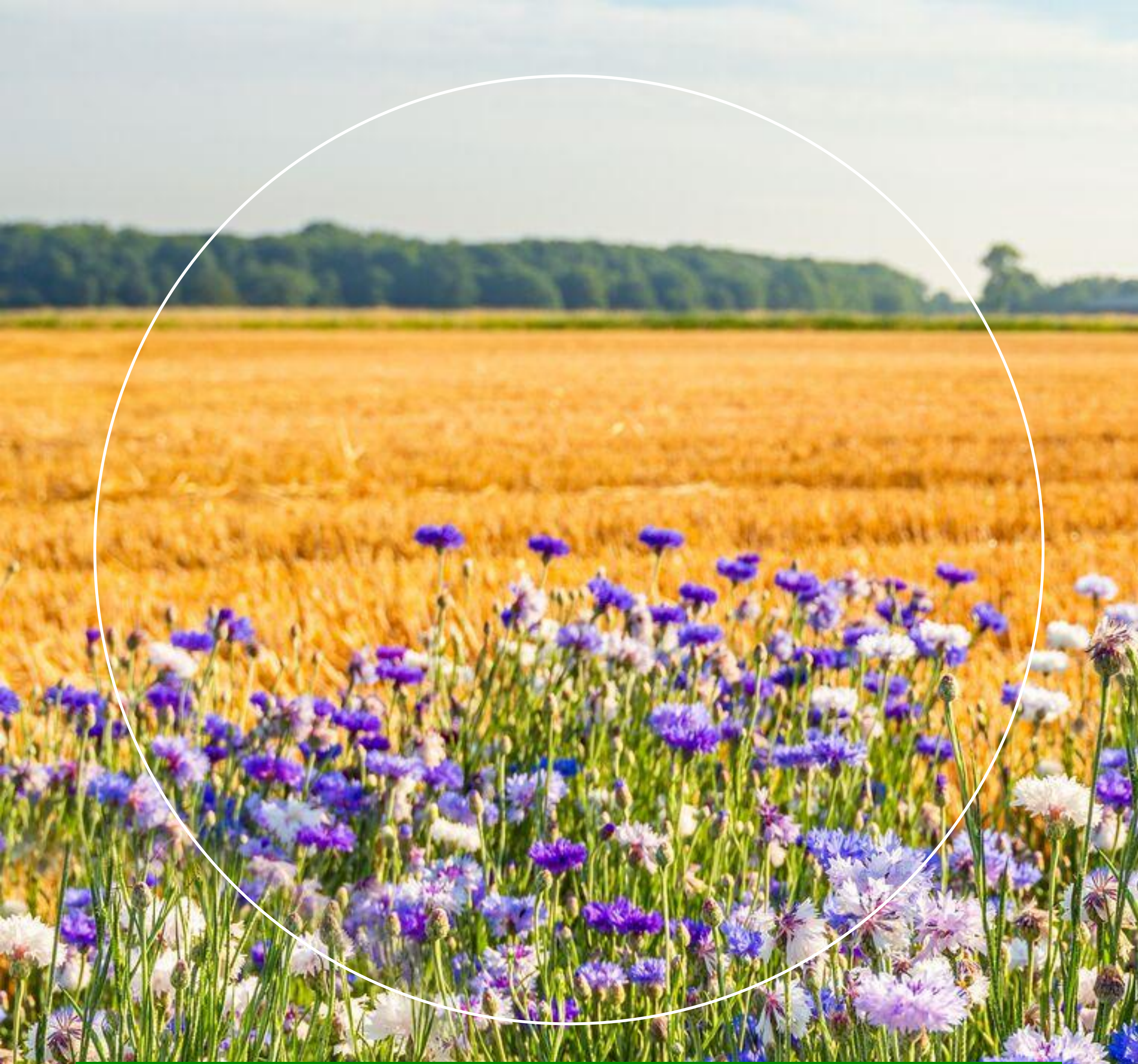


Climate footprint of food waste in the Netherlands

Dr H.E.J. (Hilke) Bos-Brouwers, M.G. (Melanie) Kok MSc, Dr A.M. (Marcela) Viquez-Zamora

PUBLIC

WAGENINGEN
UNIVERSITY & RESEARCH

Climate footprint of food waste in the Netherlands

Authors: Dr H.E.J. (Hilke) Bos-Brouwers, M.G. (Melanie) Kok MSc, Dr A.M. (Marcela) Viquez-Zamora

Institute: Wageningen Food & Biobased Research

This study was carried out by Wageningen Food & Biobased Research, subsidised, funded and commissioned by Ministry of Agriculture, Nature and Food Quality.

Wageningen Food & Biobased Research
Wageningen, May 2024

Public

Report 2571
DOI: 10.18174/661971

WFBR Project number: 6234240700
BAPS number: BO-43-110-025
Version: Final
Reviewer: ir. H.M. (Martijntje) Vollebregt
Approved by: dr.ir. H. (Henk) Wensink
Carried out by: Wageningen Food & Biobased Research
Subsidised, funded and commissioned by: Ministry of Agriculture, Nature and Food Quality
This report is: Public

PO box 17, 6700 AA Wageningen, The Netherlands, T + 31 (0)317 48 00 84, E info.wfbr@wur.nl, www.wur.eu/wfbr.

Contents

Quantitative overview of the climate impact of food waste in the Netherlands

Overview of total, food system, and food waste related Greenhouse Gas (GHG) emissions in the Netherlands[1]

- For the Netherlands the contribution of food waste to GHG emissions is estimated at 9 megaton CO_2-eq/year (based on RIVM, 2019), which is around 5% (based on RIVM, 2019) to 9% (based on Crippa et al., 2023) of the total GHG emissions in the Netherlands

System level	GHG emissions data
Total GHG emissions in the Netherlands *(reference year = 2022)*	**168 Mton CO_2-eq/year** → 100% of total GHG emissions → 9.5 ton/capita.yr
Food system induced GHG emissions *(reference year = 2018)*	**52 Mton CO_2-eq/year** → 31% of total GHG emissions → 3.0 ton/capita.yr
Food waste induced GHG emissions *(reference year = 2019)*	**8.8 Mton CO_2-eq/year** → 5% of total GHG emissions → 0.5 ton/capita.yr

Overview of the climate impact of food waste in the Netherlands across food supply chain segments and relevant climate change indicators

Impact indicators	Food Waste	GHG emissions	Blue water use	Land use	Eutrophication (N_2O emissions)
	Kton/year	Kton CO_2-eq/year	Billion litre/year	Thousand hectares /year	Ton N/year
Total	2,587	8,807	570	693	15,000
Primary production	315	(676)	(49)	(45)	(1,000)
Processing and manufacturing	1,131	(3,723)	(294)	(345)	(7,000)
Retail and distribution of food*	210	753	34	50	1,000
Restaurants and food services	83	335	19	24	1,000
Households	848	3,321	174	229	5,000

** including return of unsold bread to animal feed*

Data presented in brackets is due to lack of sufficient data quality in estimating indicators.

