of the GT in Berlin, it was assumed that one-third of vegetables and fruits donated to the Berliner Tafel could not be redistributed, due to poor quality.
- A small part of the redistributed food and drink might be wasted at household level, but this is not included in the calculations, as the GT has no influence on it.

Case Study 6:
Canteen surplus goes to food banks (Italy)

Commodity: Mixed food (no drinks)
Stage of the value chain: Consumption (food services)
Amount of annual food waste at consumption level (Italy):
9 300 000 tonnes.

Wastage impact on natural resources and the economy

In industrialized countries, food wastage happens mostly at the end of the value chain. Food services represent a particular food wastage hotspot due to the difficulty in adapting the food offer to a changing demand.

Table 14: Monetization of food wastage in Italy (consumption level only)

Annual loss	Quantity	Metric unit	Value (USD)
ECONOMIC			
Food waste	9 277 725	tonnes	9 183 709 229
Wasted subsidies (if applicable)			952 816 419
Total economic costs			**10 136 525 648**
SOCIO-ENVIRONMENTAL			
GHG	15 448 184	t CO_2e	1 745 644 820
Water[c]	63 070 510	m^3	2 783 638
Land[a]	1 474 032	ha	-
Water pollution[b]			213 267 773
Soil erosion[c]	1 752 515	tonnes soil lost	25 370 430
Water scarcity[c]	-		-
Biodiversity			40 918 966
Human health			453 491
Total socio-environmental costs			**2 028 439 118**
TOTAL VALUE OF LOSS			**12 164 964 766**

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, but this does not play a role in Italy.

[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 131 802 197.

[c] No data on water scarcity and water use data and costs are very low if compared to other countries (e.g. UK), and we judge them to be particularly uncertain.

Full-cost of wastage reduction measure

Description: In 2013, the Italian food company, Barilla, joined with Siticibo, a food redistribution project focusing on food from hotels, canteens, etc. promoted by the Italian food bank organization Banco Alimentare. With this partnership, Barilla committed to gather surplus food from the many canteens within its headquarters and main plants (located in Pedrignano), and then provide it to the Catholic charity, Caritas, for distribution to people in need.

An analysis of the food waste reduction – conducted monthly at headquarters and main plant canteens from January until December 2013 – included the number of meals recovered for the first courses (mainly pastas and soups) and main courses, and the average meals per day.

Reference scenario: All the food not eaten in the canteen is wasted.

Scope of the measure: 2 percent of all the meals served to employees can be redistributed through this initiative, equalling 1.5 tonnes of food per year.

Life span: N/A.

System boundaries: Evaluation included the impact of adding the Barilla canteen component to the Siticibo programme, not the entire system.

Data sources: The year 2013 was the reference year. Data were provided by Barilla. Calculations of the environmental impacts of the saved food used the Ecoinvent (0.000257 kg CO_2e/kg/km for transportation; 0.18 kg CO_2e/kg for refrigeration and reheating data.

Economic and environmental cost-benefit analysis of food waste reduction measure

Economic costs of the measure: The yearly wage costs necessary for the labour involved in this initiative are about Euro 2 500 (USD 3 460), which include 2 hours of work per day, 1 hour paid job/day, 1 hour volunteer work, 1 hour in Barilla canteen, and 1 hour Caritas driver's time (Salary Explorer 2014). The volunteers' time for distribution was not included. The reduced sales from the canteen (USD 1 000 per year) were not accounted for, as the food would have been wasted anyway in the reference scenario, nor was the possible loss in retail sales elsewhere, due to distribution of the saved food. The cost of the vehicle transporting the food was not considered, as it was part of Siticibo.

Economic benefits of the measure: For the beneficiaries to buy the food and prepare it themselves would have cost about Euro 5 000 (USD 6 920) per year. Loss in retail sales was not accounted for, nor were the negative effects in reduction in employment due to this, as lower sales likely result in lower labour demand.

Socio-environmental cost of the measure: Transportation cost amounted to 10 km/day in a refrigerated van, 6 hours of refrigeration between lunch and dinner, and reheating for dinner.

Socio-environmental benefits of the measure: Food saved from being wasted.

Investment burden: This measure added Barilla to the existing Siticibo system, so no particular investment was needed, as all the material was already available.

Investment breakeven point: N/A.

