MSc Thesis Business Economics

Beyond the market price: An investigation into the true price of broiler meat production in the Netherlands

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Abstract

Introduction: Intensive animal production systems aim to produce goods with the highest level of efficiency, which translates into the lowest price in monetary terms. In the current economic system, externalities are not priced, leading to market failure. Existing literature fails to comprehensively address these external costs, thereby hindering the implementation of effective measures and their integration into decision-making processes among stakeholders, including farmers, feed companies, and retailers. True Cost Accounting is an economic assessment method that quantifies externalities and converts them to a monetary value.
Objectives: The aim of this study is to make an approximate estimate of the true price of broiler meat produced in the Netherlands. This provides the required knowledge that actors in the Dutch broiler chain need to make well-considered sustainability decisions.
Methods: SimaPro and the Agri-footprint database were used to calculate the impact indicators from crop cultivation to the slaughter of broiler meat. These impacts were monetized according to the Valuation Framework for True Price Assessment of Agri-food Products. The true price is calculated by adding environmental and social costs on top of the retail price (market price).
Results: The results give insight into the impacts of the broiler supply chain in the Netherlands. The true price gap is estimated at 3.77 euros. When these costs are added to the market price, this amounts to a true price of 11.05 euros, which is a price increase of 51.7%. Fine particulate matter formation has the largest impact on the true price gap (1.35 euro), followed by land use (1.03 euro) and global warming (0.60 euro).
Conclusion: Using this method an attempt was made to calculate the true price. This method is suitable for this purpose but has some implications, such as the reliability of data and the substantiation of the method. Recommendations for players in the chain are to replace soy with animal protein or soy from countries where no deforestation takes place and to invest in air purification.

Key words: true cost accounting, broilers, life cycle assessment, environmental impact, sustainable food production

Preface

Before you lies the master thesis 'Beyond the market price: An investigation into the true price of broiler meat production in the Netherlands'. It has been written to fulfill the graduation requirements of the Business Economics program at the Wageningen University and Research in the Netherlands. This thesis was written in the period from March to October 2023.

The subject of this thesis was new to me, which enriched me with new skills in the field of Life Cycle Assessment (LCA) and True Pricing. First of all, I would like to thank my supervisor, Dr. Helmut Saatkamp, for the excellent guidance and support during the process. His commitment, support and out-of-the-box thinking helped me to successfully complete this thesis.

Finally, I want to thank my family and friends for the support during my whole study. I would also like to thank you, my reader. I hope you enjoy your reading.

Ivo Harmens
Wageningen, October 12, 2023.

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Glossary

Term	Definition
Abatement cost	The abatement cost is the cost for the industry/firms to reduce or prevent pollution.
Damage cost	Damage cost refers to the monetary value assigned to the negative impacts or harm caused by specific environmental or societal factors.
Externality	An externality is an unintended consequence or side effect of an economic activity or transaction that affects parties who are not directly involved in that activity.
Functional unit	A functional unit is a standardized measure defining the specific function or purpose of a product, process, or system in life cycle assessment, enabling the comparison of their environmental impacts.
Materiality assessment	Evaluation of which impacts are relevant per phase of a product’s lifecycle.
True costs	All external costs associated with production
True price	Sum of the market price and all external costs.

1. Introduction

1.1 Background

Since the end of World War II, stakeholders within the European broiler supply chain have been engaged in collaborative efforts to develop intensive broiler production systems that can satisfy the rising demand for cheap, safe, and sufficient quantities of broiler meat (Meerburg, 2009). These production systems, particularly those involving intensive animal production, aim to produce goods at the highest level of efficiency, which translates into the lowest price in monetary terms. As a result, food security increased and the price of meat has decreased for a significant proportion of the world's population. It is now at its lowest point in proportion to their average income in history (Godfray et al., 2018). Partly because of these developments, the industry can contribute to the rising demand for animal protein. It has relatively low cost, a short production cycle and high feed efficiency (Alkhtib et al., 2023).

However, a considerable portion of the total price associated with these production systems has been externalized, resulting in significant burdens such as pollution, emissions, and reduced animal welfare (Toorop et al., 2021). In the current economic system, these externalities are not priced, leading to market failure (Hendriks et al., 2021). This means that profits are privatized and losses are socialized. Due to the globalization of food systems, these externalities take place across borders and continents. In addition, in the current system, farmers are penalized for pursuing sustainability certification through higher relative costs and complex assessment and monitoring (Gemmill-Herren et al., 2021). van Horne (2020) calculated that based on the total revenue and costs, the income of a farm with an organic broiler system was 7,000 euro lower than the income of a conventional farming system.

Society is increasingly calling for a transition from food systems focused on yields, productivity and profitability, towards those that feed the global population while ensuring human, ecological, and animal health and well-being. A growing number of people and organizations are taking steps towards holistic and integrated approaches to evaluate food systems (Baker et al., 2020). As an illustration, one of the largest financiers of the Dutch agricultural sector, ABN Amro, suggests in a sector view that True Pricing is expected to play a major role in the future (Berntsen et al., 2021). True Pricing was also mentioned during talks on a new agricultural agreement (Anonymous, 2023). Furthermore, research indicates that a significant number of consumers are willing to pay for these externalities (van Haaster-de Winter et al., 2022).

There are several methods to evaluate food systems, such as Ecological Footprint, Life Cycle Analysis, Activity-Based Costing, Environmental Management Accounting, Full Cost Accounting and True Cost Accounting (Arendt et al., 2020). The principles of True Cost Accounting as early as the 1920s and have undergone extreme development in recent years due to technological advances in the field of data analytics. This method is an economic assessment that looks not only at the usual financial metrics, but also seeks to understand the broader human, social and ecological impacts of food systems. Externalities are quantified and converted to a monetary value. This leads to the true price of a product, which is the sum of the market price (the price at which a product is offered) and the true price gap (the cost of externalities) (Baker et al., 2020).

Nonetheless, the absence of a harmonized method for calculating the true price remains elusive, primarily due to the various methods concerning the monetization of environmental impacts. Examples include Ecotax, Stepwise2006, the Environmental Prices Handbook, Trucost, EVR and a true price assessment method for agri-food products, which has been developed by True Price and Wageningen Economic Research. This method has been used by earlier studies to calculate the true price of pork, table potato, lettuce mix, lime, flower bulps and mussels (Galgani, Van Veen, et al., 2023).

To date, there is only one known study that calculate the true price of broiler meat in the Netherlands. While broiler meat makes up a large part of the daily diet of consumers in the Netherlands. In 2022, broiler meat (21.4 kilograms) was the second most consumed meat after pork (36.3 kilograms) of the total meat consumption per capita of 75 kilograms (Dagevos et al., 2023).

The study, *'De Echte prijs van Vlees'*, concluded that the total annual damage due to meat consumption is 4.5 billion euros in the Netherlands. For broiler meat, this study estimates that the total environmental and climate damage of broiler meat amounts to 680 million euros and the price should be on average 26% higher than the current average market price (de Bruyn et al., 2018).

This study will be the first study to calculate the true price of broiler meat in the Netherlands based on the true price assessment method for agri-food products. The results can be used by agri-food companies and farmers working in the broiler value chain to better understand their impact and reduce their externalities. Furthermore, this research will show at company level, national level and international level what the externalities are, which externalities have the greatest impact, how the true price can be used and to what extent the current market price meets the true price which can lead to policy measures.

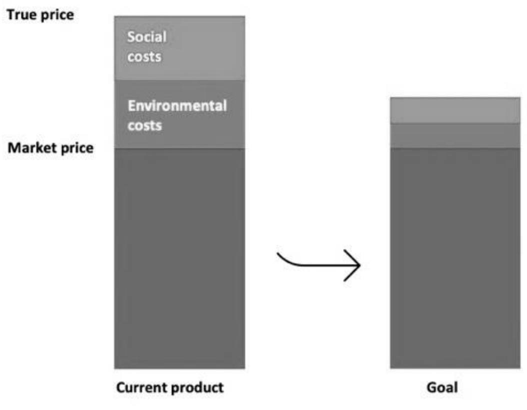


Figure 1 Overview true price

1.2 Problem statement

The problem addressed in this thesis is the lack of consideration for the environmental and social costs associated with broiler meat production in The Netherlands within the current market pricing. Existing literature fails to comprehensively address these external costs, thereby hindering the implementation of effective measures and their integration into decision-making processes among stakeholders, including farmers, feed companies, and retailers.

1.3 Objective and research questions

The aim of this study is to make the true price of broiler meat produced in the Netherlands transparent. To offer the knowledge required for actors in the Dutch broiler supply chain (farmers, enterprises, NGOs, and governments) to make informed sustainability decisions. It therefore aims to include any hidden costs that are not directly represented in current market prices and provides recommendations on how to lower these costs toward the current market price. More specifically, the following main research question needs to be addressed:

What are the total costs of broiler meat production in the Netherlands, including the market price and external costs, and how do these costs impact the true price?

This main question can be answered through the following research questions:

1) What are the main components and stages of the broiler value chain in The Netherlands?
2) What are the externalities of the broiler meat production in the Netherlands?
3) What is the economic price of these externalities?
4) What is the true price of broiler meat in the Netherlands?
5) What are measures that can be implemented to narrow the gap between the market price and the true price?

1.4 Outline of the report

This report is structured in the following way: Chapter 1 serves as the introduction, setting the context and objectives of the study. Chapter 2 outlines the Materials and Methods, detailing the general approach, product definition, product life cycle, impacts within the scope, data sources, and the factors used for monetization. In Chapter 3, the Results are presented, including the broiler meat value chain description, quantification and monetization of impacts, calculation of the true price, and the subsequent recommendations. Chapter 4 engages in a Discussion of the results, interpreting their significance, discussing their implications in relation to existing literature or industry practices, addressing limitations, and suggesting potential avenues for future research. The References are documented in Chapter 5, listing all cited sources according to a specific citation style. Finally, Chapter 6 is reserved for the Appendix, housing supplementary materials such as additional data tables, charts, graphs, and detailed calculations that provide further depth and support to the main body of the report.

2. Materials and methods

2.1 General approach

As described in the introduction, this study follows the methodology to assess the true price gap developed by True Price and Wageningen Economic Research. In addition, previous studies have been used as examples such as, the pork (Vissers & Snoek, 2023) and mussel (Hoekstra et al., 2022) studies. According to the True Price Assessment Method for Agri-Food products, a true price assessment consists of four stages and nine logical steps, as shown in Figure 2 below. This study will follow these steps in the following order:

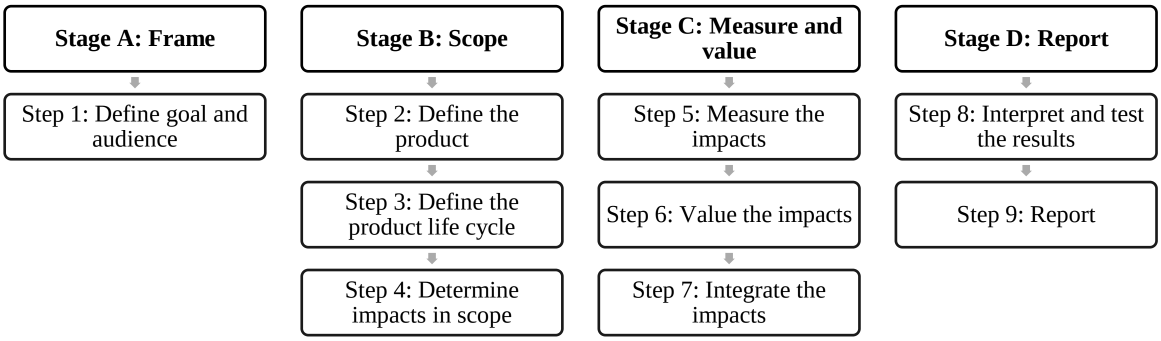


Figure 2 Steps of a True Price Assessment

2.1 Step 1: Define goal and audience

As described in the introduction, the goal of this true price assessment is to estimate the True Price of broiler meat which is produced in The Netherlands and aims to gain a global overview of the impacts and to inform stakeholders about externalities in order to make considered sustainability decisions.