Climate impact and food waste hotspots across three food supply chain segments

- The food waste from the 'Fresh meat and fish' product category attributes to the highest amount of associated GHG emissions at the retail and distribution supply chain stage.
- In the restaurant and food services and household supply chain stages, the food waste from the product group 'Other fresh products and non-perishable products' contributes most towards associated GHG emissions. Products with a high GHG emissions contribution within this product group include e.g., vegetable oils, sandwich fillings and processed meats.

[1] Please note that no data sources or references are mentioned in this part of the publication. They are included in the main body of the report, and more specifically in Chapters 2 and 3.

Retail & distribution of food		
Product groups	Food waste (kton)	Associated GHG emissions (kton CO2-eq)
Fresh meat & fish	15	205
Bread & bakery	74	176
Dairy, eggs, ready-to-eat, refrigerated products	25	126
Other fresh products and non-perishable products	29	125
Potatoes, vegetables and fruit	67	121

Restaurants & food services		
Product groups	Food waste (kton)	Associated GHG emissions (kton CO2-eq)
Other fresh products and non-perishable products	33	145
Fresh meat & fish	6	79
Potatoes, vegetables and fruit	23	42
Dairy, eggs, ready-to-eat, refrigerated products	7	37
Bread & bakery	13	32

Households		
Product groups	Food waste (kton)	Associated GHG emissions (kton CO2-eq)
Other fresh products and non-perishable products	246	1076
Fresh meat & fish	68	920
Potatoes, vegetables and fruit	288	520
Dairy, eggs, ready-to-eat, refrigerated products	85	421
Bread & bakery	161	384

Note: colours rank from the lowest (dark green) to the highest (red) amounts per chain segment.

Climate impact of food waste per ton of product in the Netherlands and worldwide

- It can be estimated that for every ton of food waste reduced in the Netherlands, 3.4 ton CO_2 emissions, 220 m^3 blue water, 0.27 hectares cropland and 5.8 kg nitrogen can be saved.

Indicator	Level	Impact amounts / ton product
GHG emissions	Global	2.86 ton CO_2-eq
	Netherlands	3.40 ton CO_2-eq
Blue water use	Global	192 m^3
	Netherlands	220 m^3
Cropland use	Global	0.56 hectare
	Netherlands	0.27 hectare
Eutrophication (N_2O emissions)	Global	No data available
	Netherlands	5.8 kg N
Biodiversity loss	Global	No data available
	Netherlands	No data available

Contribution of the food system and food waste on total GHG emissions, per capita, for the Netherlands and worldwide

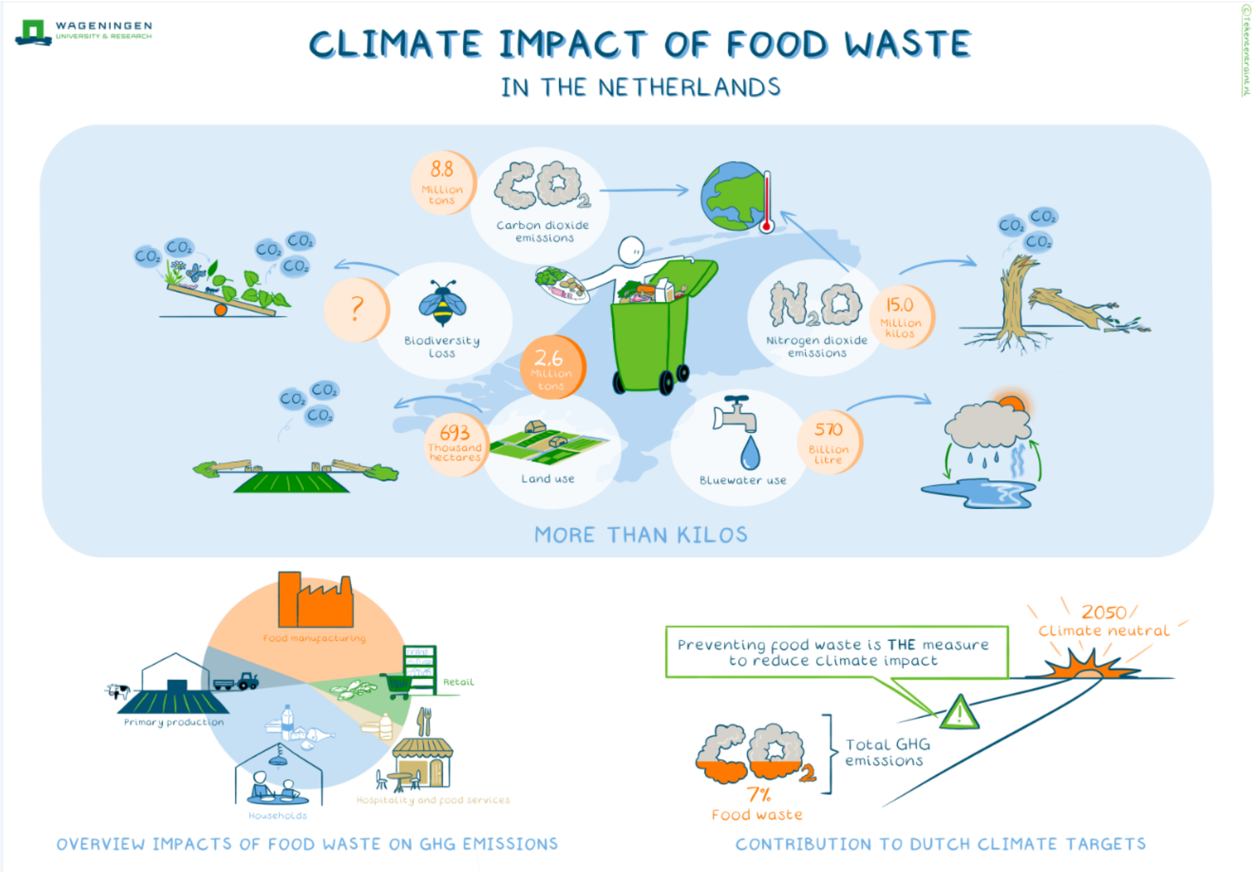
- Overall, the <u>total</u> GHG emissions in the Netherlands are higher per capita per year compared to the average worldwide, including the food system induced GHG emissions.
- However, the per capita <u>food waste and associated GHG emissions</u> in the Netherlands are lower than the global average.