Table 15: Economic and socio-environmental benefit analysis of the Barilla food redistribution project in Italy

Economic		Annual financial cost (USD)		Annual financial benefit (USD)		Annual financial net benefit (USD)	
Mitigation measure: 1.5 t of food redistributed		3 460		6 920[a]		3 460	
Socio-environmental		**Annual socio-environmental cost**		**Annual socio-environmental benefit**		**Annual socio-environmental net benefit**	
Impact category	Metric unit	Quantity	Value (USD)	Quantity	Value (USD)	Quantity	Value (USD)
GHG	kg CO_2e	22 488	2 541	2 498	282	-19 990	-2259
Water	litre			10 197	0.5	10 197	0.5
Land use[b]	ha			0.24	-	0.24	-
Water pollution[c]	-			-	34.5	-	34.5
Soil erosion	t soil lost			0.28	4.1	0.28	4.1
Biodiversity	-			-	6.6	-	6.6
Health costs	-			-	0.1	-	0.1
Total socio-environmental costs:			2 541		328		-2 213
Annual net economic and socio-environmental benefit of 1.5 t of food redistribution (USD):							
						1 247	

[a] Benefits may even be higher, USD 6 920 are based on estimates of what the food would cost to individuals buying it themselves. Barilla itself judges them to be more than USD 10 000, based on the estimated costs of alternative meals provided by a canteen supplier.

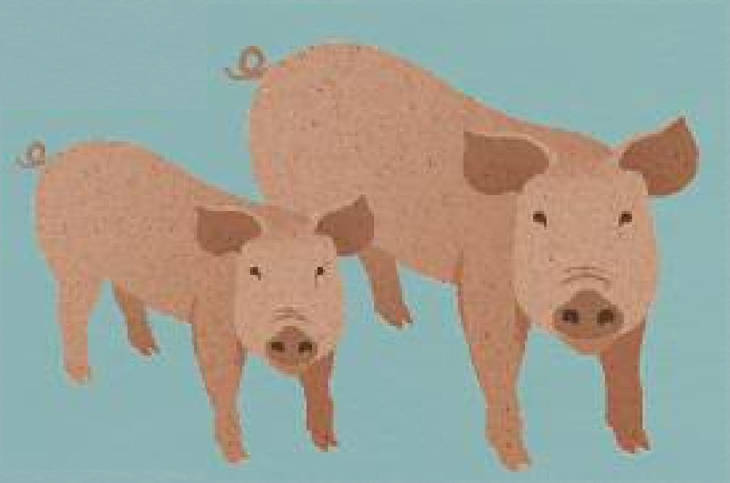
[b] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, but this does not play a role in Italy.

[c] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 21.3.

Potential of food wastage reduction measure

Opportunities: Barilla's participation in Siticibo makes sense socially and environmentally, as it feeds needy people, less food has to be produced to feed all parties in the system, and total benefits exceed the costs. However, environmentally, the measure does not make sense, as the measure itself is very GHG intensive for saving a small amount of food with correspondingly low total emissions.
Constraints: Employees need dedicated time to prepare the food donated and to manage the logistics. Some governments are now improving logistics to encourage food donations and go over these hurdles. Positive results depend on efforts of volunteer workers because, if it were necessary to pay two people, both the GHG balance and the economic balance would be negative.

Case Study 7:
Feeding food wastage to pigs vs anaerobic digestion (Australia)



Location: Australia
Commodity: Food and drinks
Stage of the value chain: Food waste from all supply chain stages
Amount of annual household food and drink waste in Australia: 3 176 046 tonnes.

Wastage impact on natural resources and the economy

In industrialized countries, food wastage happens mostly at the end of the value chain. In Australia, consumers waste about 3.2 million tonnes of food and drink each year.

Table 16: Monetization of household food and drink waste, Australia

Annual loss	Quantity	Metric unit	Value (USD)
ECONOMIC			
Food and drink waste	3 176 046	tonnes	2 271 253 113
Wasted subsidies (if applicable)			70 757 399
Total economic costs			2 342 010 512
SOCIO-ENVIRONMENTAL			
GHG emissions	26 545 745	t CO_2e	2 999 699 181
Water	200 391 771	m^3	16 887 875
Land[a]	Land occupation: 20 072 969 Related deforestation: 36 760	ha	Costs of deforestation: 68 153 216
Water pollution[b]			7 472 196 939
Soil erosion	15 393 144	tonnes soil lost	287 983 108
Water scarcity			9 578 726
Biodiversity			945 094 603
Human health			391 539
Total socio-environmental costs			11 799 985 187
TOTAL VALUE OF LOSS			**14 141 995 699**

[a] Land use is reported but it was not possible to identify a monetary value for this quantity; it could be linked to deforestation, and the corresponding value is reported. Thereby, total economic values (TEV) for forests are used and values for cropland ecosystem services are not accounted for; the Australian average is USD 1 854/ha.