2.2 Step 2: Define the product

Once the goal and audience are described, the next step is defining which product will be studied and what the related supply chain is. In the Netherlands, several systems are used to keep broilers under various labels. These include conventional stall systems, Dutch Retail Broiler, Better life one Star and Organic (van Horne, 2020). This research will focus on conventional stall systems, as data from the other systems is not available in the Agri-footprint database. The functional unit, which expresses the function of the product quantitively, is in kilograms. The monetization unit is in euros per kilogram, because the euro is the currency of the Netherlands. An overview of the product definition is shown in the Table 1 on the next page. The reference year for data is the year to which the data should (ideally) refer to in the study, in this case it is the year 2020 (time coverage).

A true pricing study can be a stand-alone or comparative assessment. A stand-alone assessment focuses on a single product, comparative assessments are designed to compare the true price of two or more products (Galgani, Van Veen, et al., 2023). This study is a stand-alone study and does not necessarily allow to draw conclusions based on comparison with results of other studies.

Table 1 Overview of the product definition

Item	**Classification**
Product type	Broiler meat
Functional unit	Kilogram
Currency	Euro
Monetary unit	Euro/kilogram
Production location	Netherlands
Reference year data	2020

2.3 Step 3: Define the product lifecycle

Following the product definition, the steps in the lifecycle of the product and the phases of the product's life cycle included in the analysis will be defined. These are called the system boundaries.

The supply chain of broilers starts with the production of feed, and includes all activities related to the production of broiler feed such as growing crops, transportation and processing. The stage of feed production is followed by the broiler production stage which involves farms with parent animals, hatcheries and broiler farms. When the broiler reaches its weight, it will be transported to the slaughterhouse where it will be slaughtered (Mostert et al., 2022). The retail and consumer stages are not included in this study because it is likely that these two stages do not have a major impact on the externalities of broiler meat.

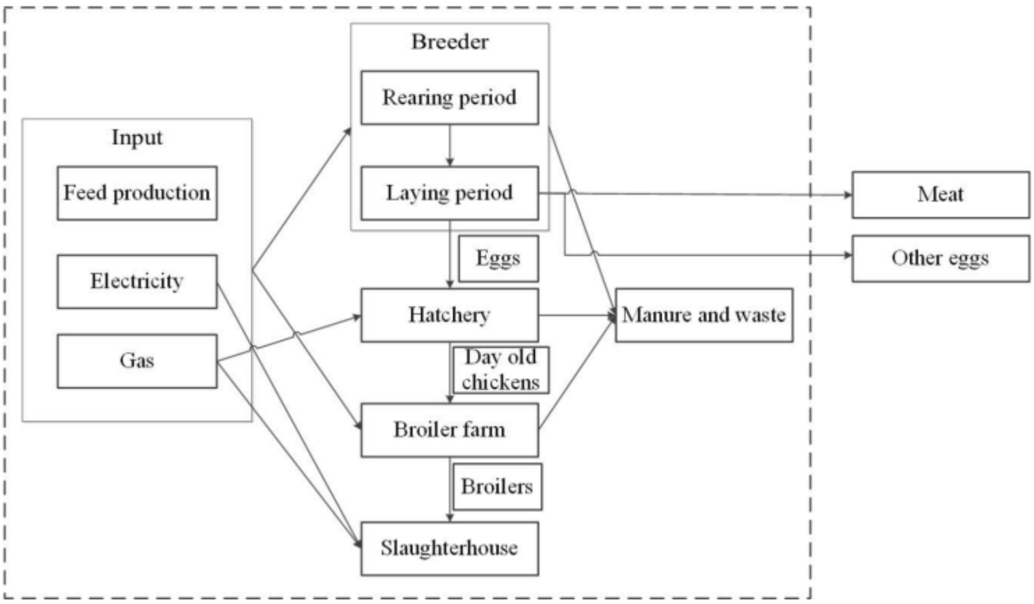


Figure 3 System boundary of stages and process included of the broiler chain (Mostert et al., 2022)

2.4 Step 4: Determine the impacts in scope

A standard list of social and environmental impacts to consider, is provided in the list of impacts in true pricing, which is applicable to any product, sector, or country and is shown in the Table 2 below (Galgani, Van Veen, et al., 2023). This list was used as a starting point for the total number of impacts to consider.

Environmental impacts are generally related to resource use, land use and emissions. Social impacts reflect negative effects of economics processes on workers, local communities, the global community, animals, and consumers. To simplify an assessment, it is possible to leave impacts out of scope, fully or for certain parts of the lifecycle (Galgani, Van Veen, et al., 2023). The decision to exclude impacts is based on the outcomes of the materiality analysis, as documented in Appendix 1.

Table 2 Overview environmental and social impacts (Galgani, Van Veen, et al., 2023)

	Impact category	**Unit**
Contribution to climate change	Global warming	kg CO2 eq
Air pollution	Stratospheric ozone depletion	kg CFC11 eq
Air pollution	Ionizing radiation	kBq Co-60 eq
Air pollution	Ozone formation, Human health	kg NOx eq
Air pollution	Fine particulate matter formation	kg PM2.5 eq
Air pollution	Ozone formation, Terrestrial ecosystems	kg NOx eq
Air pollution	Terrestrial acidification	kg SO2 eq
Water pollution	Freshwater eutrophication	kg P eq
Water pollution	Marine eutrophication	kg N eq
Soil pollution	Terrestrial ecotoxicity	kg 1,4-DCB
Water pollution	Freshwater ecotoxicity	kg 1,4-DCB
Water pollution	Marine ecotoxicity	kg 1,4-DCB
Air pollution	Human carcinogenic toxicity	kg 1,4-DCB
Air pollution	Human non-carcinogenic toxicity	kg 1,4-DCB
Land use	Land use	m2a crop eq
Depletion of non-renewable resources	Mineral resource scarcity	kg Cu eq
Depletion of fossil resources	Fossil resource scarcity	kg oil eq
Animal welfare	Animal welfare score	Welfare Quality Index Score

2.5 Step 5: Measure the impact

With the identification of the specific impacts within the broiler supply chain included in this research, the next step involves the procurement of reliable data sources. To perform a Life Cycle Assessment effectively, a standardized and well-accepted method is employed. Life Cycle Impact Models (LCIA) are used to estimate the environmental impact. This study used the ReCiPe 2016 Midpoint method (ReCiPe 2016 Midpoint (H) V.108 / World (2010), developed through cooperation between RIVM, Radboud University, Leiden University and Pré Consultants (Huijbregts et al., 2017).

The environmental impact of broiler meat is modelled using the Agri-footprint-economic library in the software program Simapro 9.5 Agri-footprint is a comprehensive LCI database about agricultural products: feed, food and biomass. The latest version, Agri-footprint 6.3, covers a wide range of impact categories including those related to water, land use, land use change, fertilizers, and pesticides (PRé Sustainability, 2020).

In addition, literature review was used to understand the broiler supply chain, validate data and find information to answer the research questions.

2.6 Step 6: Value the impacts

After the impacts have been quantified, the next step in calculating the True Price is to monetize them. This can be done using various methods described in the introduction. This study uses the PPP 'True and Fair Price for Sustainable Products' method (Galgani, Van Veen, et al., 2023). The factors have been developed for the Netherlands and on a global level. Because broiler production is cross-border, the global factors have been chosen. Using these factors, the external costs can be calculated. These external costs reflect the social and environmental costs related to the impact category and can be calculated as follows:

$$External\ cost = footprint\ indicator\ x\ monetization\ factor \quad (1)$$

Once this is calculated for all impact categories, the external costs for each impact is shown in euros. Monetization factors are specified in the separate impact-specific modules, as shown in the Table 3 on the following page.

2.7 Step 7: Integrate the impacts

Then the external costs can be integrated, in a true price gap by adding them all together. In the integration step, it is important to ensure that the impacts are all expressed in a monetary unit before combining them into the final true price.

$$True\ price\ gap = \sum(External\ cost) \quad (2)$$

The sum of the true price gap of a product and the market price, the price at which this product is on average bought and sold, represents the true price.

$$True\ price = market\ price + true\ price\ gap \quad (3)$$

An overview of the monetization factors is given in Table 3 on the next page.

Table 3 Overview of monetization factors

Impact category	Impact indicator	Unit	Type of costs	Monteziation factor	Price level	Source
Contribution to climate change	Global warming	kg CO2 eq	Abatement cost	0.168 EUR/kg CO2 eq	2023	(Galgani, Woltjer, et al., 2021)
Air pollution	Stratospheric ozone depletion	kg CFC11 eq	Damage cost	56.21 EUR/kg CFC11-eq	2020	(Galgani, Woltjer, et al., 2023)
Air pollution	Ionizing radiation	kBq Co-60 eq	Damage cost	0.000876 EUR/kg Co-60 eq	2020	(Galgani, Woltjer, et al., 2023)
Air pollution	Ozone formation, Human health	kg NOx eq	Damage cost	0.09 EUR/kg NOx-eq	2020	(Galgani, Woltjer, et al., 2023)
Air pollution	Fine particulate matter formation	kg PM2.5 eq	Damage cost	64.84 EUR/kg PM2.5 eq	2020	(Galgani, Woltjer, et al., 2023)
Air pollution	Ozone formation, Terrestrial ecosystems	kg NOx eq	Damage cost	2.85 Damage to ecosystems	2020	(Galgani, Woltjer, et al., 2023)
Air pollution	Terrestrial acidification	kg SO2 eq	Damage cost	4.68 EUR/kg SO2-eq	2020	(Galgani, Woltjer, et al., 2023)
Water scarcity	Scarce water use	M3	Restoration cost	1.29 EUR/m3	2020	(Galgani, Woltjer, Kanidou, De Adelhart Toorop, & De Groot Ruiz, 2021)
Water pollution	Freshwater eutrophication	kg P eq	Abatement cost	203 EUR/kg P-eq to freshwater	2020	(Galgani, Woltjer, et al., 2023)
Water pollution	Marine eutrophication	kg N eq	Abatement cost	14.07 EUR/kg N-eq to marine water	2020	(Galgani, Woltjer, et al., 2023)
Soil pollution	Terrestrial ecotoxicity	kg 1,4-DCB	Damage cost	0.0018 EUR/kg 1,4-DCB emitted toseawater eq	2020	(Galgani, Woltjer, et al., 2023)
Water pollution	Freshwater ecotoxicity	kg 1,4-DCB	Damage cost	0.040 EUR/kg 1,4-DCB emitted to freshwater eq	2020	(Galgani, Woltjer, et al., 2023)
Water pollution	Marine ecotoxicity	kg 1,4-DCB	Damage cost	0.0018 EUR/kg 1,4-DCB emitted to seawater eq	2020	(Galgani, Woltjer, et al., 2023)
Air pollution	Human carcinogenic toxicity	kg 1,4-DCB	Damage cost	0.342 EUR/kg 1,4 DCB	2020	(Galgani, Woltjer, et al., 2023)
Air pollution	Human non-carcinogenic toxicity	kg 1,4-DCB	Damage cost	0.023 EUR/kg 1,4 DCB	2020	(Galgani, Woltjer, et al., 2023)
Land use	Land use	m2a crop eq		2,118EUR2020/MSA.ha.yr	2020	(Galgani, Woltjer, de Adelhart Toorop, de Groot Ruiz, Varoucha, et al., 2021)
Depletion of non-renewable resources	Mineral resource scarcity	kg Cu eq	Remediation cost	0.225 EUR2020/ kg Cu-eq	2020	(Galgani, Woltjer, De, Toorop, & De Groot Ruiz, 2021)
Depletion of fossil resources	Fossil resource scarcity	kg oil eq	Remediation cost	0.446 EUR2020/kg oil-eq	2020	(Galgani, Woltjer, De, Toorop, & De Groot Ruiz, 2021)
Animal welfare	Animal welfare score	Welfare Quality Index Score	Abatement cost	4.52 EUR/ kg live weight	2023	(Vissers et al., 2023)

2.8 Step 8: Interpret and tests the results

Interpretation is the process of drawing conclusions from the results, while testing refers to an evaluation of the quality of the results. The results should be interpreted in the context of the true price concept.