System level	Level	Amounts per capita.yr	Source
Total food waste volume	Global	**316 kg/capita.yr** *Based on 2.5 Gton/year (data from 2021)*	WWF-UK, 2021
	Netherlands	**149 kg/capita*.yr** *Based on 2.6 Mton/year (data from 2021)*	EUROSTAT, 2023
Total GHG emissions	Global	**6.7 ton CO_2-eq/capita.yr** *Based on 53.8 Gton (data from 2022)*	Crippa et al., 2023
	Netherlands	**9.5 ton CO_2-eq/capita.yr** *Based on 168 Mton (data from 2022)*	Crippa et al., 2023
Food system induced GHG emissions	Global	**2.2 ton CO_2-eq/capita.yr** *Based on 17 Gton CO_2-eq/year (data from 2018)*	EDGAR-FOOD, 2021, method applied from Crippa et al., 2021; 2023; IPCC 2019
	Netherlands	**3.0 ton CO_2-eq/capita.yr** *Based on 52 Mton CO_2-eq/year (data from 2018)*	EDGAR-FOOD, 2021, method applied from Crippa et al., 2021
Food waste induced GHG emissions	Global	**0.6 ton CO_2-eq/capita.yr** *Based on 4.4 Gton CO_2-eq/year (data from 2011)*	FAO, 2013b; IPCC, 2019
	Netherlands	**0.5 ton CO_2-eq/capita.yr** *Based on 9 Mton CO_2-eq/year (data from 2019)*	Derived from RIVM, 2019; Crippa et al., 2023

Population sizes in the reference years

	Netherlands	*Global*
2011	*16.7 million*	*7.1 billion*
2018	*17.2 million*	*7.7 billion*
2019	*17.3 million*	*7.8 billion*
2021	*17.5 million*	*7.9 billion*
2022	*17.6 million*	*8.0 billion*

Infographic of the climate impact of food waste in the Netherlands



Note: Data presented here are based on best available estimations from reference years 2019-2022

1 Introduction: the climate impact of food waste

Approximately one-third of the food produced globally never reaches consumers; instead, it is being lost or wasted at various stages of production, distribution, and consumption (FAO, 2011; FAO, 2019). This issue is not just about lost nutrients or food discarded in trash; it represents significant economic, environmental, and social costs. Food waste translates to wasted resources (including money, time, water, energy, land use) and lowered food security throughout the entire food supply chain, from farming and processing to transportation, retail and consumption. These inefficiencies not only squander resources but also contribute to climate change, as illustrated in Figure 1. Moreover, the visible impacts of climate change serve as clear reminders that our planet's capacity is finite. Urgent action is needed to reduce the strain on our environment and create a more sustainable food system.

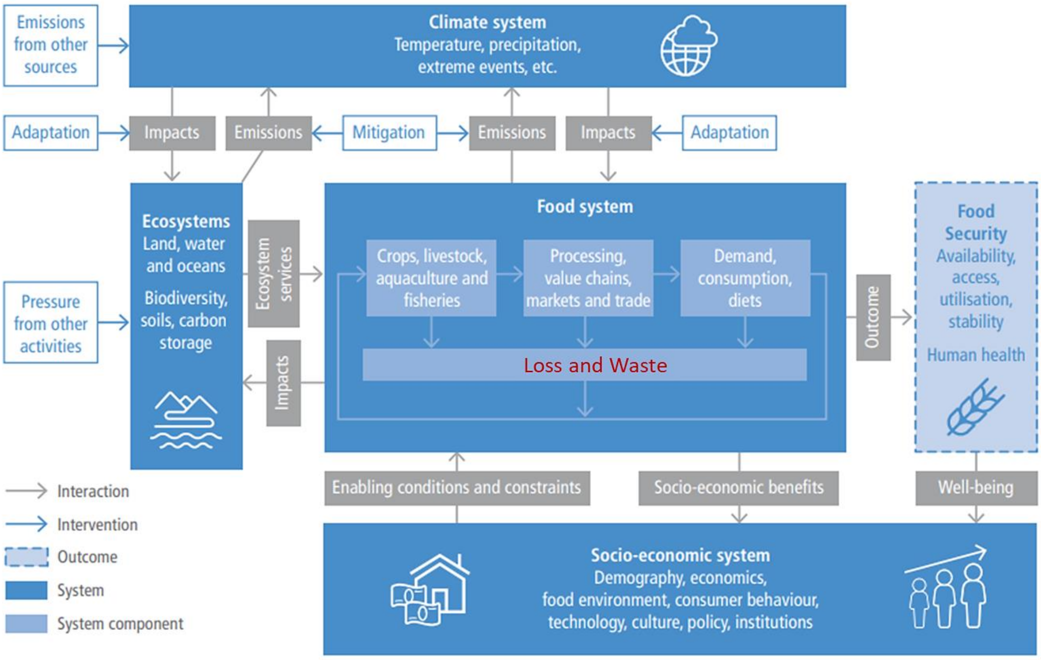


Figure 1 Interlinkages between the climate system, food system, ecosystems (land, water and oceans) and socio-economic system.

Source: IPCC, 2019.

Food waste serves as a symptom of unsustainable food systems. By targeting food loss and waste (FLW), we can address inefficiencies within agricultural food systems and work toward reducing the substantial greenhouse gas (GHG) emissions generated throughout food supply chains. Additionally, improving resource efficiency not only lessens the strain on essential resources like water, energy, and land (Springmann *et al.*, 2018), but also aligns with broader sustainability objectives, as outlined in Dutch commitments to diminish environmental impacts. Therefore, efforts to reduce food waste not only combat inefficiencies but also contribute to achieving overarching sustainability goals, including zero waste, food security and mitigating climate change.

The Dutch Ministry of Agriculture, Nature and Food Quality is seeking to gather information and insights regarding the "climate footprint" of food waste within the Netherlands. The results of this research will assist in developing a comprehensive understanding of policy options and requirements for incorporating food waste into climate change agendas and programs within the country. Climate change extends beyond carbon dioxide emissions, encompassing effects such as biodiversity loss, land use changes, water consumption, eutrophication, and global temperature rise and sea level increase. This research aims to address the multifaceted impacts of climate change by considering the role of food waste in the broader context of environmental sustainability.

This document explores the climate footprint of food loss and waste, offering both qualitative and quantitative insights relevant to policy making. It establishes a connection between food waste and climate change impact by utilizing various indicators, with greenhouse gas (GHG) emissions measured in CO_2 equivalents being the most widely recognized. Additionally, it discusses other indicators commonly cited in the literature to evaluate the food system's contribution to climate change, such as land-use changes, loss of biodiversity, depletion of freshwater resources, and pollution of aquatic and terrestrial ecosystems due to nitrogen runoff from fertilizer and manure application. (RIVM 2019; Springmann et al. 2018; Bajželj et al. 2014). While the direct link of these indicators to climate change may be less known, they are not less relevant for climate change. Through a comprehensive analysis of these indicators, this document aims to provide policymakers with valuable information for addressing the environmental consequences of food waste and advancing sustainable food system policies.

Overview of indicators used in the research:

- **Greenhouse gas (GHG) emissions**, typically measured in CO_2-equivalents, refer to gases in the Earth's atmosphere that can trap heat. These gases absorb heat from the sun, retaining it in the atmosphere and hindering its escape into space. This process, known as the greenhouse effect, contributes to maintaining the Earth's temperature at a level higher than it would naturally be.
- **Land-use change** refers to altering forested or unfarmed areas, which are effective at capturing CO_2, into farmland, which is less efficient at CO_2 absorption.
- **Biodiversity loss** disrupts the balance within ecosystems, reducing their ability to effectively capture CO_2.
- **Eutrophication**, primarily driven by nitrogen runoff from agricultural activities and urbanization, exacerbates climate change by releasing nitrous oxide, a potent greenhouse gas. Nitrous oxide has a much greater warming potential than carbon dioxide, contributing significantly to the greenhouse effect and accelerating global warming.
- **Bluewater use,** depletion of freshwater resources disrupts rainfall patterns, altering weather conditions and exacerbating climate variability. Furthermore, water extraction disrupts natural hydrological cycles, degrading ecosystems and reducing their capacity for carbon sequestration. Additionally, freshwater use involves energy-intensive processes such as pumping, treating, and distributing water, often relying on fossil fuels, further contributing to climate change.