[b] Water pollution is based on eutrophication from N/P runoff plus nitrate and pesticide pollution of drinking water; some double counting with soil erosion may arise due to N/P runoff, but there is no double counting with biodiversity. Most relevant in this number are the eutrophication costs of P runoff with USD 7 249 372 489.

Full-cost of wastage reduction measure

Description: Feeding food waste to pigs offers an alternative to using anaerobic digestion to process food waste. This means collecting food waste from households or from larger waste producers (food industry, farms, retailers) and bringing it to farmers, who feed it to their pigs, instead of using industrial pig feed that is produced from primary products. However, under current veterinary laws, no meat can be fed to pigs, which means measures are needed to ensure compliance. This study considered the average food waste amount produced by a household in Australia (182 kg per year) as a functional unit.

Reference scenario: If this measure is not implemented, food waste is collected and brought to an anaerobic digestion plant (life span about 12 years), which produces biogas from the food waste. This procedure is considered more environmentally friendly than centralized composting, incineration or landfilling. Only home composting performs better than anaerobic digestion, but home composting calls for the compost to be aerated regularly (Lundie and Peters 2005). Although rare, it still should be noted that, depending on the type of management chosen, compost has the potential to generate considerable methane and nitrous oxide emissions. As for their outputs, both compost and slurry from anaerobic digestion can be used to replace mineral fertilizers, although it is not clear what fares better. If the slurry were assumed to be dumped and compost were to be used to replace mineral fertilizers, then composting would definitely be more advantageous.

Scope: All household food waste of plant origin, including milk and eggs, but not meat, will be fed to pigs.

System boundaries: This study only considered the environmental impact of the two options. It did not consider transporting, as it was assumed to be similar in both options. Greenhouse gases and water use were considered in evaluating the environmental costs, and biodiversity impacts were considered for the option of growing feed. It was assumed that demand for pig meat does not change due to this food waste reuse measure and, therefore, other emissions from pigs (e.g. methane emissions from manure storage and application) were not taken into consideration.

Data sources: Data for the pig feeding measure (e.g. Australian food waste mix and substitution of concentrate feed) were calculated with the SOL-model. The case was based on an example of pig feeding use of wastage from UK, taken from (Stuart 2009). The reference scenario with anaerobic digestion was based on life-cycle calculations of anaerobic digestion and other wastage mitigation measures presented by Evangelisti *et al.* (2014), and Lundie and Peters (2005). Potential impacts from food waste sorting or heating were not considered.

Economic and socio-environmental cost-benefit analysis of food waste reduction measure

Economic cost of the measure: Not considered due to lack of data.

Economic benefits of the measure: Not considered due to lack of data.

Socio-environmental cost of the measure: There is no production of gas through anaerobic digestion as the wastage is fed to pigs.

Socio-environmental benefits of the measure: Emissions decrease due to reduced fodder requirements and due to use of anaerobic digestion. The study considered that 182 kg of wastage corresponded to the metabolisable energy content of 112 kg of concentrates in Australia, after subtracting the meat (which cannot be fed to pigs due to regulations) from the wastage quantities.

Investment burden: There is no substantial investment burden expected for this measure. On the contrary, investments would be higher for establishing an anaerobic digestion plant.

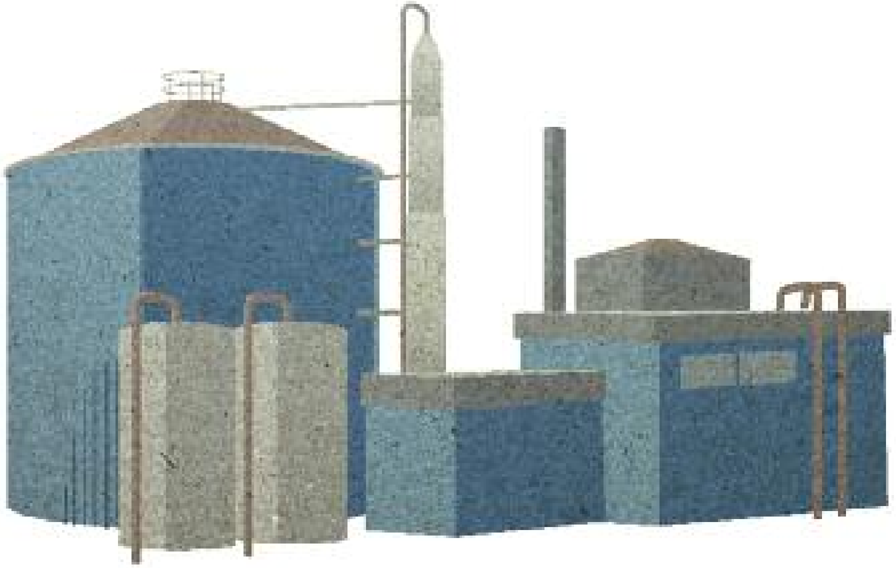
Table 17: Economic and socio-environmental benefit analysis of feeding food waste to pigs in Australia