2.9 Step 9: Report

The last step, Step 9: Report, includes the reporting of the true price assessment.

3. Results

The results are broken down by research question.

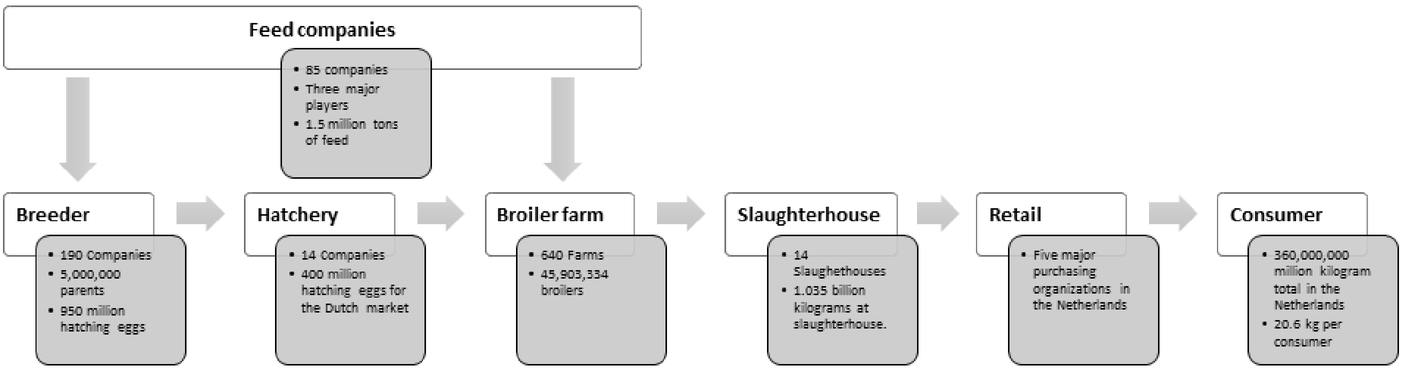
3.1 The broiler value chain

The broiler meat industry is a relatively young industry in the Netherlands. In the years before and immediately after World War II, mainly laying hens and fattened cockerels of laying breeds were sold as poultry meat. Starting in 1960, further development and specialization of the industry became possible, driven by agricultural policies focused on efficiency. During this period, the first integrations in Dutch poultry farming emerged. The advantage of this was the better matching of production to consumer demand. However, an important disadvantage of these integrations was the concealment of prices and the loss of independence of broiler farms. This led to the fact that part production emerged, and broilers were delivered at heavier weights around 1965 (Houwers et al., 2004).

These developments in the broiler industry have resulted in a complex set of organizations and companies influencing each other in various ways. Whereas in other major poultry meat producing countries such as Brazil and the United States, as well as closer in France and Italy, production is largely in hands of integrations, in the Netherlands it is still mostly independent operators (van Horne, 2007). Each of these companies is responsible for producing a product that is supplied to the next company in the value chain, as shown in Figure 4 below.

The main economic indicators of the poultry sector are economic value added and the employment it provides. The added value of the total chain is 1.59 billion euros with employment for 22,500 people. This means that each poultry farmer keeps 12 people employed in the chain. It should be noted that this data consists broiler and egg production.

Figure 4 Overview of the value chain



3.1.1 Breeding

The first stage of the value chain are the farms that provide the reproduction of the broilers. The eggs of the hens at a breeding farm are meant to hatch. These eggs are therefore fertilized and called hatching eggs. At a breeding and raising farm, the hens and roosters are kept that are supplied by a breeding organization. In the Netherlands, there are 190 breeding companies (van Horne, 2022).

The income (excluding the VAT) for the rearing of broiler parent stock is calculated per 100 hens reared with an age of 22 weeks. Revenues consist of hatching eggs, consumption eggs, slaughter animals and selection animals. Costs consist mainly of feed and other allocated costs such as electricity, health care and heating. The income excluding interest amounts to 681 euros per 100 hens raised on an annual basis (Blanken et al., 2021).

3.1.2 Hatchery

The hatching eggs laid on the breeding farms are then transported to one of the 14 hatcheries in conditioned trucks. After hatching the eggs, the chicks are counted and vaccinated if necessary. In clime-controlled trucks, they are transported from the hatcheries to one of the 640 broiler farms in The Netherlands, or exported to broiler farms abroad. Key parameters for the parent rearing and one day chicken breeding production systems are shown in the Table 4 below (van Horne, 2022).

Table 4 Parameters parent rearing and one day chicken breeding

Parameter	**Unit**	**Value**
Parent rearing period length	Days	140
Parent rearing empty period length	Days	21
Reared pullet liveweight	Kg/animal	2.27
On-day chicken weight	g/animal	42
Pullet mortality rate	%	11
Pullet compound feed intake	Kg/reared pullet	4.96
One-day chicken breeding period length	Days	286
One-day chicken breeding empty period length	Days	40
Egg weight	g/egg	61.5
Parent mortality during one-day chicken breeding	%	2.2
Infertile egg output	Eggs/reared pullet	10
Hatching egg output	Eggs/reared pullet	174
Parent weight at the end of the cycle	Kg/animal	3.93
Parent FCR during one-day chicken breeding	Kg/ kg egg	4.21
One day chicken per hatched egg	#/#	0.8

3.1.3 Broiler farm

The young broilers arrive at broiler farms. These farms increased in size over the years and the number of farms decreased. Whereas in 1960 there were still 200,000 farms with chickens, this number of farms decreased sharply to a total number of 484 broiler farms in 2022, while the number of broilers slaughtered increased from 4,525 million to 45,903 million 2022. The average farm in the Netherlands then has around 84,000 broilers (CBS, 2023). Broilers are raised on broiler farms for 6 to 8 weeks to a final weight of 1.8 to 2.8 kg. After that, the broilers are taken to a slaughterhouse (van Horne, 2022).

Due to societal concerns regarding animal welfare and environmental considerations, regulatory frameworks have involved to these pressures, while the demands of supermarket chains have also shifted. This has resulted in notable transformation of broiler meat production systems. ABN Amro's projections indicate that, by 2025, the proportion of broilers reached according to the current supermarket concepts will fall to zero (Berntsen et al., 2021). Table 5 below presents a breakdown of estimates for both current and projected broiler systems.

Table 5 Broiler production systems

System	Current estimate	Estimate for 2025
Conventional	60 – 65%	20 – 40%
Supermarket	25 – 30%	0%
Beter Life 1 Star	5 – 10%	60 - 80%
Organic	0 – 5%	1 – 3%

As described in the methodology, the database which is used during the study, contains only data from conventional broiler production systems. The high welfare and organic systems are not included. In conventional Dutch broiler production, the period length for rearing is 42 days, followed by an eight day empty period. The desired target weight for each broiler is 2.8 kilograms per animal. The mortality rate among broilers is 3.2%, while the feed conversion ratio indicates an efficiency of 1.55 of feed required to yield 1 kilogram of weight gain, as shown in the Table 6 below (Blonk et al., 2023).

Table 6 Parameters broiler production

Parameter	Unit	Value
Broiler period length	Days	42
Broiler empty period length	Days	8
Broiler target weight	Kg/animal	2.8
Broiler mortality rate	%	3.2
Broiler FCR	Kg/kg	1.55

Broiler meat producers have two options for the pricing of the broilers: free market or contract. Their income depends on the weight delivered per chick and the contact or market price, and is calculated per 100 chicks put up per round. The average income was 199.18 euros in 2020. The biggest cost is feed (125.20) kilograms and the chicks (33.0). Feed thus makes up 70% of the total allocated cost of broiler production. The balance excluding interest per 100 chicks put up is 139.4 euros on an annual basis (Blanken et al., 2021).

3.1.4 Slaughterhouse

When the broiler reaches the desired weight, they are transported to the slaughterhouse. In the Netherlands, this sector is highly concentrated. There are, as seen in Table 7 below, only four major slaughterhouses, namely: Plukon Food Group, Sisters Storteboom, Esbro and Clazing (Nepluvi, 2020)

Table 7 Overview of slaughterhouses in the Netherlands

Company	**Production**	**Location**
	< 20,000 tons	
KemperKip B.V.		Uden
Van der Linden Poultry Products B.V.		Panningen
	20,000 – 50,000 tons	
Pluimveeslachterij Gebr. Heijs B.V.		Leek
Mieki Hunsel B.V		Hunsel
Pluimveeverwerking Jan van Ee		Stroe
Pluimveeslachterij C. van Miert B.V		Breukelen
CFG Frisia B.V.		Haulerwijk
	50,000 – 80,000 tons	
Van den Bor Pluimveeslachterij B.V.		Nijkerkerkerveen
	> 80,000 tons	
Sisters Stroteboom		Putten, Kornhorn
Plukon Food Group		Dedemsvaart, Blokker, Goor
Exportslachterij Clazing B.V.		Zevenhuizen
Esbro B.V.		Wehl

Around one third of the Dutch production is sold through supermarkets, restaurants and processing plants in the Netherlands. From export, about 70% goes to the surrounding countries Germany, the United Kingdom, Belgium, France and Denmark (van Horne, 2020). Dutch consumers mainly consume the fillet of the broiler. Other parts of the broiler such as the legs, wings and organs are mostly exported. This is referred to as ‘vierkantsverwaarding’ (Leenste et al., 2009).

3.1.5 Retail

Besides the fact that the slaughterhouse market is highly concentrated, this is also the case when looking at the supermarket purchasing organizations. Five major purchasing organization operate for supermarkets in the Netherlands: Ahold Delhaize, Jumbo Group, Lidl, Aldi and Superunie. These five purchasing organizations determine the assortment and make arrangements with suppliers (Gemma Tacken et al., 2021). Taking the initiative regarding broiler production systems, began in the area of animal welfare. A number of sizable retailers took the lead. They made the decision to shift their product assortment from conventional broiler meat to their own concepts with higher animal welfare. This was after the success of the first nationwide middle segment, Volwaard, was limited (Saatkamp et al., 2019). Now more and more supermarket chains are not only focusing on better animal welfare, but also on the environment and the income of the farmer. The supermarkets decided in 2021 that the entire fresh broiler meat shelf in a time frame of two years would be replaced by meat from broilers kept according to the criteria of the Better Life 1 Star.