The EU definition of **food waste** as stated in the Waste Framework Directive (EC) No. 851/2018, is formulated as follows: “all **food** as defined in Article 2 of the general Food Law -Regulation (EC) No 178/2002 (European Parliament and Council, 2002) - that has become waste”. **Waste** is further defined in the same Waste Framework Directive (2018) as “any substance or object which the holder discards or intends or is required to discard”. Therefore, food waste is discarded food and its associated inedible parts, destined towards applications such as bio-energy, composting, incineration and landfill. Animal feed and biomaterials are not considered food waste within the European Union.

2 Food Loss and Waste and GHG - current situation

2.1 Total GHG emissions and the contribution of the food system

In 2022, global CO_2-equivalent emissions were estimated at approximately 53.8 gigatons (Crippa et al., 2023). The food system is a significant contributor to greenhouse gas (GHG) emissions, accounting for 17 gigatons CO_2-eq/year in 2018 globally, which represents 21-37% of total emissions worldwide. In the Netherlands, the food system emitted around 52 megatons CO_2-eq/year in 2018, constituting 31% (EDGAR-FOOD, 2021) of the country's total GHG emissions (IPCC, 2019; Crippa et al., 2023; EDGAR-FOOD 2021).

The largest portion of these GHG emissions within the food system arises from agricultural production, including both crop cultivation and livestock farming, as well as land use and changes in land use such as deforestation and peatland degradation. A smaller portion of emissions can be attributed to activities across the remainder of the food supply chain (Figure 2) (Crippa et al., 2023). All these activities include FLW which is estimated to account for 8-10% of the global GHG emissions, totalling 4.4 gigatonnes of CO_2-equivalent annually globally (IPCC, 2019; FAO, 2013b). In terms of individual nations, food waste could rank as the third-largest GHG emitter globally, and without intervention, emissions from food waste are projected to rise from 4.4 to 6.2 gigatonnes by 2050 (Searchinger et al., 2018). This predicted 40% increase is based on the projections of population growth and changes in diet. Therefore, it is important to understand how measures to reduce food waste can mitigate and alleviate pressure on the system (IPCC, 2019).

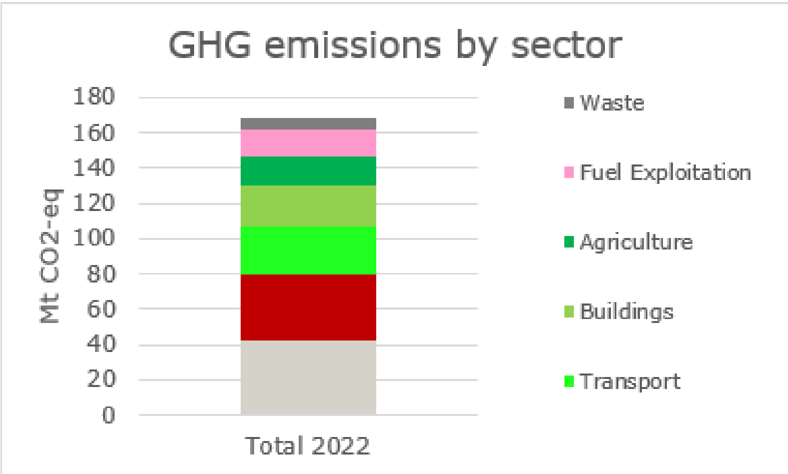


Figure 2 GHG emissions impact by sector in The Netherlands.
Data retrieved from EDGAR-FOOD. Source: Crippa et al, 2023

2.2 Total amounts of food waste and GHG emissions

Worldwide, an estimated 2.5 billion tons of food are lost or wasted annually in the supply chain (WWF-UK, 2021). Within the food service, retail, and household sectors, approximately 1.05 billion tons (28%, 12%, and 60% respectively) are wasted, amounting to 132 kilograms per capita and nearly one-fifth of all available food (UNEP, 2024). Furthermore, this global food loss and waste corresponds to 24% of uneaten calories, 25% of wasted water and fertilizer, and unutilized land area larger than China (WRI, 2023). In Europe, 6% of GHG emissions are attributed to food waste, equating to approximately 2.5 - 3 kg of CO_2-eq per kg of wasted food (FUSIONS, 2016).

In the Netherlands, approximately 2.6 million tons of food are wasted annually throughout the entire food chain, from production to consumption (Eurostat, 2023). Despite the Netherlands' relatively small contribution compared to global figures, this amount of food waste is equivalent to a continuous traffic jam stretching from Utrecht to Barcelona, with trucks filled with food bumper to bumper (https://samentegenvoedselverspilling.nl/; Soethoudt & Vollebregt, 2023). The associated CO_2 emissions from this food waste, totalling 8.8 million tons, are equivalent to approximately 1.0 million trips around the equator or providing energy for 5.6 million households for a year, based on average household energy consumption in the Netherlands.

Despite the interconnectedness between FLW and greenhouse gas (GHG) emissions, these topics are typically addressed separately. Additionally, when food waste is reported, it may not always be distinguished from waste originating in other sectors such as the power industry, industrial processes, transportation, agriculture, and waste management, see Figure 2 (Crippa et al., 2023).

3 Calculating the climate impact of food waste in the Netherlands

It's important to recognize that there are various ways to determine the climate impact of food systems, including, to varying degrees, the impact of food loss and waste. Equivalents used to convert food loss and waste (FLW) into climate impact indicators can be applied globally or tailored to specific regions or countries, such as the Netherlands. This chapter provides both global-level equivalents and those specific to the Netherlands where available, offering a comprehensive perspective on the climate impact of FLW.

Indicators used (e.g., RIVM, 2019) to assess the climate impact of FLW include

- GHG emissions in ton CO_2-eq/ton product,
- blue water use in M^3/ton product,
- cropland use in m^2/ton product and
- Eutrophication (nitrogen) in kg N/ton product

International sources such as Springmann et al. (2018) and Bajželj et al. (2014) also include biodiversity loss as an indicator of climate change. Despite ongoing efforts, including initiatives like the Aichi biodiversity targets, the Living Planet Index (global), and the Dutch "Biodiversiteit voetafdruk", linking these results with the amount of food wasted remains challenging (WWF, 2022; Westveer et al., 2022; CLO, 2015). Therefore, while we acknowledge biodiversity as an important indicator, we do not quantify it in this paper.

To calculate the impact of food loss and waste for the different indicators (GHG emissions, blue-water use, cropland use, nitrogen eutrophication, we used the FLW volume per food supply chain stage in the Netherlands, including primary production, processing and manufacturing, distribution and retail, restaurant and food services, and households (based on EUROSTAT 2023), and combined it with the calculated impact equivalents per product group in the waste composition per supply chain stage for the Netherlands (see figure 3).

