Master's Thesis Internship – master Sustainable Business and Innovation

Stranded assets of the future

The impact of pricing negative environmental externalities on the profitability of Dutch economic sectors

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Management summary

Motivation

With the growing concern of environment-related risks among economic sectors and political entities, the call for monetary valuation of negative environmental externalities is on the rise. The pricing of negative environmental externalities is gaining more and more public attention as a possible solution towards physical environment-related risks like climate change, biodiversity loss and the overall pressure on natural capital. Renowned parties like the OECD, IPCC, IPBES and the IMF underline the importance of such a policy intervention, with the focus primarily lying in the pricing of carbon dioxide output. But carbon dioxide is far from the only environmental externality causing these environment-related risks. This lack of knowledge motivated this research: To look at the impact of pricing in total 30 different environmental externalities on the profitability of Dutch economic sectors. This is especially important as both the physical environment-related risks, and the policy on these physical risks can lead to the creation of stranded assets in the future. This research supports De Nederlandsche Bank's ongoing ambition to remain thought leader on cutting edge topics like the effects of increasing sustainability efforts within the economic and financial system.

This research has been conducted as a master thesis for the master Sustainable Business and Innovation at the University of Utrecht. The research builds further on the recently published report of Values at Risk, published by De Nederlandsche Bank, detailing multiple sustainability risks and goals in the Dutch financial sector.

Method

Using global input-output tables the research calculated the total consumption-based footprint of the Dutch economy for in total 30 environmental externalities. For analysing the total footprint of the Netherlands, the Exiobase EEMRIO database has been used. Exiobase is a worldwide input-output model with regional data precision that includes environmental externalities like the use of certain resources and the output of pollutive substances. With the use of this database, not only the direct output of these environmental externalities can be calculated, but also the supply-chain output of these externalities can be considered, specifically for each economic sector within the Netherlands. Within this analysis, a consumption-based perspective is used, meaning that the environmental damage generated by production is allocated to the sector that finally sells these products to their customers (this means that for instance the environmental damage generated by the steel-producing sector to produce cars, will be allocated to the car manufacturing industry). The analysis thus shows the environmental footprint of Dutch consumption. This means that production by Dutch companies used for export has not been considered within this footprint. After all, using a consumption-based perspective this part of the footprint should be imputed to the country that ultimately sells these products to the consumer.

In total, three groups of environmental externalities have been considered: GHG emissions, pollution and water use. GHG emissions comprehend of the known greenhouse gasses and are expressed in CO_2 equivalents. Pollution is divided in air, water and land pollutants and water use is divided in both the consumption and withdrawal of water (with for instance the cooling of power plants). In total, these thirty externalities cover a substantial part of the known environmental externalities. Land use transformation and the production of waste have not been considered within this research due to data limitations. While the extent and completeness of the used database is unique, it does have its limitations. Most notably is the fact that data on the mining sector is lacking, which creates some biases within the results.

We monetized the environmental externalities to show the related damage costs of the externalities. With the use of data provider TruCost, we apply a monetary value to each of the 30 underlying externalities. TruCost uses different methodologies for determining both the social and environmental damage costs of the different environmental externalities. The price of carbon has for instance been set by using an Integrated Assessment Model that uses both economic and population growth scenarios to predict the consequences of rising GHG emissions on the rise in electricity needs, the growing output of the agricultural sector, sea level rise, forest fires, extreme weather conditions etc. The costs of particulate matter are for instance partly measured by an average loss of years lived due to its pollutive qualities. Using the value of statistical yea (VOLY) these lost years can then be monetarily valued.

We calculate the "impact ratio" to give insight into the impact of pricing environmental externalities. We divide the total environmental and social costs of an economic sector by the three-year average of the total generated profits of this economic sector. We call this the impact ratio. The impact ratio gives us a quantitative measure of scale in terms of the impact internalization of negative environmental externalities would have on a given economic sector.

The environmental footprint of the Dutch economy

The Dutch economy is responsible for the output of 4.8 billion tons of CO_2 equivalents, 7,9 million tons of polluting substances and 103 trillion litres of water. The output of GHG emissions is mostly due to the following economic sectors: The manufacturing industry (33%) – where refineries (21%) and food processing (16%) are the most prominent sub-sectors -, the electricity sector (18.5%), and the transport sector (10%). The total output is mostly due to carbon dioxide (80%), followed by methane (14%) and nitrous oxide (4%). The total output of GHG emissions of the Dutch economy, divided by direct and supply-chain output is shown in figure 1.