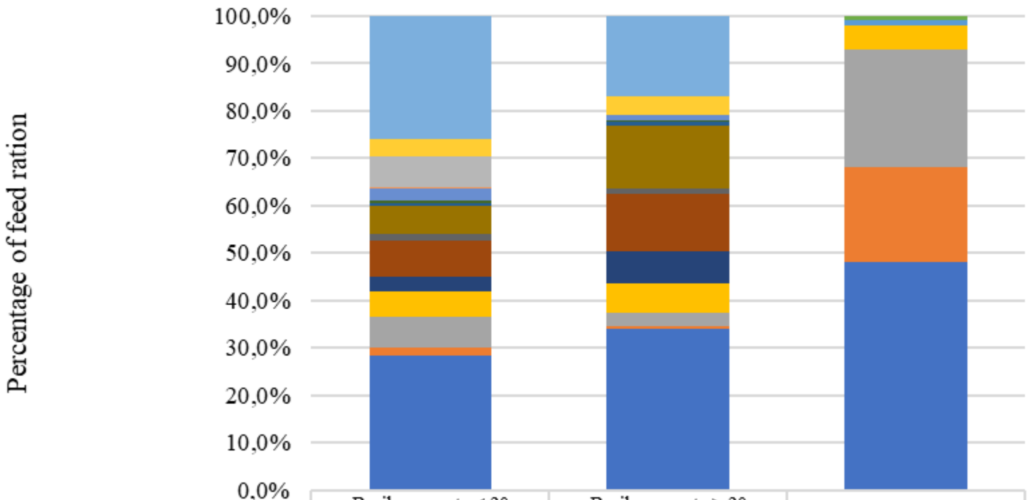
3.1.6 Consumer

The consumption market in the Netherlands consists of over 17 million people, who collectively consume 360,000,000 kilograms of poultry meat in restaurants, from catering or bought in the supermarket. This amounts to a consumption of 20.6 kilograms per person. This makes poultry the second most eaten meat type in the Netherlands after pork (36.3 kilograms per person) (Peter van Horne, 2020). Meat consumption has been shifting towards poultry. In lower income developing countries this reflects the lower price of poultry as compared to other meats, while in high-income countries this indicates an increased preference for white meats which are more convenient to prepare and perceived as a healthier food choice. Globally, poultry meat is expected to represent 41% of all the protein from meat sources in 2030, an increase of two percentage points when compared to 2020 (*FAO*, 2021).

3.1.7 Feed companies

As described, a large portion of the broiler production costs consists of feed. This feed is supplied by feed companies. There are three major companies in the Netherlands which dominate the broiler feed market, namely: De Heus, ForFarmers and Agrifirm. Together they deliver around 65% of the produced feed to broiler farms. The remaining market is divided among several dozen smaller players who often operate in a particular region or are more specialized in a particular product (Peter van Horne, 2022). While nutritional requirements of broilers is relatively consistent, the makeup of compound feeds varies notably across regions, depending on local markets and climate. For the composition of feed for broilers in the conventional sector, Agri-footprint 6 was consulted (Blonk, 2022). The compound feed of conventional broilers consists of the ingredients shown in Figure 5 on the next page, in which 100% is the total feed composition.

It is estimated that in 2020, around 10.5% of the raw feed materials is from Dutch production, 65.5% from imports from geographical Europe and 23.9% from outside geographical Europe (Veraart et al., 2023).



	Broiler parents < 20 weeks	Broiler parents > 20 weeks	Broilers
Maize gluten meal	26,0%	17,0%	0,0%
Other	3,5%	4,0%	0,0%
Citrus pulp dried	6,5%	0,0%	0,0%
Peas, dry	0,5%	0,0%	0,0%
Fat from animals	2,5%	1,0%	0,0%
Crude palm oil	0,5%	0,3%	0,0%
Oat grain	0,5%	1,0%	0,0%
Sunflower seed meal (solvent)	6,0%	13,0%	0,0%
Wheat gluten meal	1,5%	1,3%	0,0%
Wheat bran	7,5%	12,0%	0,0%
Barley grain	3,0%	7,0%	0,0%
Total minerals, additives, vitamins	0,0%	0,0%	1,0%
Calcium carbonate, precipitated	0,0%	0,0%	1,0%
Rapeseed meal (solvent)	5,5%	6,0%	5,0%
Soybean meal (solvent)	6,5%	3,0%	25,0%
Maize gluten meal	1,5%	0,5%	20,0%
Wheat grain	28,5%	34,0%	48,0%

Figure 5 Feed ration broilers

3.2 Externalities of the broiler meat supply chain

Now that the key stakeholders in the broiler value chain have been described, is the next step to identify the externalities belonging to these stakeholders. This is necessary to be able to monetize this qualitative data per indicator to a true price. Furthermore, this is of importance because the development of new, sustainable, broiler production systems requires a multi-dimensional approach. This refers to an approach that analyzes the systems in terms of their economic, ecological and social performance (Bokkers & de Boe, 2009).

(Vissers et al., 2021) reviewed Dutch newspapers and the scientific and semi-scientific literature for external factors related to broiler production systems in the Netherlands. Eleven indicators were identified, as shown in Table 8 below. These factors have been supplemented with which pillar they relate to, and whether they were included in this study. Not all of these factors are included in this study because they are not part of the impact modules and therefore there are no monetization factors for these external factors.

Table 8 Overview of external factors associated with Dutch broiler production

External factor	**Indicator**	**Impact category** Environmental	 Social	 Economic	**Stakeholder**	**Included in study**
Ammonia emission	kg NH3/animal place/year	O	O		Broiler farm	Yes
Animal health			O	O	Broiler farm, retail, slaughterhouses	No
Animal welfare	Welfare Quality index score		O		Broiler farm, retail, slaughterhouses	Yes
Antibiotic use	Defined daily doses animal		O	O	Broiler farm	No
Poultry house fire			O	O	Broiler farm	No
Global warming		O	O	O	Feed companies, broiler farm	Yes
Odor emission			O		Broiler farm	No
Particulate matter emission	g PM10/animal place/year	O	O		Broiler farm	Yes
Visual pollution			O		Broiler farm	No
Water pollution		O	O		Feed companies, slaughterhouses	Yes
Zoonoses			O	O	Broiler farm, slaughterhouses	No

Nevertheless, broiler meat production in the Netherlands does not only affect the environment in Netherlands, but also the countries from which raw materials for feed are sourced. As described in the methodology, there are eighteen impact categories which are examined in this study and this analysis will also include the impacts abroad.

Considered was the availability of data and whether the factor are part of a Life Cycle Assessment, the following factors are included in this study: ammonia emissions, animal welfare, global warming, particulate matter emission and water pollution. Because these factors were identified as the most important they will be further explained in this chapter. This will describe what these indicators mean and what the impacts is in the Netherlands.

3.2.1 Externalities within the Netherlands

Ammonia (NH_3)

Ammonia is a colorless gas and is a compound of nitrogen (N_2) and hydrogen (H_2). Ammonia causes fertilization in nature and on farmland: the soil becomes increasingly rich in nutrients. Plants that grow well on rich soils, such as grass and nettles, displace plants that grow on poor soils. As those plants disappear, so do the animals that live off those plants. Eventually there are fewer species of plants and animals: biodiversity deteriorates. Following a ruling by the Administrative Law Division of the Council of State, ammonia emission led to a legal and ecological crisis in the Netherlands since 2019. The agricultural sector is important for a large portion of the ammonia emissions (86%) in the Netherlands (RIVM, 2023).

Of this, about 12% was caused by poultry farming (Agrimatie, 2022). Looking at the total agricultural ammonia emissions, have they been stable since 2010, totaling between 110 and 115 million kilograms of ammonia. The goal of the Dutch government is to reduce these ammonia emissions by 50% in 2030 compare to the year 2020.

The trade-off between animal welfare and ammonia levels is apparent. Emission factors for ground and aviary housing is higher than that of battery housing, which offers lower animal welfare standards. This trade-off is also exemplified by the transition from conventional systems to the Better Life 1 Star systems. Ammonia emission do not decrease, and in some cases even increase at barn level, which has led regulatory authorities to withhold environmental permits due to the prevailing uncertainty surrounding ammonia emissions.

Ammonia emissions are also associated with terrestrial acidification and particulate matter formation (Heller & Salim, 2022).

Fine particulate matter

Air pollution that causes primary and secondary aerosols in the atmosphere can have a substantial negative impact on human health, ranging from respiratory symptoms to hospital admissions and death. For one of these air pollutants, particulate matter, a distinction is made between PM_{10} and $PM_{2.5}$. Particulate matter formation consist of primary aerosols and secondary $PM_{2.5}$ aerosols that are formed in air from emission of sulfur dioxide (So_2), ammonia (NH_3), and nitrogen oxides (NO_x), among other elements. According to epidemiologic research, exposure to fine particulate matter formation is linked to a number of negative health outcomes and a shortening of life expectancy, including lung cancer, diabetes, cardiovascular morbidity and adverse birth outcomes (Fantke, 2022).

It is therefore very important to tackle this problem at the source, in this case broiler farms in the Netherlands. With a 64% share, poultry farming is the main source of particular matter in agriculture and horticulture. Therefore, in areas with many poultry farms such as Gelderse Vallei, De Meijerij, the Peel area, and parts of Twente, the concentration of particulate matter is relatively high compared to other regions in the Netherlands. In poultry farming, fine particular matter emissions doubled between 1995 and 2015 as a result of the transition from battery housing to floor and aviary housing (Leusink, 2022). Which shows that there is not only a trade-off between ammonia and housing systems, but also between housing systems and particulate matter.

As part of air quality policy, limit values for PM10 particulate matter were set by the European Union in 1999. Regulations for the finer fraction (PM2.5) followed in 2008. In almost all of the Netherlands, calculated concentrations of particulate matter were below the European limits in the year 2020. Locally, there are still some exceedances. In several cities, this is due to heavy traffic and in rural areas due to livestock farms. The Clean Air Agreement, signed in 2020, sets the goal of reducing emissions from agriculture by 37% in 2030 compared to 2016. For poultry farming, it was agreed that fine particular matter emissions should be halved in 10 years with barn measures (RIVM, 2021).

Global warming

Climate change poses one of the biggest risk to current food systems. Agriculture is not only affected by climate change, but also responsible for a large part of total emissions. In the Netherlands, the goal for agriculture is to reach a maximum emission of 18.9 megatons of CO2 equivalent by 2030 (Brand, 2023). That is about 30 percent less than the total greenhouse gas emissions from agriculture in 2021. Most of the emissions of the greenhouse gases from agriculture are emitted by ruminants, particularly cattle, and by methane which is created in manure stores (e.g., on pig, poultry and cattle farms).

The greenhouse gas emissions are about 70% from cattle farming and about 20% from pig farming. Approximately 10% come from the other livestock sectors such as poultry, goats and sheep (RVO, 2023). Although poultry farming in the Netherlands is not a significantly high contributor to emissions, it should be heavily committed to reduction of CO2 encouraged by retail. For example, pig and poultry farmers who participate in the Albert Heijn project 'Better for Nature & Farmer' must significantly reduce their CO2 emissions. They have to reduce 45 percent of the emissions in 2030, compared to 2018 (AH, 2022). It should be noted here that this does not apply only to production in the Netherlands, but across the entire value chain.

Animal welfare

In addition to government initiatives and agricultural practices, it’s important to note that a significant driving force behind the growing emphasis on animal welfare in the Netherlands is the strong societal pressure and awareness on the issue. There is a trend toward broiler production systems with higher welfare requirements, that use slower growing broiler strains, apply a reduced stocking density and provide environmental enrichment (de Jong, 2022).

Consequently, since 2007, the government has had the ambition to increase the percentage of integrally sustainable barns (RVO, 2022). Integrally sustainable is defined as a barn or husbandry system in which several sustainability characteristics have been improved in relation to the regular applied barns or systems. These include animal welfare, as well as environmental, animal health and working conditions.

Although there is great pressure to transform housing systems, it is difficult to assign a (monetary) value to animal welfare, as this is subjective. This study used the Welfare Quality Index.

Water pollution

Clean water is important for many reasons: for example, public health, agriculture, food, biodiversity, tourism and recreation. But water quality is under pressure, especially due to agricultural intensification, chemical pollution, climate change and urbanization (WUR, 2023).

Because the quality of surface and groundwater in the Netherlands is insufficient, the Netherlands is at risk of not meeting the standards for the European Water Framework Directive. In addition, water is becoming increasingly scarce not only in the Netherlands, but worldwide. It is therefore of great importance that the poultry industry is committed to reducing the use of water and fewer emissions to water, across the entire chain.