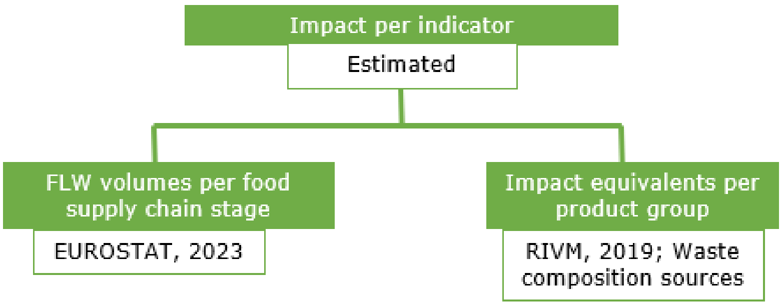


Figure 3 Methodology to calculate the impact of FLW on climate change in the Netherlands.

3.1 Quantitative overview of the climate footprint of food waste in the Netherlands

In the Netherlands, the total amount of GHG emissions is estimated at 168 Mton CO_2-eq/year (RIVM, 2019). Within this amount, the food system contributes 52 Mton CO_2-eq/year (EDGAR-FOOD, 2021), while food waste contributes 8.8 Mton CO_2-eq/year (based on RIVM, 2019). This means that food waste accounts for approximately 5% (based on RIVM, 2019) to 9% (based on Crippa et al., 2023) of the total GHG emissions in the Netherlands.

Table 1 Total, food system and food waste related GHG emissions in the Netherlands.

System level	GHG emissions data
Total GHG emissions in the Netherlands *(reference year = 2022)*	**168 Mton CO_2-eq/year** → 100% of total GHG emissions → 9.5 ton/capita.yr
Food system induced GHG emissions *(reference year = 2018)*	**52 Mton CO_2-eq/year** → 31% of total GHG emissions → 3.0 ton/capita.yr
Food waste induced GHG emissions *(reference year = 2019)*	**8.8 Mton CO_2-eq/year** → 5% of total GHG emissions → 0.5 ton/capita.yr

Data is derived from the following sources: Total GHG emissions (Crippa et al., 2023); Food system emissions (EDGAR-FOOD, 2021, method applied from Crippa et al., 2021; Crippa et al., 2023); Food waste emissions (RIVM, 2019 (own calculation); Crippa et al., 2023)

Table 2 displays the total amount of food waste in the Netherlands and its annual impact across a range of climate impact indicators. It also provides the results per supply chain segment in the Netherlands. Please note that the values provided above are based on available data on food waste composition per supply chain stage and average equivalent impact data from the RIVM database (2019). Currently, there are no reliable data available on biodiversity loss as an impact indicator for climate, so it has not been included in the table.

Table 2 Climate impact of food waste in the Netherlands, per supply chain segment across various indicators.

Indicators	Food waste	GHG emissions	Blue water use	Cropland use	Eutrophication (N_2O emissions)
	Kton/year	Kton CO_2-eq/year	Billion litre/year	Thousand hectares /year	Ton N/year
Total	2,587	8,807	570	693	15,000
Primary production	315	(676)	(49)	(45)	(1,000)
Processing and manufacturing	1,131	(3,723)	(294)	(345)	(7,000)
Retail and distribution of food*	210	753	34	50	1,000
Restaurants and food services	83	335	19	24	1,000
Households	848	3,321	174	229	5,000

* including return of unsold bread to animal feed

Data is derived from the following sources: Food waste amounts (EUROSTAT, 2023), data derived from RIVM, 2019; FAOSTAT, 2020 (for primary production and processing & manufacturing); Vollebregt, 2022 (retail and distribution of food); Van Westerhoven & Steenhuisen, 2010 (food restaurants and food services); Van Lieshout & Knüppe, 2022 (households).

Underlying assumptions:

- For the primary production, processing, and manufacturing supply chain stages, there is a lack of reliable data on waste composition at the product group level specific to the Netherlands, which is necessary to calculate GHG emissions within these stages. Therefore, the waste division presented by FAOSTAT (2020) is utilized. However, the reliability of this data is highly uncertain, hence the estimates of the different climate change indicators are presented within brackets for these supply chain stages.
- The equivalents provided in the RIVM (2019) database encompass two datasets: one includes information up to and including processing, while the other extends up to and including retail. The former dataset was utilized for the primary production and processing & manufacturing segments, while the latter was employed for the retail & distribution, restaurants & food services, and household supply chain segments. These datasets represent the best available data currently accessible for these purposes.

3.2 Climate impact and food waste hotspots

Table 3 presents the amounts of food waste per product group with its associated GHG emissions for three supply chain segments in the Netherlands. For the primary production and processing and manufacturing sectors, no reliable data on the composition of product groups are currently available. Therefore, specific product group breakdowns are not provided for these segments.

Table 3 Food waste amounts and associated GHG emissions per product group within three supply chain segments in the Netherlands.

Retail & distribution of food			Restaurants & food services			Households		
Product groups	Food waste (kton)	Associated GHG emissions (kton CO2-eq)	Product groups	Food waste (kton)	Associated GHG emissions (kton CO2-eq)	Product groups	Food waste (kton)	Associated GHG emissions (kton CO2-eq)
Fresh meat & fish	15	205	Other fresh products and non-perishable products	33	145	Other fresh products and non-perishable products	246	1076
Bread & bakery	74	176	Fresh meat & fish	6	79	Fresh meat & fish	68	920
Dairy, eggs, ready-to-eat, refrigerated products	25	126	Potatoes, vegetables and fruit	23	42	Potatoes, vegetables and fruit	288	520
Other fresh products and non-perishable products	29	125	Dairy, eggs, ready-to-eat, refrigerated products	7	37	Dairy, eggs, ready-to-eat, refrigerated products	85	421
Potatoes, vegetables and fruit	67	121	Bread & bakery	13	32	Bread & bakery	161	384

Source: Derived from RIVM, 2019; Vollebregt, 2022 (retail & distribution of food); Van Westerhoven & Steenhuisen, 2010 (restaurants & food services); Van Lieshout & Knüppe, 2022 (households)

The table highlights that food waste from the 'Fresh meat and fish' product category contributes the most to the amount of GHG emissions at the retail and distribution supply chain stage, despite having a relatively low food waste amount compared to other product groups. Conversely, in the restaurant and food services, as well as households supply chain stages, the product group 'Other Fresh Products ' and 'Non-perishable Products', respectively, contribute the most to GHG emissions. Notably, products like vegetable oils, sandwich fillings, and processed meats within these groups contribute significantly to GHG emissions.

3.3 International comparison of climate impacts

Table 4 shows the climate impact of food waste per ton product, presented at the global level and for the Netherlands specifically. These equivalent amounts per ton product can be used to provide comparable insights into the climate impact of food waste across the food supply chain. Based on these numbers it can be estimated that for every ton FLW we reduce in the Netherlands, we will save: 3.40 tons CO_2 emissions, 220 m^3 blue water, 0.27 hectares cropland and 5.8 kg nitrogen.