Economic		**Annual financial cost (USD)**		**Annual financial benefit (USD)**		**Annual financial net benefit (USD)**	
Mitigation measure: feeding 182 kg food waste mix to pigs		Not determined		Not determined		Not determined	
Socio-environmental		**Annual socio-environmental cost**		**Annual socio-environmental benefit**		**Annual socio-environmental net benefit**	
Impact category	Metric unit	Quantity	Value (USD)	Quantity	Value (USD)	Quantity	Value (USD)
GHG	kg CO_2e	11.8	1.57	80.8	9.13	69	7.56
Water	litre			3 808	0.38	3 808	0.38
Land use[a]	ha			0.0351	-	0.0351	-
Deforestation	ha			0.00064	0.12	0.00064	0.12
Water scarcity	-			-	0.18	-	0.18
Total socio-environmental costs:			1.57		9.81		8.24
Annual net economic and socio-environmental benefit of feeding 182 kg food waste mix to pigs (USD):							
						8.24	

[a] Land use is reported but it was not possible to identify a monetary value for this quantity. It could be linked to deforestation, and the corresponding value is reported. Thereby, total economic values (TEVs) for forests are used and values for cropland ecosystem services are not accounted for; the Australian average for forest ecosystem services is USD 1854/ha.

Potential of food wastage reduction measure

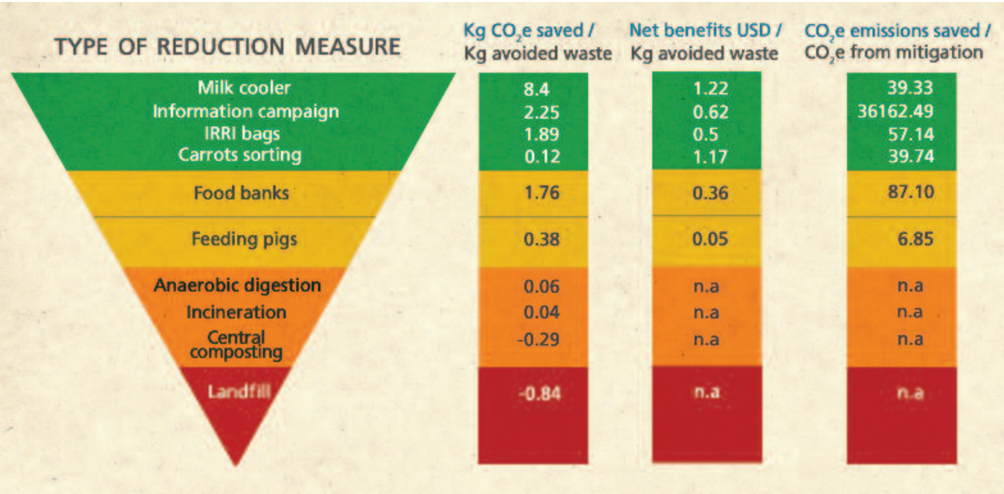
Opportunities: Feeding food waste to pigs instead of using it in biogas plants makes sense from an environmental standpoint. In terms of GHG emissions, water use and scarcity, and land occupation, this study determined that 380 g CO_2e, 21 litres of water and about 2 m^2 of arable land could be saved per kilogram of food waste fed to pigs (economic figures are lacking for this case study).
Constraints: Proper sorting of the food waste is needed to avoid contamination with animal pathogens and disease-causing agents. Technologies need to be developed in order to make this measure feasible.