3.2.2 Value of footprint indicators of the broiler value chain (step 5)

Now that the total emissions in the Netherlands are known, the externalities of broiler meat production can be further assessed through Life Cycle Assessment, where cross-border impacts are included. Table 9 below summarizes the results per kilogram of carcass weight broiler from cultivation to the end of the slaughter process across all scenarios and impact categories. The indicators included below are based on the midpoint indicators and sources as indicated in the methodology. The indicator on animal welfare is based on 'A method for calculating the external costs of farm animal welfare based on the Welfare Quality Protocal' by Vissers (2022), and applies only to broiler farms.

Table 9 List and value of the footprint indicators

	Impact category	**Unit**	**Results**
Contribution to climate change	Global warming	kg CO2 eq	3,58007910
Air pollution	Stratospheric ozone depletion	kg CFC11 eq	0,00002098
Air pollution	Ionizing radiation	kBq Co-60 eq	0,04620864
Air pollution	Ozone formation, Human health	kg NOx eq	0,00709932
Air pollution	Fine particulate matter formation	kg PM2.5 eq	0,02085829
Air pollution	Ozone formation, Terrestrial ecosystems	kg NOx eq	0,01021306
Air pollution	Terrestrial acidification	kg SO2 eq	0,02268249
Water pollution	Freshwater eutrophication	kg P eq	0,00112144
Water pollution	Marine eutrophication	kg N eq	0,00353106
Soil pollution	Terrestrial ecotoxicity	kg 1,4-DCB	6,24581660
Water pollution	Freshwater ecotoxicity	kg 1,4-DCB	0,25561016
Water pollution	Marine ecotoxicity	kg 1,4-DCB	0,09967335
Air pollution	Human carcinogenic toxicity	kg 1,4-DCB	0,03598670
Air pollution	Human non-carcinogenic toxicity	kg 1,4-DCB	4,54028520
Land use	Land use	m2a crop eq	5,25039830
Depletion of non-renewable resources	Mineral resource scarcity	kg Cu eq	0,00343114
Depletion of fossil resources	Fossil resource scarcity	kg oil eq	0,40674922
Water use	Water consumption	M3	0,04267114
Animal welfare	Welfare Quality Index Score	Welfare Quality Index Score	139.4

Table 9, which is presented on the previous page, shows the total values of various impact of broiler meat production. However, these impacts are not uniformly distributed throughout the broiler value chain. Figure 6 employs a contribution analysis to visually depict the specific contributions of each link in the production chain to the overall impact category, with the total sum representing 100% of the impact.

As illustrated in the contribution analysis below, it becomes evident that the majority of the externalities within the broiler meat production are primarily attributed to the production of animal feed. It is noteworthy, however, that with regards to fine particulate matter and terrestrial acidification, animal feed production does not constitute the largest source of externalities. Moreover, the slaughtering process predominantly influences ionizing radiation, ozone formation, fossil resource utilization, and human carcinogenic toxicity, which can be primarily attributed to the utilization of electricity in the slaughter facilities.

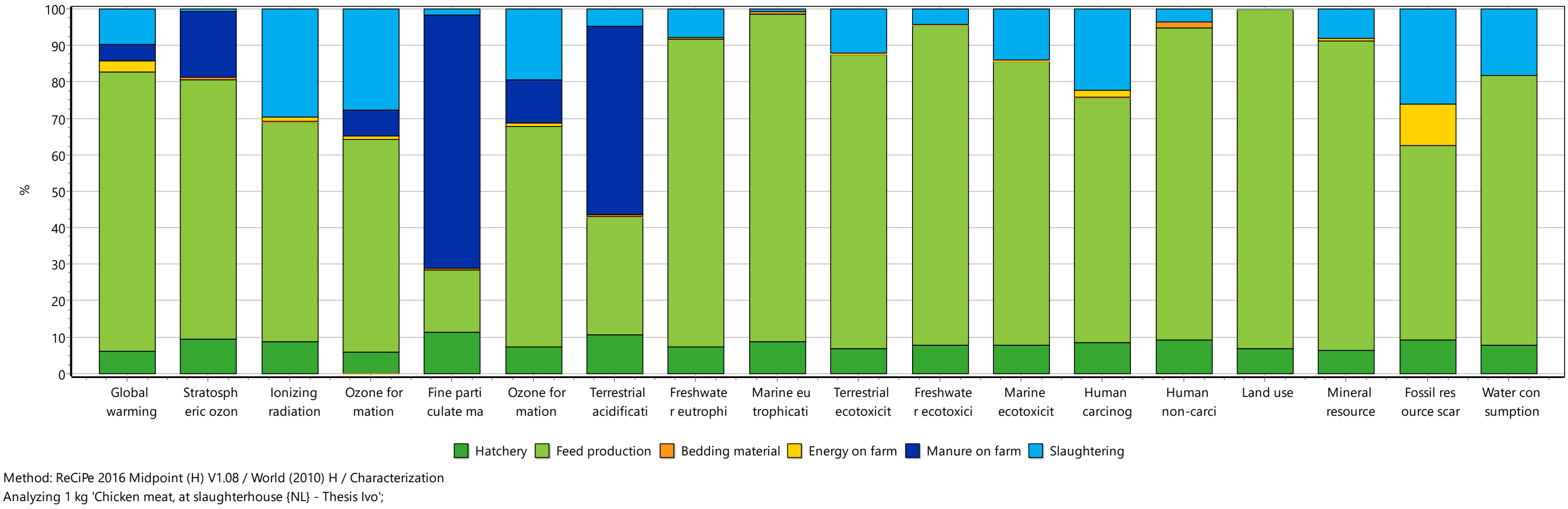


Figure 6 Contribution analysis of the Life Cycle Assessment

3.3 The price of the externalities (step 6)

The impact values of the externalities associated with broiler meat production in the Netherlands can now be monetized to give them an economic value. These external costs are the elements that form the true price cap.

Table 10 lists the monetization factors used in this study, which type of price and which module was used for these monetization factors can be found in the method and methods. The table shows that around 90% of the price of the externalities during the production of broiler meat in the Netherlands are related to global warming, fine particular matter formation, freshwater eutrophication, land use and fossil resource scarcity. The sum of all external costs, except animal welfare, related to broiler meat production in the Netherlands is 3.77 euros.

In the rest of this chapter, the externalities will be explained per indicator and will be clarified if the results make sense, what the largest and smallest impacts are and what the surprising outcomes are.

Table 10 Monetization of externalities

Impact category	**Impact indicator**	**Unit**	**Value of indicator**	**footprint**	**Monteziation factor**	**Value of external costs**
Contribution to climate change	Global warming	kg CO2 eq	3.580	x	0.168 EUR/kg CO2 eq	0.60144
Air pollution	Stratospheric ozone depletion	kg CFC11 eq	0.000	x	56.21 EUR/kg CFC11-eq	0.00000
Air pollution	Ionizing radiation	kBq Co-60 eq	0.046	x	0.000876 EUR/kg Co-60 eq	0.00004
Air pollution	Ozone formation, Human health	kg NOx eq	0.007	x	0.09 EUR/kg NOx-eq	0.00063
Air pollution	Fine particulate matter formation	kg PM2.5 eq	0.021	x	64.84 EUR/kg PM2.5 eq	1.36164
Air pollution	Ozone formation, Terrestrial ecosystems	kg NOx eq	0.010	x	2.85 Damage to ecosystems	0.02850
Air pollution	Terrestrial acidification	kg SO2 eq	0.023	x	4.68 EUR/kg SO2-eq	0.10764
Water scarcity	Scarce water use	M3	0.043	x	1.29 EUR/m3	0.05547
Water pollution	Freshwater eutrophication	kg P eq	0.001	x	203 EUR/kg P-eq to freshwater	0.20300
Water pollution	Marine eutrophication	kg N eq	0.004	x	14.07 EUR/kg N-eq to marine water	0.05628
Soil pollution	Terrestrial ecotoxicity	kg 1,4-DCB	6.246	x	0.0018 EUR/kg 1,4-DCB emitted toseawater eq	0.01124
Water pollution	Freshwater ecotoxicity	kg 1,4-DCB	0.256	x	0.040 EUR/kg 1,4-DCB emitted to freshwater eq	0.01024
Water pollution	Marine ecotoxicity	kg 1,4-DCB	0.100	x	0.0018 EUR/kg 1,4-DCB emitted to seawater eq	0.00018
Air pollution	Human carcinogenic toxicity	kg 1,4-DCB	0.036	x	0.342 EUR/kg 1,4 DCB	0.01231
Air pollution	Human non-carcinogenic toxicity	kg 1,4-DCB	4.540	x	0.023 EUR/kg 1,4 DCB	0.10442
Land use	Land use	m2a crop eq	5.250	x	2,118EUR2020/MSA.ha.yr	1.03005
Depletion of non-renewable resources	Mineral resource scarcity	kg Cu eq	0.003	x	0.225 EUR2020/ kg Cu-eq	0.00068
Depletion of fossil resources	Fossil resource scarcity	kg oil eq	0.407	x	0.446 EUR2020/kg oil-eq	0.18152
Animal welfare	Animal welfare score	Welfare Quality Index Score	139.4	x		4.52

External cost of climate change

Climate change is an indicator of potential global warming due to emissions of greenhouse gases to the air. The costs related to climate change are based on the costs to prevent the last ton of CO2 from being emitted once the target is reached (abatement costs) and can divided into three sub-categories based on the emission source: Fossil resources, bio-based resources and land use change (Galgani, Woltjer, De, Toorop, De Groot Ruiz, et al., 2021).

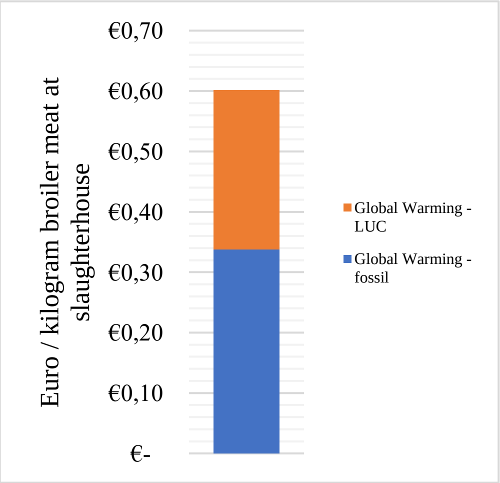


Figure 7 External costs of climate change

The total external cost attributed to the contribution of climate change of broiler meat is 0.60 euro. Of this, 0.26 euro is attributable to land use change and 0.34 euro to fossil resources. This is , as shown in the contribution analyses, largely due to the land use change, i.e. land that has been converted to agricultural land over the past 20 years for the agricultural production.

External cost of air pollution

The total external cost attributed to air pollution during the production process of broiler meat, as shown in Figure 8, is 1.61 euro. Fine particular matter formation contributes most to the external costs of air pollution, namely 1.35 euro (84.2%). This is due to the high costs attributed to damages by this externality. This is followed by terrestrial acidification 0.11 euro (6,9%) and human non-carcinogenic toxicity 0.10 euro (6.3%).