Table 4 Impact amounts per ton of product at global level and within the Netherlands.

Indicator	Level	Impact amounts / ton product
GHG emissions	Global	2.86 ton CO_2-eq
	Netherlands	3.40 ton CO_2-eq
Blue water use	Global	192 m^3
	Netherlands	220 m^3
Cropland use	Global	0.56 hectare
	Netherlands	0.27 hectare
Eutrophication (nitrogen)	Global	No data available
	Netherlands	5.8 kg N
Biodiversity loss	Global	No data available
	Netherlands	No data available

Source: GHG emissions (global: Springmann et al., 2018; FUSIONS, 2016); Blue water use (global: FAO, 2017); Cropland use (global: FAO, 2013a). All Dutch data are derived from RIVM, 2019.

Another way to present the climate impact of food waste is per capita per year. Table 5 presents total GHG emissions, GHG emissions associated with the food system and the GHG emissions related to food waste, at global level and for the Netherlands specifically. Overall, the total GHG emissions in the Netherlands are higher per capita per year compared to the average worldwide, including the food system induced GHG emissions. However, the per capita food waste and associated GHG emissions in the Netherlands are lower than the global average.

Table 5 *Contribution of the food system and FLW on the total GHG emissions per capita, for the Netherlands and worldwide.*

System level	Level	Amounts per capita.yr	Source
Total food waste volume	Global	**316 kg/capita.yr** *Based on 2.5 Gton/year (data from 2021)*	WWF-UK, 2021
	Netherlands	**149 kg/capita.yr** *Based on 2.6 Mton/year (data from 2021)*	EUROSTAT, 2023
Total GHG emissions	Global	**6.7 ton CO_2-eq/capita.yr** *Based on 53.8 Gton (data from 2022)*	Crippa et al., 2023
	Netherlands	**9.5 ton CO_2-eq/capita.yr** *Based on 168 Mton (data from 2022)*	Crippa et al., 2023
Food system induced GHG emissions	Global	**2.2 ton CO_2-eq/capita.yr** *Based on 17 Gton CO_2-eq/year (data from 2018)*	EDGAR-FOOD, 2021, method applied from Crippa et al., 2021; 2023; IPCC 2019
	Netherlands	**3.0 ton CO_2-eq/capita.yr** *Based on 52 Mton CO_2-eq/year (data from 2018)*	EDGAR-FOOD, 2021, method applied from Crippa et al., 2021
Food waste induced GHG emissions	Global	**0.6 ton CO_2-eq/capita.yr** *Based on 4.4 Gton CO_2-eq/year (data from 2011)*	FAO, 2013b; IPCC, 2019
	Netherlands	**0.5 ton CO_2-eq/capita.yr** *Based on 9 Mton Co_2-eq/year (data from 2019)*	Derived from RIVM, 2019; Crippa et al., 2023

- *In 2011, the Dutch population was 16.7 million people, and 7.1 billion globally*
- *In 2018, the Dutch population was 17.2 million people, and 7.7 billion globally*
- *In 2019, the Dutch population was 17.3 million people, and 7.8 billion globally*
- *In 2021, the Dutch population was 17.5 million people, and 7.9 billion globally*
- *In 2022, the Dutch population was 17,6 million people, and 8.0 billion globally.*

4 Contribution of food waste reduction towards achieving climate change targets

4.1 Challenges and rebound effects

The global interconnectedness of the food system gives rise to interactions between climate change and food loss and waste, impacting social, environmental, and economic aspects within the triple-bottom-line sustainability framework. Addressing these challenges involves navigating complex issues affecting people, planet and profit. Socially, effective communication and collaboration are crucial, but diverse interests and politicization of environmental issues pose challenges. Environmentally, crop failures and biodiversity loss are intertwined with both climate change and FLW impacts, with consequences for ecosystems and food systems. Economically, climate-related disasters contribute to market volatility, while reducing FLW can enhance market dynamics. Water scarcity, often undervalued, underscores the need for understanding the interplay between climate, food systems, and water resources. Practical challenges in generating accurate estimations and policy formulation arise due to fragmented theoretical landscapes and limited evidence linking FLW to climate change. Collaborative efforts are essential to develop strategies prioritizing environmental sustainability and food security. Political challenges complicate integration efforts, with FLW often sidelined compared to climate change. Establishing a unified vision integrating considerations of food production, climate impacts, and FLW reduction is crucial. Hegwood et al. (2023) conducted a study focused on modelling the potential rebound effects of food loss and waste solely at the consumer level. Their findings indicated that as FLW decreases and the food supply expands, market dynamics may respond by lowering food prices and boosting consumer purchasing power. This scenario could lead to increased consumption levels and, consequently, a rise in FLW. Additionally, Hagedorn & Wilts (2019) calculated that lower-income groups might experience greater rebound impacts from increased spending. These studies highlight the intricate interplay between supply, demand, and waste in food systems, emphasizing the necessity of integrated approaches.

4.2 Reducing food waste as THE climate change measure in sustainable food systems

The European Union (EU) is committed to achieving climate and environmental sustainability, with food waste prevention and reduction being key components of agreements such as the European Green Deal (including the Farm to Fork Strategy and the related Fit for 55 Climate strategy), the Sustainable Development Goals and the Paris Agreement on Climate Change. However, despite their importance, food waste measures are not explicitly mentioned in most nationally determined contributions to the Paris Agreement, and only 11 mention food losses in primary production (Schulte et al., 2020). Implementing measures focused on food production, such as addressing land-use changes and agricultural emissions, could potentially reduce global emissions by 7.2 billion metric tons of CO_2-equivalent annually. Similarly, initiatives aimed at minimizing food loss and waste and transitioning to sustainable diets could cut emissions by 1.8 billion metric tons of CO_2-equivalent per year, contributing to approximately 20% of the necessary global mitigation by 2050 to achieve the 1.5°C target (Roe et al., 2019). Project Drawdown (2021), identifies reducing food waste as the most impactful strategy for reducing emissions and combating climate change within the food system. Targeting FLW and promoting sustainable and healthy diets has the potential to reduce emissions by 1.8 gigaton CO_2-eq/year (Roe et al., 2019). As the world population continues to grow within the constraints of finite planetary resources, addressing inefficiencies within the food system becomes paramount to bridging the projected food gap by 2050. The World Resources Insitute (WRI, 2021) underscores the importance of reducing food loss and waste as a key strategy to close this gap without the need for expanding cultivated areas. By optimizing the utilization of existing resources and minimizing waste, progress can be made towards ensuring food security for a growing global population while alleviating environmental pressures linked to agricultural expansion. Respecting planetary boundaries is more effectively achieved by reducing food loss and waste by 5% rather than increasing food production by the same percentage.

5 Accelerating towards 2050 – Advocacy statements

The Netherlands is emerging as a leader in circularity and aims to achieve a waste-free economy by 2050 (Ministry of Infrastructure and Water Management, 2023). Reducing food loss and waste (FLW) is integral to this vision, as it contributes to a circular economy where resources are used efficiently and waste is minimized, aligning with broader sustainability objectives. However, according to Bos-Brouwers et al. (2023), the current rate of FLW reduction falls short of achieving these goals, estimated to be between 1.3% and 2.9% per year (minimum and maximum range) (see Figure 5).