2.2 Synthesis of case studies

In summarizing the case studies, it is important to note that climate change mitigation is also a key topic in the food wastage debate. Figure 2 illustrates the key indicator "kg CO_2e saved/kg avoided waste" in relation to the different mitigation measures presented in this report. However, the case studies and the comparison of the respective indicators (e.g. CO_2e reductions per kilogram wastage saved) have purely illustrative character only. The environmental impact of wastage depends on its type – there are enormous differences for some indicators, such as between carrots and milk, or for different compositions of aggregate food waste at retail level in different nations. Those differences have to be considered when discussing the results. Therefore, it is important to analyse the effects of food wastage mitigation measures with other criteria as well (as displayed in the third and fourth columns of Figure 2). For example, in terms of net benefits per kilogram of waste reduced and emissions reduced per emissions from the mitigation measure, carrots and milk fare similarly regarding the CO_2e emissions saved per CO_2e needed for the mitigation, while in emissions per kilogram wastage saved, the difference is huge. Determining the overall effect, however, calls for analyzing how the size and efficiency of the measure combine. Measures that avoid a large amount of food wastage with relatively low CO_2e emissions per tonne wastage can save as much as measures that avoid a smaller amount of wastage with high CO_2e emissions per tonne wastage. These and other key indicators for the different case studies are collected in the Annex.

Figure 2. Key indicators of food wastage measures along the food wastage pyramid



TYPE OF REDUCTION MEASURE	Kg CO_2e saved / Kg avoided waste	Net benefits USD / Kg avoided waste	CO_2e emissions saved / CO_2e from mitigation
Milk cooler	8.4	1.22	39.33
Information campaign	2.25	0.62	36162.49
IRRI bags	1.89	0.5	57.14
Carrots sorting	0.12	1.17	39.74
Food banks	1.76	0.36	87.10
Feeding pigs	0.38	0.05	6.85
Anaerobic digestion	0.06	n.a	n.a
Incineration	0.04	n.a	n.a
Central composting	-0.29	n.a	n.a
Landfill	-0.84	n.a	n.a

For example, the indicator "kg CO_2e saved per kg food waste" indicates that anaerobic digestion is 15 times a better mitigation option than landfilling; however avoiding food wastage is 140 times better than anaerobic digestion from a GHG emission perspective. The carrot-sorting mitigation measure performs poorly according to this indicator, as carrot production has a low emission potential per kilogram. However, if the indicators "net benefits per kg food wastage avoided" or "ratio of emissions reduced per unit emission from the wastage measure" are considered, the carrot-sorting mitigation measure appears as performing as the milk cooler mitigation measure. This is due to the fact that carrot-sorting results in high savings on production value and labor, while being a low emission mitigation measure. Incineration and centralized composting are added in the pyramid for illustration purposes only (Lundie and Peters 2005), as there are no detailed calculations provided for those.

3. Lessons learned from the case studies

The following identifies lessons drawn from the case studies on the full cost of food wastage and their respective mitigation measures.

Avoidance of food wastage is the primary goal

Preventing food wastage in the first place is much more beneficial than food wastage management. For example, reusing food wastage as pig feed fares quite well and also cuts back on industrial production, namely of feed. However, it still is more beneficial to avoid food wastage, even if it means having to produce the feed.

Focus should be on high impact wastage or hotspots

Given limited resources, there is need to address those supply chains and mitigation measures that offer the highest net benefits. This calls for informing decision-makers on how to measure benefits. For example, results will differ on whether measurements refer to total GHG emissions saved, GHG saved per GHG emitted for mitigation, or GHG saved per dollar invested. For instance, as shown in Case Study 4, which looked at carrot production in Switzerland, wastage in carrots can be avoided at little cost but the effort will only result in relatively low environmental improvements because carrot production has low environmental impact. On the other hand, Case Study 1, which looked at milk cooling machines for Kenyan farmers, found mitigation costs high but the environmental benefits high as well. A situation that has both high total reduction of impacts and high reductions in impact per dollar invested clearly has the best potential, while a situation that avoids low impact wastage with high impact measures should be seen critically (e.g. cold storage of fruits produces much lower GHG emissions per tonne than milk).

Obstacles to food wastage mitigation need to be better understood

Although the case studies showed that some wastage mitigation measures provide financial benefits for some operators – carrot sorting, bags for rice storage or avoided household food waste in general

– their implementation has not been widespread. This indicates there must be non-economic reasons when operators do not implement the measures, such as lack of knowledge about causes for wastage or about mitigation options. It becomes crucial for regulators, governmental agencies, policy-makers and also NGOs to design and suggest optimal food wastage mitigation policies and activities that set incentives for effective reductions.