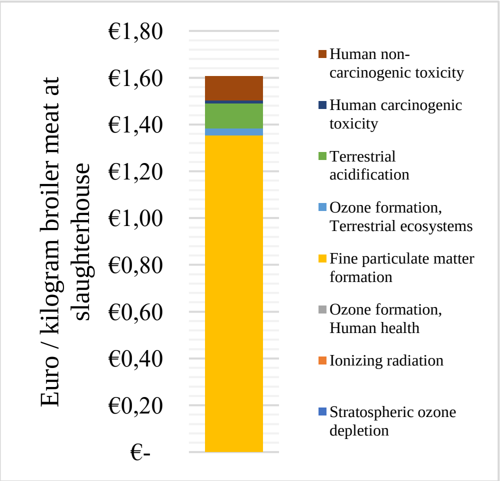


Figure 8 External costs of air pollution

External cost of water related indicators

The total external cost of water related indicators is 0.34 euro, and with an estimated cost of 0.23 euro freshwater eutrophication has by far the greatest impact in the water category. This is followed by water consumption (0.06 Euros) and water ecotoxicity (0.05 Euros). Marine ecotoxicity has the lowest impact with an estimated cost of 0.00018 euro. All of these externalities occur during the feed production.

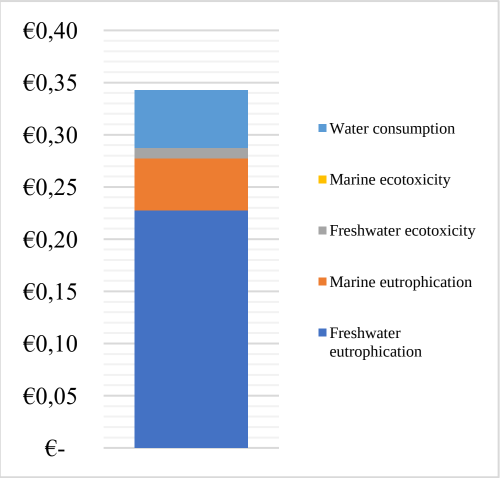


Figure 9 External cost of water related indicators

Distribution of external costs over the broiler supply chain

Now that is clear that the total external costs of the production of broiler meat in The Netherlands are 3.77 euros, it is essential to investigate where these externalities are distributed along the value chain. In the context of the broiler supply chain, it is noteworthy that feed production constitutes a substantial proportion of the total external costs, specially 58.0% of the total external costs. This finding underscores the significance of feed production in the overall environmental impact associated with broiler meat production. Following closely behind, the on farm management of manure accounts for 27.0% of the external costs, while hatchery operations contribute 9.0% to the overall external costs.

It is worth mentioning that other activities within the broiler supply chain, while present, exert a comparatively smaller influence on the external costs incurred during the production of broiler meat. These findings highlight the critical areas within the supply chain where measures and sustainability strategies may be particularly warranted, with a primary focus on feed production, on-farm manure management, and hatchery operations.

Breaking down the analysis into stages, as represented in Figure 10 below, it becomes evident that a significant portion of the total external costs, specifically 2.53 euros, is attributed to farm inputs. Furthermore, 1.07 euros are associated with on-farm activities, while an additional external cost of 0.18 euros is linked to the slaughtering process.

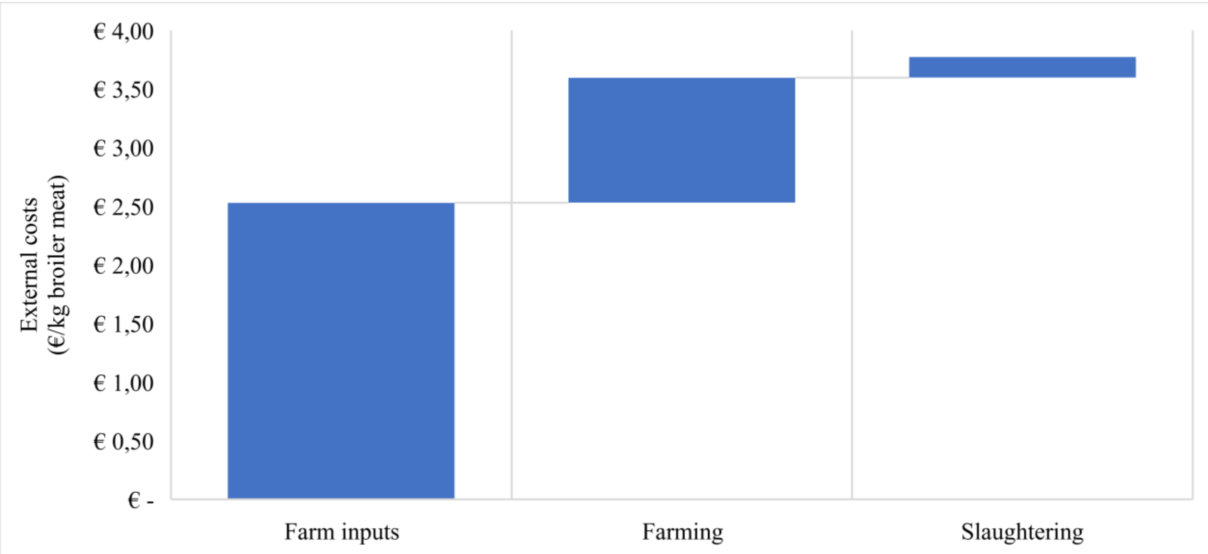


Figure 10 External costs over the value chain

3.4 The true price of broiler meat production in the Netherlands (step 7)

The broiler meat reference price at the supermarket is estimated at 7.28 euros per kilogram. As demonstrated in the previous chapter, the total external costs of production, encompassing feed production, farming, and slaughtering, are estimated at 3.77 euros. The total true price amounts to 11.05 euros, reflecting an increase of 51.8% in comparison to the current market price. The breakdown of the True Price, as shown in Figure 11, is as follows: the market price is 7.28 euros, with additional components such as a 0.60 euro contribution to climate change, 1.61 euros for air pollution, 0.29 euros for water pollution, a mere 0.01 euro for soil pollution, 1.03 euros for land use, zero euros for depletion of non-renewable resources, 0.18 euros for depletion of fossil resources, and 0.06 euros for water consumption.

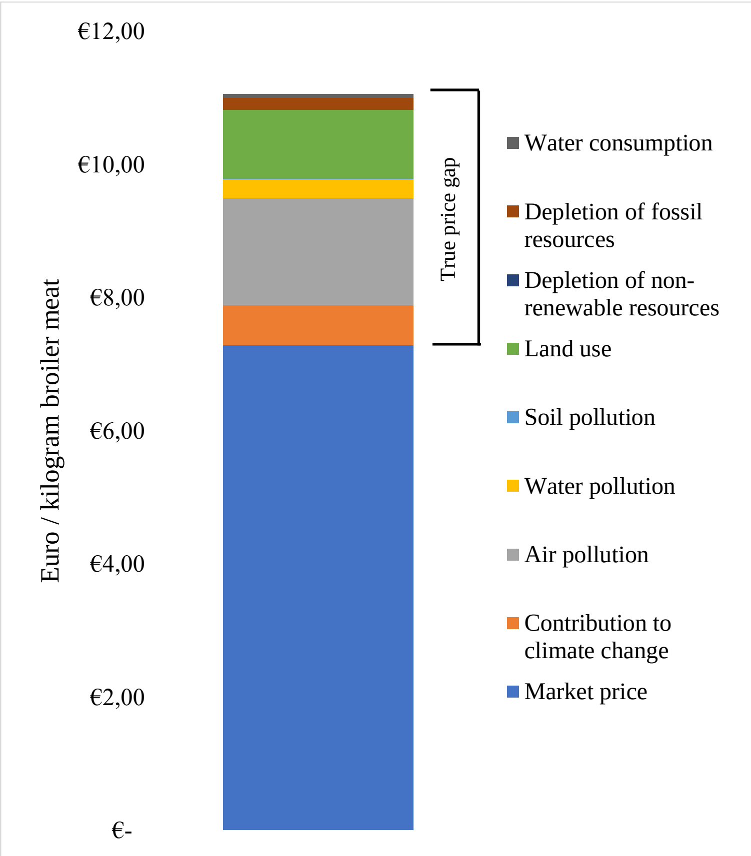


Figure 11 True price of broiler meat

3.5 Measures to narrow the gap between the markt price and the true price

<u>Overall impact</u>

Stakeholders involved: feed companies, farmers and retail

As the contribution analysis in Figure 6 shows, a large part of the external impacts of broiler meat production in the Netherlands are caused by the production of feed, for which the majority of crop cultivation takes place abroad. The highest impact from feed production is caused by soybeans from Brazil, this due to deforestation which takes place in order to increase agricultural lands. The carbon stored in in several carbon pools in these forests (for example above ground biomass, surface litter, dead organic biomass, release of soil nutrients) is released due to deforestation. LCA takes these emission into account, which are a result of Land Use Change (LUC) (Blonk, 2022). This makes crop cultivation may have additional negative effects on climate change. In addition to this contribution to global warming, the use of land to produce animal feed accounts for 27% of the external costs.

Partly because of the powerful market position of feed manufacturers, it is possible to control feed composition. For example, it is possible to reduce the impact on the external cost by replacing soybeans from Brazil with soybeans from other countries, which are not grown on land for which land is being transformed calculated over a 20-year period. One of these countries is the United States, which along with Brazil accounts for 83 percent of the global exports of soybeans (ERS, 2021). The United States exported 59 a million metric ton of soybeans and Brazil exported 63 million metric ton, while Argentina was the third-leading exporter with 6.9 million metric ton in 2016. In fact, 90% of the imports into the Netherlands were soybeans from Brazil and the United States. The price difference between the two beans on the market is almost zero (USDA, 2022).

It is possible to create various modeling scenarios in SimaPro with parameters on a project level. To find opportunities to reduce the true price gap, three scenario analysis where conducted to test the sensitivity: one default scenario, one with soybeans from Brazil and one with soybeans from the United States.

The Figure 12 below shows the results for the environmental indicators across three scenarios, in which 100 indicates the highest impact of the three options. The results show that compared to the baseline values (default scenario) the impact on global warming is reduced by 39.9% when only soybeans produced in the United States are used. In addition, large impacts can be observed on freshwater eutrophication (-18.65%), land use (-15.4%) and terrestrial ecotoxicity (-7.7%). However, soybean production in the United States does use significantly more water (+47.7%) and ionizing radiation increases by 8.8%.

However, it must be taken into account that changing the feed composition can lead to higher prices, this while as described earlier, feed costs account for over 70% of the total production costs. According to ABN Amro (2022), one percent reduction in the carbon footprint of a standard poultry feed will result in approximately 10 cents per 100 kg in additional costs.

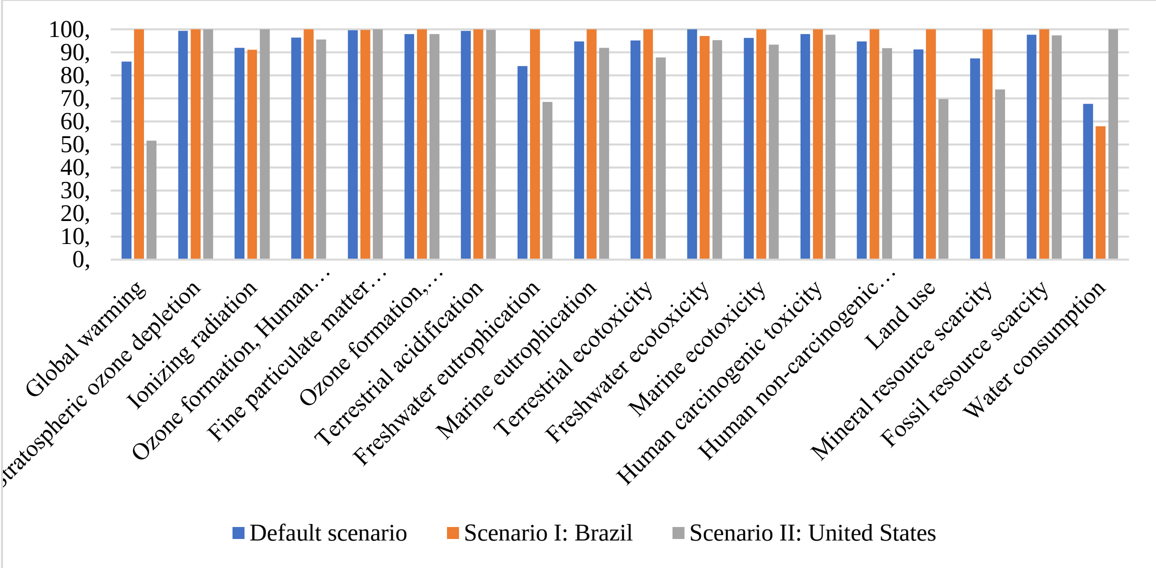


Figure 12 Scenario analysis soy

When these externalities are monetized as previously done, it emerges that the true price of broiler meat from broilers feed with just soyabeans from the United States is 18.6% lower that when feed with only soyabeans from Brazil. In addition, external costs in this scenario are 13.2% lower than in the standard scenario where a combination of the two countries is conducted.