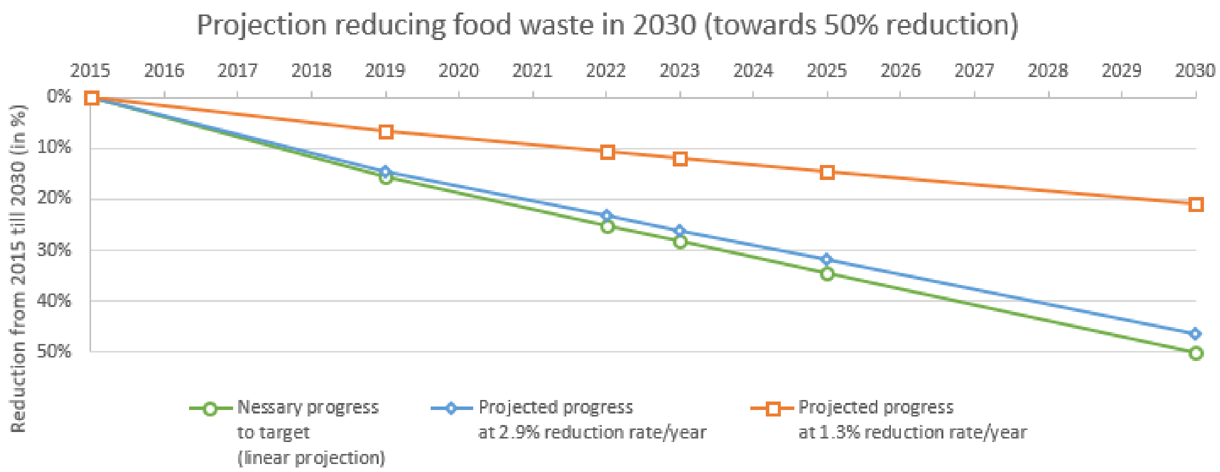


Figure 5 Projection of food waste reduction rate by 2030 (2015 as reference year).
Source: Bos-Brouwers et al., 2023.

Leading the path towards a waste-free economy can elevate the Netherlands' international reputation as a sustainable and environmentally conscious nation. As a global hub for food trade, implementing measures to reduce losses and waste can significantly impact supply chains worldwide. Additionally, the Netherlands can continue to contribute expertise and technology to enhance value chains and food systems globally, whilst safeguarding food security.

Summarized statements from interviews with interdisciplinary experts at WUR (interviews, 2023) propose several key elements to advocate for integrating FLW into the Climate Change Agenda:

1. Regulating and incentivizing food loss and waste (FLW) reduction measures within specific supply chains can effectively mitigate GHG emissions. This includes addressing the indirect link via agricultural production impacts at the company level and targeting hotspots for implementing interventions that drive positive change efficiently. By focusing efforts on specific supply chains and strategically implementing interventions, significant progress can be made in reducing FLW and its associated environmental impacts.
2. Strengthening regulations and offering clear implementation guidance can empower stakeholders to take decisive actions in reducing food loss and waste (FLW). By distinguishing actions requiring support from individuals and those impacting company levels, such as creating business cases for solutions, targeted strategies can be developed. Expanding the food use hierarchy as a guiding principle can aid in assessing the value that can still be derived from food currently lost or wasted, promoting more efficient resource (re-)utilization.
3. In the Netherlands, proactive measures to address water-related challenges such as flooding and drought are crucial to safeguarding water resources and mitigating extreme events. Integrating these concerns into initiatives aimed at reducing food loss and waste (FLW) underscores the interconnectedness of environmental issues and promotes holistic approaches to sustainability. By addressing water problems alongside FLW reduction efforts, the Netherlands can enhance resilience in food systems while ensuring the sustainability of its water resources.
4. Integrating circularity into climate change policies can yield policies with multiple co-benefits, maximizing effective solutions for both people and the planet. This approach underscores the

importance of limiting consumption and producing only what is necessary to mitigate continuous economic growth, promoting sustainability and resource efficiency.

5. Incorporating food loss and waste (FLW) reduction efforts into Carbon Accounting Mechanisms can make FLW more tangible, offering a measurable way to track progress. Additionally, recognizing technology choices and innovations that mitigate FLW through mechanisms like ECO labels can incentivize suppliers to adopt more sustainable practices, further driving reductions in FLW.
6. Quantifying the impact of food loss and waste (FLW) and linking it to broader transitions can bolster advocacy for sustainable practices. Connecting FLW to issues like resource depletion, reduced fossil fuel use, and water conservation highlights its multifaceted impacts. Additionally, creating a separate registration item for FLW in platforms like the Landelijk Meldpunt Afvalstoffen can enhance monitoring and management efforts, facilitating more effective mitigation strategies.
7. Encouraging data contribution for monitoring and enhancing transparency, including de-anonymization processes, is crucial for understanding the link between climate change and food loss and waste (FLW). However, caution should be exercised in using data arguments to substantiate this link, considering potential biases or limitations. Additionally, recognizing and addressing potential rebound effects is essential for promoting long-term solutions and ensuring the effectiveness of FLW reduction efforts.
8. Focusing on household-level food loss and waste (FLW) and promoting innovation through high-tech and digital tools can empower consumers to drive change. Utilizing mobile alerts and other technological solutions enables individuals to take proactive steps in reducing waste in their daily lives, fostering a culture of sustainability and responsible consumption.
9. Connecting conversations can facilitate meaningful discussions, especially when considering the engagement of media and young generations. Leveraging existing communication materials can enhance outreach efforts, making use of platforms and resources already familiar to these audiences. By tapping into these channels, stakeholders can effectively engage with diverse demographics and foster greater awareness and participation in initiatives to address food loss and waste.

Actions aimed at reducing food loss and waste offer a triple-win scenario: they conserve food resources for a growing population, cut costs for businesses and consumers, and diminish the climate footprint of food consumption and production, thereby reducing the demand for additional land. Moreover, coupled with the transition to sustainable and healthy diets, reducing food loss and waste can catalyse a bottom-up movement towards more sustainable food systems, aligning with the Dutch national objective of achieving a waste-free economy by 2050.

Literature

Bajželj, B., Richards, K. S., Allwood, J. M., Smith, P., Dennis, J. S., Curmi, E., & Gilligan, C. A. (2014). Importance of food-demand management for climate mitigation. Nature Climate Change, 4(10), 924-929.

Bos-Brouwers, H., Achterbosch, T. J., Castelein, B., & Cloutier, J. M. I. (2023). Theory of change: versnellingsagenda verminderen voedselverspilling 2022-2025: Adviezen aan het Ministerie van LNV (No. 2405). Wageningen Food & Biobased Research.

CLO (2015). Nederlandse biodiversiteitsvoetafdruk, 1990 – 2010. https://www.clo.nl/indicatoren/nl146402-nederlandse-biodiversiteitsvoetafdruk-1990-2010

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A.J.N.F. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2(3), 198-209.

Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf E., Becker, W., Monforti-Ferrario, F., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Brandao De Melo, J., Oom, D., Branco, A., San-Miguel, J., Vignati, E. (2023) GHG emissions of all world countries. Publications Office of the European Union, Luxembourg. doi:10.2760/953332, JRC134504.

EDGAR-FOOD (Emissions Database for Global Atmospheric Research) Community GHG Database, a collaboration between the European Commission, Joint Research Centre (JRC), the International Energy Agency (IEA), and comprising IEA-EDGAR CO2, EDGAR CH4, EDGAR N2O, EDGAR F-GASES version 6.0, (2021) European Commission, JRC (Datasets). The complete citation of the EDGAR Community GHG Database is available in the 'Sources and References' section. https://edgar.jrc.ec.europa.eu/edgar_food

Eurostat (2023). Food waste and food waste prevention by NACE Rev. 2 activity - tonnes of fresh mass. https://ec.europa.eu/eurostat/databrowser/view/env_wasfw/default/table?lang=en

Fusions (2016). Estimates of European food waste levels.

FAO (2011). Global Food Losses and Food Waste – Extent, Causes and Prevention.

FAO (2013a). Food wastage footprint: Impacts on natural resources. FAO.: https://www.fao.org/3/i3347e/i3347e.pdf

FAO (2013b) Food wastage footprint & Climate Change. Available from: https://www.fao.org/nr/sustainability/food-loss-and-waste

FAO (2017). Water for sustainable food and agriculture a report produced for the G20 presidency of Germany. Rome. https://www.fao.org/3/i7959e/i7959e.pdf

FAO (2019). The state of food and agriculture. Moving forward on food loss and waste reduction.

Hagedorn, W., & Wilts, H. (2019). Who should waste less? Food waste prevention and rebound effects in the context of the Sustainable Development Goals. GAIA-Ecological Perspectives for Science and Society, 28(2), 119-125.

Hegwood, M., Burgess, M. G., Costigliolo, E. M., Smith, P., Bajželj, B., Saunders, H., & Davis, S. J. (2023). Rebound effects could offset more than half of avoided food loss and waste. Nature Food, 4(7), 585-595.

IPCC (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. In press.

Ministry of Infrastructure and Waste Management, 2023. National Circular Economy Programme 2023-2030. https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/documenten/beleidsnotas/2023/02/03/nationaal-programma-circulaire-economie-2023-2030

RIVM (2019). Database milieubelasting voedingsmiddelen. https://www.RIVM.nl/documenten/database-milieubelasting-voedingsmiddelen.

Roe, S., Streck, C., Obersteiner, M., Frank, S., Griscom, B., Drouet, L., Fricko, O., Gusti, M., Harris, N., Hasegawa, T. and Hausfather, Z. (2019). Contribution of the land sector to a 1.5° C world. Nature Climate Change, 9(11), 817-828. https://www.nature.com/articles/s41558-019-0591-9.

Schulte, I., Bakhtary, H., Siantidis, S., Haupt, F., Fleckenstein, M., & O'Connor, C. (2020). Enhancing NDCs for Food Systems: Recommendations for Decision-Makers. WWF Germany & WWF Food Practice. https://wwfint.awsassets.panda.org/downloads/wwf_ndc_food_final_low_res.pdf.

Soethoudt & Vollebregt (2023). Monitor Voedselverspilling Update 2009 – 2020. Hoeveel kilo gaat er in Nederland verloren? https://edepot.wur.nl/590306.

Searchinger, T., R. Waite, C. Hanson, and J. Ranganathan. 2018. Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050—Synthesis Report, December. Washington, DC: World Resources Institute. Retrieved from: https://www.wri.org/research/creating-sustainable-food-future

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., ... & Willett, W. (2018). Options for keeping the food system within environmental limits. Nature, 562(7728), 519-525. https://www.nature.com/articles/s41586-018-0594-0%C2%A0

STV (no publishing date). Hoeveel voedsel verspillen we in Nederland? https://samentegenvoedselverspilling.nl/kennisbank/hoeveel-voedsel-verspillen-we-in-nederland. Accessed on 14 May 2024.

UNEP (2024). Think Eat Save. Tracking Progress to Halve Global Food Waste. Food Waste Index Report 2024. https://wedocs.unep.org/bitstream/handle/20.500.11822/45230/food_waste_index_report_2024.pdf?sequence=5&isAllowed=y

Van Lieshout & Knūppe (2022). Voedselverspilling bij consumenten thuis in Nederland in 2022. Rapport. https://www.voedingscentrum.nl/Assets/Uploads/voedingscentrum/Documents/Professionals/Pers/Pers%20overig/Rapport%20Voedselverspilling%202022.pdf

Van Westerhoven, M., & Steenhuisen, F. (2010). Bepaling voedselverliezen bij huishoudens en bedrijfscatering in Nederland. CREM BV: Amsterdam, The Netherlands. https://www.afvalcirculair.nl/onderwerpen/linkportaal/publicaties/downloads-0/eindrapport-bepaling/

Vollebregt, M. (2022). Minder voedselverspilling in supermarkten. https://www.wur.nl/nl/onderzoek-resultaten/onderzoeksinstituten/food-biobased-research/show-fbr/nederlandse-supermarkten-maken-voedselverspilling-inzichtelijk-f00dwa5-1.htm

Westveer, J, Freeman, R., McRae, L., Marconi, V., Almond, R.E.A, and Grooten, M. (2022) A Deep Dive into the Living Planet Index: A Technical Report. WWF, Gland, Switzerland. https://www.wwf.nl/globalassets/pdf/lpr/lpr-2022-a-deep-dive-into-the-living-planet-index.pdf

World Resource Institute (2021). Reducing Food Loss and Waste: Setting a Global Action Agenda. https://wriorg.s3.amazonaws.com/s3fs-public/reducing-food-loss-waste-global-action-agenda_0.pdf

World Resources Institute (2023). The Global benefits of reducing food loss and waste, and how to do it. By Liz Goodwin. https://www.wri.org/insights/reducing-food-loss-and-food-waste

WWF-UK (2021). Driven to waste: The Global Impact of Food Loss and Waste on Farms. Woking. https://wwfint.awsassets.panda.org/downloads/wwf_uk__driven_to_waste___the_global_impact_of_food_loss_and_waste_on_farms.pdf

WWF (2022). Living Planet Report 2022 – Building a nature positive society. Almond, R.E.A., Grooten, M., Juffe Bignoli, D. & Petersen, T. (Eds). WWF, Gland, Switzerland. https://www.wwf.nl/globalassets/pdf/lpr/living-planet-report-2022-wwf.pdf

Wageningen Food & Biobased Research
Bornse Weilanden 9
6708 WG Wageningen
The Netherlands
E info.wfbr@wur.nl
wur.eu/wfbr

Report 2571

The mission of Wageningen University & Research is “To explore the potential of nature to improve the quality of life”. Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,700 employees (7,000 fte), 2,500 PhD and EngD candidates, 13,100 students and over 150,000 participants to WUR’s Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.