Harvesting the potential of certain mitigation measures requires technical and social innovations, as well as changes in policies and regulations

Existing regulations and lack of technologies or wastage management options can hinder implementation of mitigation measures. Case Study 7, looking at feeding food wastage to pigs, showed the enormous environmental benefits of this, but current legal conditions and household waste collection practices do not allow the widespread reuse of large amounts of food wastage in this way because meat needs to be separated from food wastage. This can increase reuse costs considerably, but the measure can be highly beneficial if the basic food wastage does not contain any meat from the beginning. Technical innovations and changes in the legal framework are thus necessary to make the feed reuse measure feasible and effective at large scale. Similarly, Case Study 5, which looked at the example of food banks in Germany, illustrated that restrictive regulations on best-before dates in combination with bans to reuse food that has exceeded these dates reduce the potential of such measures.

Good socio-environmental choices do not necessarily require sacrificing economic benefits

As most case studies show, net economic benefits parallel net environmental benefits. However, not all economically viable measures make sense according to all environmental indicators. Case Study 6, which looked at an Italian food manufacturer establishing a system for donating food from its headquarters and factory employee canteens to charity, had high GHG emissions compared with emissions saved. Furthermore, the presence of volunteer work can be decisive for the economic performance and needs to be taken into account when comparing measures.

Labour costs can be a decisive aspect of the profitability of food wastage measures

In high-income countries, reducing labour costs is important as shown in Case Study 4, which looked at carrot sorting options in Switzerland. Also, in Case Study 5, which looked at German food bank associations, the absence of labour costs due to charity work was a major determinant of its success. More generally, a simplified assessment may be achieved by focusing on key inputs and any corresponding key impact reductions. For example, if large fossil energy use is involved in the mitigation measure, as for cooling within a coal-based electric system, the GHG emission balance will play a key role. If labour costs are high, measures with low labour input or those that reduce high labour inputs (e.g. carrot sorting) have a big advantage in relation to labour-intensive measures that cannot build on voluntary work.

The lower the product prices, the less profitable the food waste mitigation

Along the supply chain, operators have stronger incentives for reducing the waste of high-priced foodstuffs such as milk and meat, as compared with lower priced products. Mitigation measures become economically feasible sooner for those products. Such higher value commodities also show some correlation with higher environmental footprints, if the value added derives from higher input use, as with animal products. This is not (or much less) the case if the higher value derives from high labour inputs in contexts with high wages, or if it derives from situations of demand surpassing supply, thus resulting in higher prices. Clearly, for commodities with fluctuating prices, the economic feasibility of mitigation measures is subject to corresponding changes. In such cases, a longer-term view is needed for an economic assessment, which can identify benefits in relation to some longer-term average price development.

Some reduction options can be less environmentally friendly than some re-use options

The inverted food wastage pyramid indicates the general order of decreasing environmental benefits from food wastage measures as a gradient of reduce-reuse-recycle-landfill. However, in some cases, the order may be different. In particular, this can arise when different types of food wastage or resources are involved. For example, reusing food wastage as pig feed in Australia as described in Case Study 7, saves more CO_2e per tonne of wastage than reducing carrot waste in Switzerland, as described in Case Study 4. The benefits from the pig feeding case arise due to the avoidance of producing pig feed which has a higher environmental footprint than carrots. The footprint of the Australian food wastage itself does not enter the comparison here, as the food is still wasted but it is used as feed instead of dumped. However, reducing the food wastage in the first place and giving the pigs actual pig feed would still be better, as the environmental footprint of the food wastage is higher than the footprint of the pig feed.

The relative performance of mitigation measures can change with different types of food wastage

Although similar to Lesson 8, this lesson is a more general formulation based on the relative performance of the mitigation measures, as driven by the different food wastage types they apply to. Country-specific contexts and regional differences can also drive differences in the relative performance of mitigation measures. With one single type of wastage in a specific geographic context, the order of the pyramid is kept – reducing food wastage by avoiding its production is always better than reusing it. This is also the case if reusing leads to replacing other inputs that can then be saved. In such situations, it is usually more beneficial and efficient to replace those inputs with a specifically targeted replacement, rather than with food wastage. For example, producing food wastage and then recycling it in an anaerobic biogas digester to produce natural gas usually is less efficient than producing specific substrates to load the digester.