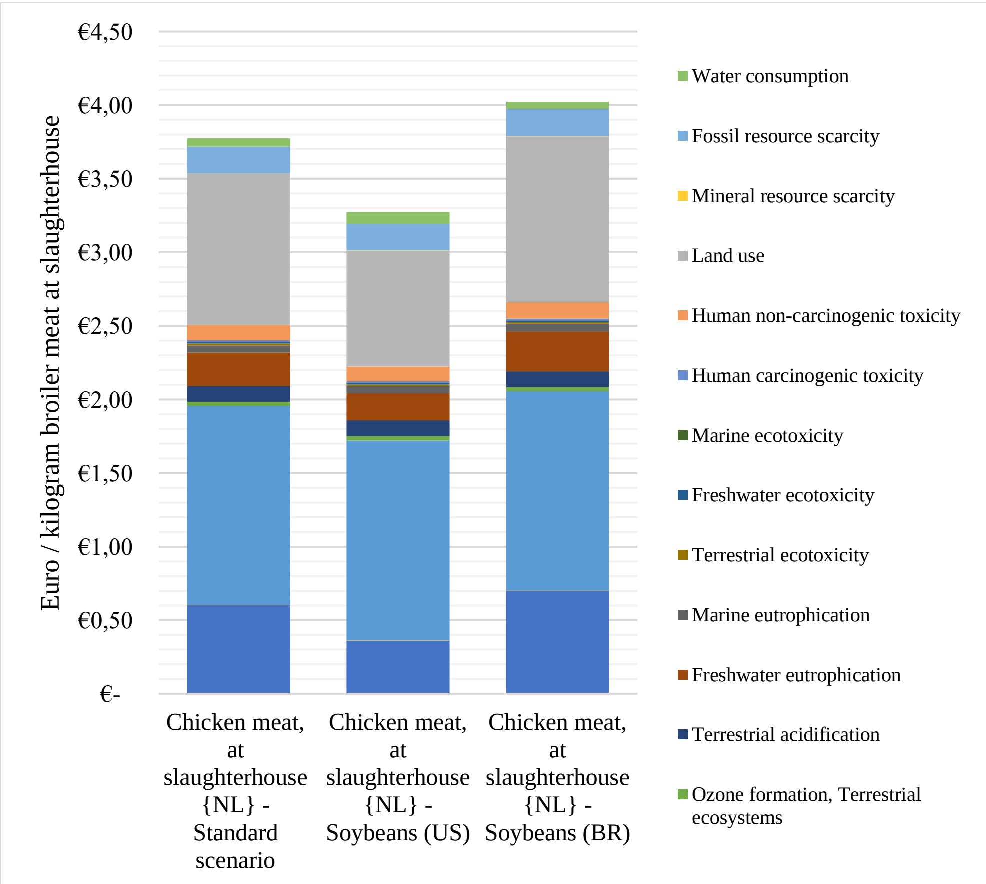


Figure 13 Scenario analysis soybeans

Replacing soy with animal protein

Stakeholders involved: Feed companies, farmers, governmental institutions, retailers

In addition, one option to mitigate the externalities associated with soy, one viable strategy is to explore the replacement of soy with alternative protein sources. While one option is to replacing Brazilian soy with soy sourced from the United States, an other option is to consider substituting soy with animal protein.

AgruniekRijnvallei has taken a step in this direction by incorporating animal protein into conventional and VLOG poultry feed. The source of this processed animal protein is Sonac, which derives pig protein from processed meat industry by-products. Importantly, these by-products originate from animals approved for human consumption (Agruniek, 2023).

Nevertheless, it is crucial to acknowledge that comprehensive research in terms of animal welfare, economic feasibility, and environmental impact is still in its infancy in this domain. Therefore, before fully embracing the integration of animal protein alternatives into feed production, it is recommended to conduct further studies and assessments. These studies should assess the effects on animal health and well-being and risks, evaluate the economic viability of this approach, and analyze the potential environmental consequences.

Fine particulate matter formation

Besides the impact of soybeans on the true price gap of broiler meat production in the Netherlands, fine particulate matter accounts for over a third of the external costs. This is due the fact that the monetization factor for this indicator is relatively high.

Assuming the targets also apply to PM2.5, with regard to halving emissions, and these are met. Then the true price gap would decrease by 17.9% from €3.77 to €3.10.

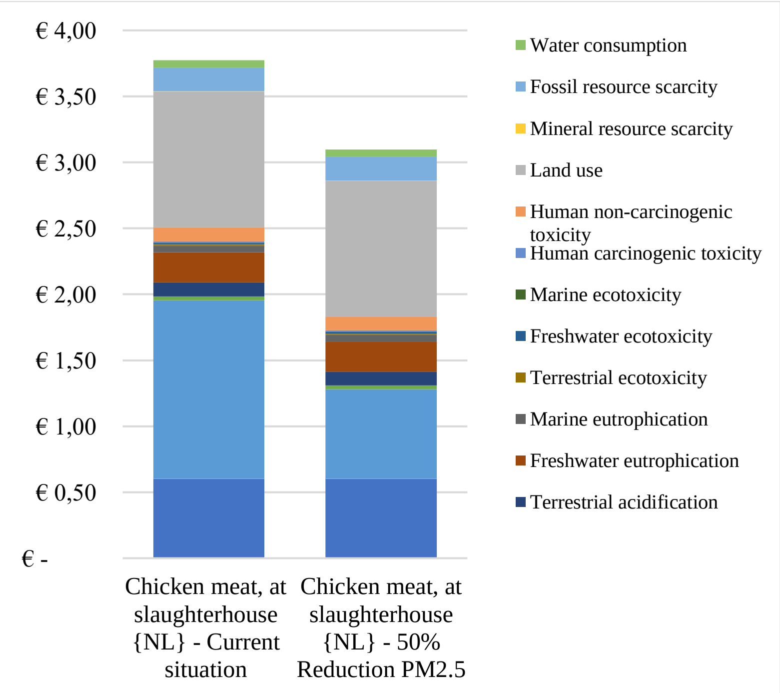


Figure 14 Scenario analysis fine particulate matter

Scenario analysis animal welfare

Figure 15 below shows the results for the environmental and social indicators across two scenarios. A scenario in which animal welfare was applied to conventional broiler production as done throughout the study. And a scenario in which the externalities of higher welfare broiler production were estimated. These estimates were made using the study: 'Environmental implication of alternative pork and broiler production systems in the US, China, Brazil, and the EU' (Heller, 2022), shown in Appendix 2. Which was carried out in a project with World Animal Protection.

We can conclude that while the higher welfare estimated scenario shows higher impacts in some categories, but both scenarios have no impact in various other categories like stratospheric ozone depletion, ionizing radiation, ozone formation for human health, and various ecotoxicity categories. The greatest price differences can be seen in the following categories: human non-carcinogenic toxicity (+18.6%), fine particulate matter formation (+17.0%) and stratospheric ozone depletion (+13.9%). The total price increase from conventional to higher welfare is estimated at 3.5%.

The price difference in animal welfare is only 4.2% leaving the external cost of animal welfare relative high at 4.33 euros. According to the method of calculating the price of animal welfare (Vissers, 2023), the external cost of animal welfare of the broiler production systems have been caused by the major differences between the maximum score of animal welfare of 270 and the animal welfare score of the production systems.

Which would mean that all the production systems are far from optimal for the broiler, this because organic production of broilers scores 199.3 points, 1 star 170.3 points and conventional 139.4 points. In addition to this large differences in scores, there are some other implications attributable to the method of calculating the true price of animal welfare, which are described in the discussion and implications chapter.

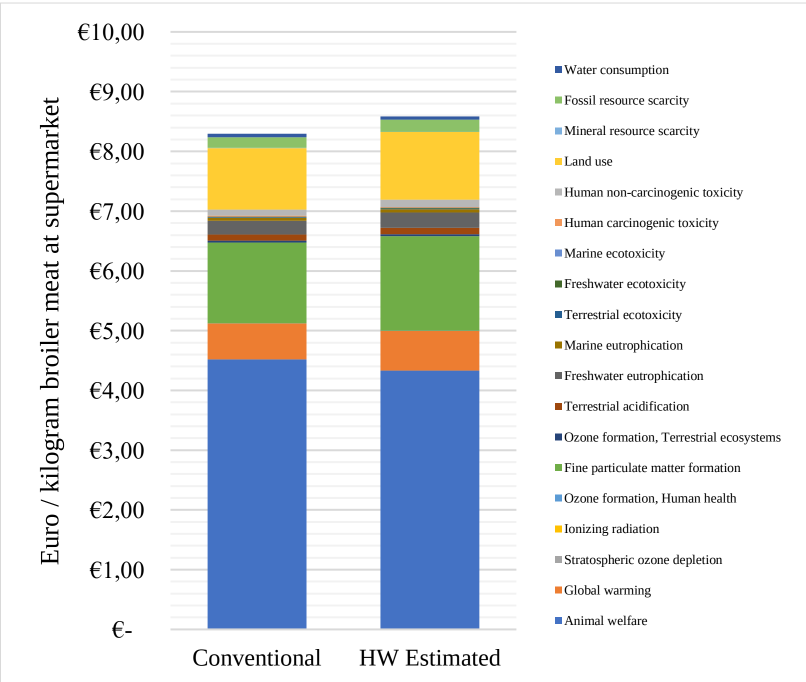


Figure 15 Scenario analysis animal welfare

4. Discussion and conclusions

While broiler meat is part of the daily diet of consumers, is there a lack of consideration for the environmental and social costs associated with broiler meat production within the current market pricing. True Pricing is mentioned as part of a move towards a more sustainable agricultural sector and can be used by stakeholders to implement effective measures and their integration into decision-making processes.

The objective of this study was to analyze the True Price of broiler meat produced in the Netherlands, with the aim of providing critical insight to stakeholders along the supply chain, including farmers, government, bank and slaughterhouses. These insights are intended to empower these stakeholders with information needed to make well-informed decisions regarding sustainability within the broiler supply chain.

This research showed that a significant portion of the external costs associated with broiler meat production can be attributed to the production of feed, outside the country's borders. Notably, the most impacts comes from soybean cultivation in Brazil, primarily due to the deforestation activities aimed at expanding agricultural lands. Within the borders of the Netherlands, a substantial share of the costs can be linked to the emission of fine particulate matter at broiler farms.

This chapter conducts a critical examination of the robustness of the results, taking into consideration aspects such as geographical representation, technological relevance, and methodological soundness. Followed by the questions for further research, the identified limitation and the conclusion.

4.1 Answer to the aim

The aim of this study was to make transparent the true price of broiler meat produced in the Netherlands. To offer the knowledge required for actors in the Dutch broiler supply chain (farmers, enterprises, NGOs, and governments) to make informed sustainability decisions.

A literature review was conducted to investigate the value chain of broiler meat production within the Netherlands. The analysis revealed the international structure of this value chain, encompassing the importation of input products and the exportation of meat products. Furthermore, it became evident that certain segments of the value chain, notable slaughterhouses and retail purchasing organizations, exhibited substantial levels of concentration.

The next phase of the research measured and valued the externalities related to the broiler value chain. The results show that the sum of all external costs related to broiler meat production in the Netherlands is 3.77 euros. Fine particulate matter formation has the largest impact on the true price gap at 1.35 euro, followed by land use (1.03 euro) and global warming (0.60 euro). The main measures to reduce these externalities focus on feed composition and barn system measures. Overall, it can be concluded that through True Cost Accounting it can be made clear which externalities arise within the chain, and which parties are responsible for these externalities.

4.2 Discussion

The data quality should be sufficient to meet the aim of this research. Data quality is determined by several aspects on the Product Environmental Footprint recommendations:

- Time representativeness

Time representativeness implies that the data used reflects specific conditions of the product under study in terms of time. The data sources used were all published within the last five years. However, diving deeper into these sources reveals that for example the feed composition of the broilers is based on confidential information from major feed producers in the Netherlands from the year 2010. So it is possible that, in this case, the feed composition has changed in recent years. It may be that this data has been superseded by changes in the composition of feed, however, no information on this was found and has not been taken into account in this study.

Furthermore, in the past year and during this study, feed prices have risen sharply due to the war in Ukraine. This may affect production systems, feed compositions and the market price of broiler meat. This was not considered during this study. This can have impacts both positive and negative, and is important to consider in future studies particularly when geopolitical circumstances necessitate such considerations.

- Geographical representativeness

Geographical representativeness implies that the data reflects specific conditions of the product under study in terms of geographical area. The data used in this study represents the broiler production system in the Netherlands. Because the input products are imported, and externalities there take place across borders, it was chosen to use global monetization factors in stead of monetization specific for the Netherlands. However, this has the disadvantage of not distinguishing where the emission take place (in The Netherlands or abroad) and what the costs of these externalities are, which leads to a higher uncertainty.

- Technological representativeness

Technological representativeness implies that the data used in this study reflects specific conditions of the product under study in terms of technology, type or organization and product. This study focuses only on conventional broiler production systems due to the lack of data of higher welfare systems. However, this is not the only system used in The Netherlands. As described in the results, estimates are that between 60-65% of the broiler production systems in the Netherlands are conventional, decreasing to 20-40% by 2025. High welfare and organic systems are not included.

Externalities are expected to be higher for these high welfare stall systems because broilers grow slower to achieve the same final weight and therefore require more feed and excrete more manure.

In addition, emission reduction technologies at housing (either due to housing design or mitigation technology such as air washers) are not considered in these systems. This leads to emissions from farms, especially particulate matter, being overestimated in this study and thus leads to higher external costs.

Looking at the parameters at broiler farm level, some differences are observable between the averages according to the KWIN and the data used in modeling:

Table 11 Broiler farm parameters

Parameter	Unit	Agrifoood	KWIN (Average)	KWIN (Range)
Broiler period length	Days	42	41	(36 – 48)
Broiler empty period length	Days	8	8	(6 – 16)
Broiler target weight	Kg/animal	2.8	2.4	(1.8 – 2.6)
Broiler mortality rate	%	3.2	3.5	(2.5 – 4.5)
Broiler FCR	Kg/kg	1.55	1.59	

- Completeness

Completeness means that the data sources cover sufficiently each impact category, in this case the scope and impacts of the study are considered.

Due to data availability in the agrifood database, some externalities were left out of scope. In particular, social externalities such as child labor, forced labor, underpayment in the value chain and negative effects of consumer health and safety were not considered. Beside these social externalities, some impacts identified in Table 3 were not included such as animal health, antibiotic use, poultry house fire, odor emission and visual pollution. This impacts the True Price by making the True Price gap smaller than if these externalities were included.

However, some of these externalities may be related to those that are included in the study, such as odor nuisance which is related to emissions from the farm. Furthermore, the size of the externalities is relatively low based on the materiality analysis. In contrast, positive externalities are also not included in this study, which would lower the True Price gap.

In addition to some externalities not being included in the study, not all links of the value chain were investigated. This study focused on the cultivation stage until the slaughter stage. The retail and consumer phase were excluded because it has been assumed that these have a minor impact. Furthermore, it is important to note that only conventional broiler meat production was considered and regulations already have a significant impact on this production system.

- Methodological appropriateness and consistency

The study method is applied uniformly to the various components of the analysis. This should be in line with the goal and scope of the assessment.

- Data uncertainty

Data uncertainty means that the variability of the data values for each data expressed (e.g., variance) is sufficiently low. This is related to the process data, not to the modelling parameters. Such analyses are often difficult in LCAs of agriculture where uncertainty of underlying data can be high but is rarely reported. There is an uncertainty in the data used in this study because it assumes the national average of broiler production in the Netherlands. Beside this uncertainty, for example PM10 was assigned as PM2.5 in this study, which led to a higher price of this externality. The True Price is paid on chicken in Dutch supermarkets, which is an overestimated price, because the costs of the externalities are not recovered abroad.
A literature review is a comparison of the findings with those of studies with a similar focus. This study arrives at a higher price of externalities than that of CE Delft, which can be explained by the fact that more impacts were included in the study. Additionally, expert consultation of the material impacts and the Life Cycle Assessment is not included in this study.

In addition to the uncertainty in data, there are implication related to the impact modules. For example, emissions from land use and land use change are monetized the same way as other GHG emissions. A specific method to quantify them is not emphasized in the document of the impact module, which recommends to use commonly accepted methods. The monetization is based on abatement cost in a 2-degree scenario.

The regional specificity of the current air pollution method is limited to the country-level. However, the effects of pollution depend on region-specific circumstances This means that emissions (in particular ammonia and particulate matter emissions) might be overestimated compared to an average country system.

4.3 Conclusion

In conclusion, this research has provided valuable insight into the externalities associated with broiler meat production in The Netherlands. The study offered an overview of these externalities and has made an estimation of their costs in monetary terms, projecting a total of 3.77 euros.

The findings indicate that the production of feed stands out as the primary contributor to these externalities, followed by the formation of fine particulate matter. These results align with the sustainability objectives of stakeholders within the value chain, emphasizing the importance of addressing these specific areas for enhanced sustainability. Furthermore, this research reveals that the costs associated with water related indicators and depletion of fossil and non-renewable resources are relatively low in comparisons to the other externalities.

Notably, the most surprising result is the significant impact of land use change resulting from soybean production in Brazil. This highlights a potentially effective avenue for reducing the externalities of broiler meat production, presenting a accessible opportunity for sustainability improvement. By replacing soy with soy from other countries, or alternative raw materials such as animal protein.

To further advance the understanding and knowledge in the field of True Pricing of broiler meat, future research should delve into various broiler production systems and explore different feed compositions. This will enable a more comprehensive overview of the trade-offs between production systems.

It is recommended that these stakeholders focus on feed composition and technological developments in air scrubbers.

It is also very important that stakeholders take into account the trade-offs that exist between economy, environment and animal welfare.

4.4 Questions for further research

Future research should focus on various broiler systems such as the Better Life Star and organic. This will classify how impacts change and which trade-offs exists between the social, environmental and economic impacts. This allows an objective choice to be made for the development of new production systems and concepts. The preliminary findings in this study suggest that, although the external costs for animal welfare are lower, the overall external costs of the higher welfare categories is higher.

Furthermore primary data from companies in the broiler value chain, instead of country averages, would also be an important improvement. It is also important to include and adjust feed compositions, looking at externalities and nutritional value. For example, the impact of replacing soy with animal protein could be examined.

In addition, it is important to improve the quality and accuracy of the data by including impacts that have not yet been possible. New methods need to be developed for this, but also a qualitative assessment could provide valuable insight as well as a true price assessment.

The most important areas to improve in future studies are the following:

- Impacts with high materiality and low data quality
- impacts with high materiality that are out of scope
- impacts with currently unknown materiality

These impacts can be found in the materiality analysis in Appendix 1. Given the technological advancements in new true pricing models and externalities modeling techniques, it is anticipated that in the future, more accurate estimates of the True Price of broiler meat can be made.

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7. Appendices

Appendix 1. Materiality assessment

	Phase in product life cycle						
	Crop cultivation	Post-harvest processing	Market mix	Processing into feed	Feed compound	Broiler production	Slaughterhouse
Environmental capital impacts							
Contribution to climate change	++	+	+	+	+	+	+
Air pollution	++	+	+	+	+	++	+
Water pollution	++	+	+	+	+	+	++
Soil pollution	++	-	-	-	-	+	-
Land use	++	-	-	+	+	+	-
Land transformation	++	-	-	+	+	-	+
Fossil fuel depletion	++	+	+	++	+	++	++
(Other) non-renewable material depletion	++	+	+	+	+	+	+
Scarce water use	++	++	+	-	-	+	++
Soil degradation	++	-					
Overuse of other renewable resources	-	-	-	-	-	-	-
Social and human capital impacts							
Child labor	+-	+-	+-	+-	+-	+-	+-
Forced labor	+-	+-	+-	+-	+-	+-	+-
Gender discrimination	+-	+-	+-	+-	+-	+-	+-
Underpayment in the value chain	+-	+-	+-	+-	+-	+-	+-
Lack of social security	+-	+-	+-	+-	+-	+-	+-
Excessive and underpaid overtime	+-	+-	+-	+-	+-	+-	+-
Living income	+-	+-	+-	+-	+-	+-	+-
Occurrence of harassment	+-	+-	+-	+-	+-	+-	+-
Lack of freedom of associaton	+-	+-	+-	+-	+-	+-	+-
Negative effects on workers health and safety	+-	+-	+-	+-	+-	+-	+-
Negative effects of community health and safety	+-	+-	+-	+-	+-	+-	+-
Animal welfare	-	-	-	-	++	++	++
Breach of indigenous rights	+-	+-	+-	+-	+-	+-	+-
Breach of land rights	+-	+-	+-	+-	+-	+-	+-
Occurrence of corruption	+-	+-	+-	+-	+-	+-	+-
Tax evasion	+-	+-	+-	+-	+-	+-	+-
Deliberate misinformation / lack of transparency	+-	+-	+-	+-	+-	+-	+-
Negative effects of consumer health & safety	+-	+-	+-	+-	+-	+-	+-
Breaches of privacy	+-	+-	+-	+-	+-	+-	+-

++ Material impact
+ Material impact
- Non-material impact
+/- Impact of unknown materiality

Appendix 2. Scenario analysis soybeans

Impact category	**Chicken meat, at slaughterhouse {NL} - Soybeans (US)**	**Chicken meat, at slaughterhouse {NL} - Soybeans (BR)**
Global warming	-39,9%	16,2%
Stratospheric ozone depletion	0,7%	0,7%
Ionizing radiation	8,8%	-0,9%
Ozone formation, Human health	-0,9%	3,7%
Fine particulate matter formation	0,4%	0,1%
Ozone formation, Terrestrial ecosystems	0,0%	2,2%
Terrestrial acidification	0,4%	0,7%
Freshwater eutrophication	-18,6%	18,9%
Marine eutrophication	-2,9%	5,6%
Terrestrial ecotoxicity	-7,7%	5,2%
Freshwater ecotoxicity	-4,7%	-2,9%
Marine ecotoxicity	-3,0%	3,9%
Human carcinogenic toxicity	-0,2%	2,2%
Human non-carcinogenic toxicity	-3,0%	5,6%
Land use	-23,6%	9,5%
Mineral resource scarcity	-15,4%	14,5%
Fossil resource scarcity	-0,3%	2,4%
Water consumption	47,7%	-14,4%