Reducing food wastage can have negative effects which needs to be recognized

Case Study 5, which looked at German food banks, showed that they provided food to the needy but also led to reduced retail food sales, with corresponding negative effects on retailers' revenues and, potentially, on related jobs. This may only have a small effect within a local economy, but there can be hot-spot situations, where these effects have a broader impact. For example, chicken meat consumed in Europe is mainly from breasts, while the rest of the meat (legs, wings, necks and feet) is exported on a large scale to western Africa. This undermines local production and has detrimental impacts on the local economies in the target countries (ACDIC *et al.* 2007, APRODEV *et al.* 2006). Albeit a food wastage reduction measure, expectedly with environmental benefits, it may be judged negatively due to these side-effects indicating that promoting consumption of all parts of the chicken in Europe would be a better approach.

Ultimately, effective mitigation of food wastage depends not only on effective single measures but fundamental changes in the food system and culinary habits

Food wastage, particularly at retail and consumer levels, is often due to consumer expectations for immediate and uninterrupted availability, and to supporting regulations that control freshness and appearance of the products. Furthermore, consumers in developed countries have become increasingly selective, consuming only certain parts of animals (e.g. chicken breasts) or crops (e.g. white flour) and leaving the rest (e.g. offals) to be dumped or sold elsewhere. Raising awareness of these issues with consumers and policy-makers and promoting more "sufficient" lifestyles with more moderate expectations and consumption patterns regarding those aspects would help reduce this waste.

4. Conclusions and recommendations

With globalization and modernization of the food sector, families are now much less likely to stock their own fresh and preserved foods within their households. As a result, they have lost their understanding of the source and value of food and have become "consumers" at the end of the ever-lengthening food supply chain. Food is not a "commodity" but an offering from Earth, human labour and (as reflected in many sacred texts since ancient times) the divine. Above all, mitigating food wastage is a moral imperative for all.

While there is a global consensus that mitigating food wastage is imperative, it remains important to raise awareness of the situation and how individuals and the industry can participate in mitigation measures. The "zero loss or waste of food" element of the Zero Hunger Challenge put forward by the UN Secretary General, and various studies and policy targets (e.g. EU 2025) suggest that approximately half of food wastage could actually be prevented. More specifically, global agricultural losses could be reduced by 47 percent and global consumption waste by 86 percent (Kummu *et al.* 2012). Yet, despite on-going efforts, investments remain insufficient to create the necessary conditions or change behaviour towards this end. Furthermore, global population dynamics and changing lifestyles and consumption patterns are expected to exacerbate food wastage, especially in developing countries that do not have the necessary infrastructure (e.g. conservation equipment). Economic growth has come with increasing waste that is expected to increase further in coming decades. However, this increase in waste will be accompanied by expansion of energy recovery, central composting and recycling. It is interesting to note that UNEP (2011) estimated that sorting and processing recyclables can sustain ten times more jobs than landfilling or incineration on a per tonne basis and, at the same time, reduce financial pressure on governments.

This document has assessed, to the extent possible, the cost-benefit potential of different mitigation options by monetizing indirect social and environmental costs. The inefficient use of environmental resources, coupled with the wasted use of human resources undermines the basis for food security and wellbeing. It has been shown that societal externalities can change the ratio of food loss and waste if operators and private actors reassess their processes that generate wastage, and recognize that they need to take steps to curb the wastage both for their own benefit and for society's, and to invest in mitigation measures. Return on investments become more acceptable to public or private actors when societal benefits are understood, unveiling the huge costs of inaction.

It is important to acknowledge that pursuing the absolute goal of zero food wastage is unrealistic and economically inefficient, due to high marginal costs. However, much could be achieved by public policies to correct market failures that cause food wastage (e.g. matching production and consumption demand or setting up "pay-as-you-throw" systems) or by creating a sustainable consumption culture. Food waste at retail and consumer level can often be traced to demand for choice, which

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[4] European Parliament, 2012.
[5] Less than 5 percent of funding to agricultural research is allocated to post-harvest systems.

includes food aesthetics and overstocking of household pantries. Whatever mitigation measure is taken will have economic costs but, in turn, will also offer more global efficiency and equity.

Reducing the level of food wastage is often beyond the capability of individual farmers, distributors or consumers. Providing food supply is more than meeting cultural or traditional demand. It depends on systems outside the food and agriculture sector, including markets, trade, energy security and transportation, in addition to cultural and culinary food choices.

As shown in this report, public bodies, private enterprises and civil society institutions that have the authority to make or influence policy decisions need to develop actions. For example, policy instruments such as subsidies on harvested areas rather than planted areas, taxing waste according to its cost to society, or collaborative action should be applied in order to reduce, prevent and manage food wastage throughout all steps of the food supply chain.

Therefore, there is need for a holistic approach to food wastage mitigation:

Multi-stakeholders linkages

This calls for improving dialogue and cooperation of different authorities, including various ministries, such as health, rural development, environment, bioenergy and agriculture and municipalities, as well as food supply chain actors, from producers to consumers. Improving communication can resolve discrepancies between demand and supply, such as what happens when farmers do not find a market for their production and leave crops to rot in the field, when a parent cooks dinner for five but only three family members actually make it to the table, when supermarkets downsize product orders at the last minute, leaving producers with unsellable products, or when restaurants overestimate demand and overstock food supplies which then are wasted. Establishing coordinated joint action by building relationships along the supply chain is crucial, as it allows for sharing the burden of risk (e.g. overplanting due to contracts calling for specific quantity and shape of products). Innovative deal structures hold promise for reducing food wastage, while strengthening the sense of community.

Multi-disciplinary food web linkages

Addressing food web linkages – from agro-ecosystem health to food quality and safety to consumer preferences and nutrition – is a starting point for establishing food wastage mitigation measures that address negative externalities (e.g. GHG emissions) across the food system. In particular, public good investments and policies seeking to reduce food wastage involve improving farm productivity, supporting research, avoiding price volatility and promoting sustainable consumption.

Food wastage impact assessment

Applying some type of food wastage impact assessments is needed when introducing instruments in other areas that may indirectly increase food waste. Integrating food wastage impact assessment into standard practices will pave the way for effective operations.

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ANNEX

DIFFERENT INDICATORS OF THE ENVIRONMENTAL AND FINANCIAL PERFORMANCE OF FOOD WASTAGE MITIGATION MEASURES

**Food and Agriculture Organization
of the United Nations**

Mitigation Measure	Wastage avoided	Total benefits	Net benefits	Total economic costs of measure	Emissions of the mitigation measure	Total emission reductions	Net emission savings	Net benefits per kg wastage avoided	Net emissions saved per kg wastage avoided	Total emissions of mitigation measure per kg waste saved	Total emissions reduced per emission from the measure	Net emissions saved per emission from the measure	Net emissions saved per economic costs	Rate of return: total benefits per economic costs
	kg wastage	USD	USD	USD	kg CO_2e	kg CO_2e	kg CO_2e	USD/kg	kg CO_2e/ kg wastage	kg CO_2e/ kg wastage	kg CO_2e/ kg CO_2e/	kg CO_2e/ kg CO_2e/	kg CO_2e/USS	%
Milk cooler	54 750	72 555	66 581	4 708	12 000	472 000	460 000	1.22	8.40	0.219178	39.33	38.33	97.71	1 543
Information campaign WRAP	272 665 000	1 024 097 370	169 144 898	854 950 576	17 000	614 770 000	614 753 000	0.62	2.25	0.000062[a]	36162.94[a]	36161.94[a]	0.72	120
IRRI super bag season	5	2.836	2.3	0.5	0.168	9.6	9.432	0.46	1.89	0.033600	57.14	56.14	18.86	567
IRRI super bag off season	5	3.2	2.7	0.5	0.168	9.6	9.432	0.54	1.89	0.033600	57.14	56.14	18.86	640
Carrot sorting	375 000	388 255	435 380	-47 258[b]	1 180	46 889	45 709	1.16	0.12	0.003147	39.74	38.74	-0.97[b]	-821[b]
Food bank, Tafel Germany	8 060 000	26 264 183	2 926 903	23 318 661	164 770	14 352 000	14 187 230	0.36	1.76	0.020443	87.10	86.10	0.61	113
Food bank, Barilla Italy	1 500	7 248	1 247	3 460	22 488	2 498	-19 990[c]	0.83	-13.33[c]	14.992000	0.11	-0.89	-5.78[c]	209
Pig feeding	182	9.81	8.24	n.a.	11.8	80.8	69	0.05	0.38	0.064835	6.85	5.85	n.a.	n.a.

Notes:

a The WRAP programme is highly emissions efficient.

b The carrot sorting machine has negative economic costs, this has to be taken into account when interpreting these numbers.

c The Barilla food bank is very GHG intensive, therefore it performs bad regarding criteria related to GHG emission reductions.

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