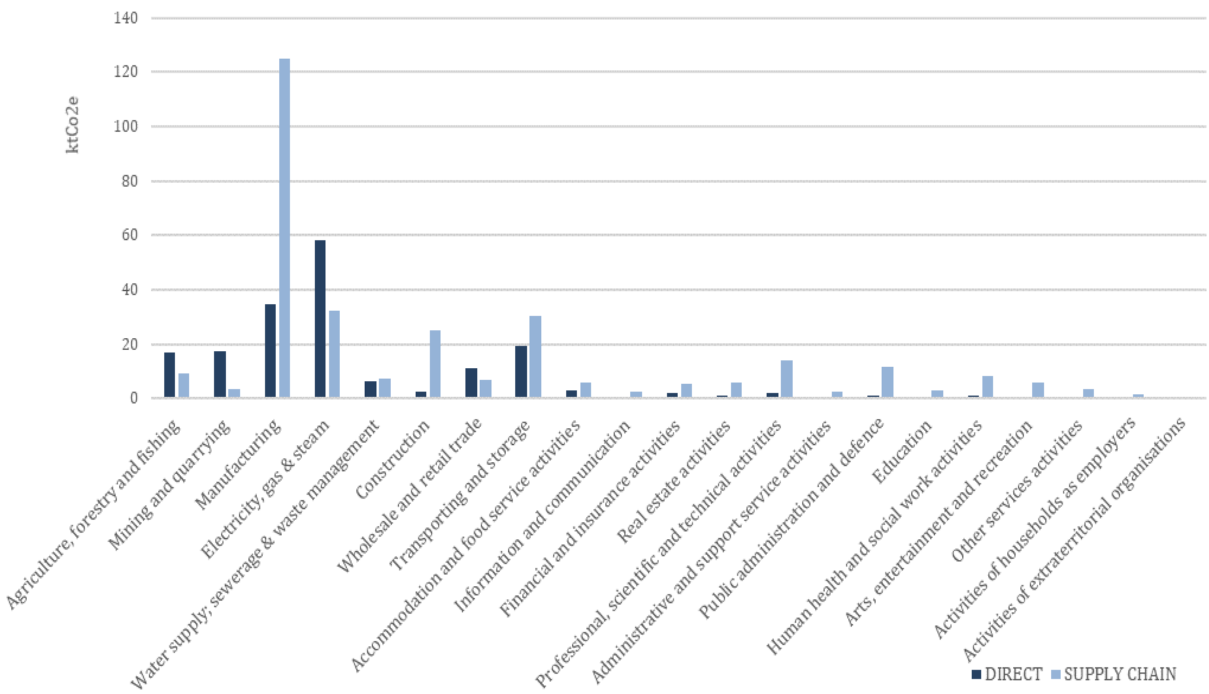

Figure 1. The total output of GHG emissions for the Dutch economy in CO_2 equivalents.

The water footprint of 103 trillion litres of water is for 53% due to the manufacturing industry, followed by the agricultural and electricity producing sector which both take a share of 11% of the total. Within the manufacturing industry 51% of the water footprint is due to the production of food products. In total, the food producing sector is thus responsible for 46% of the total water footprint of the Netherlands (including the agricultural and beverages industry).

The 7,9 million tons of polluting substances exists of in total 18 different substances, where carbon monoxide (40%), nitric oxide (19%), ammonia (13%) and sulphur oxide (10%) have the largest share. The manufacturing industry again has the largest share of 43% of the total, mostly because of the food producing industry (19%) and the metal industry (14%). Second and third are the sectors of transportation (12%) and agriculture (10%).

Environmental and social damage costs of the Dutch economy

Of the total environmental and social damage costs of the Dutch economy, EUR 80 billion, roughly two-thirds is due to the supply-chain. Of the total environmental and social damage costs of 80 billion (11% of Dutch GDP) 26 billion is due to direct damages within Dutch economic sectors, and 54 billion is due to supply-chain damages. The supply-chain includes the supply of products, services and semi-finished products from both within and outside of the Netherlands.

The total damage costs are highest within the manufacturing industry (EUR 28.4 bn), followed by the electricity sector (EUR 11.2 bn) and the transportation sector (EUR 8.2 bn). Both the direct and supply-chain damage costs are shown in figure 2.

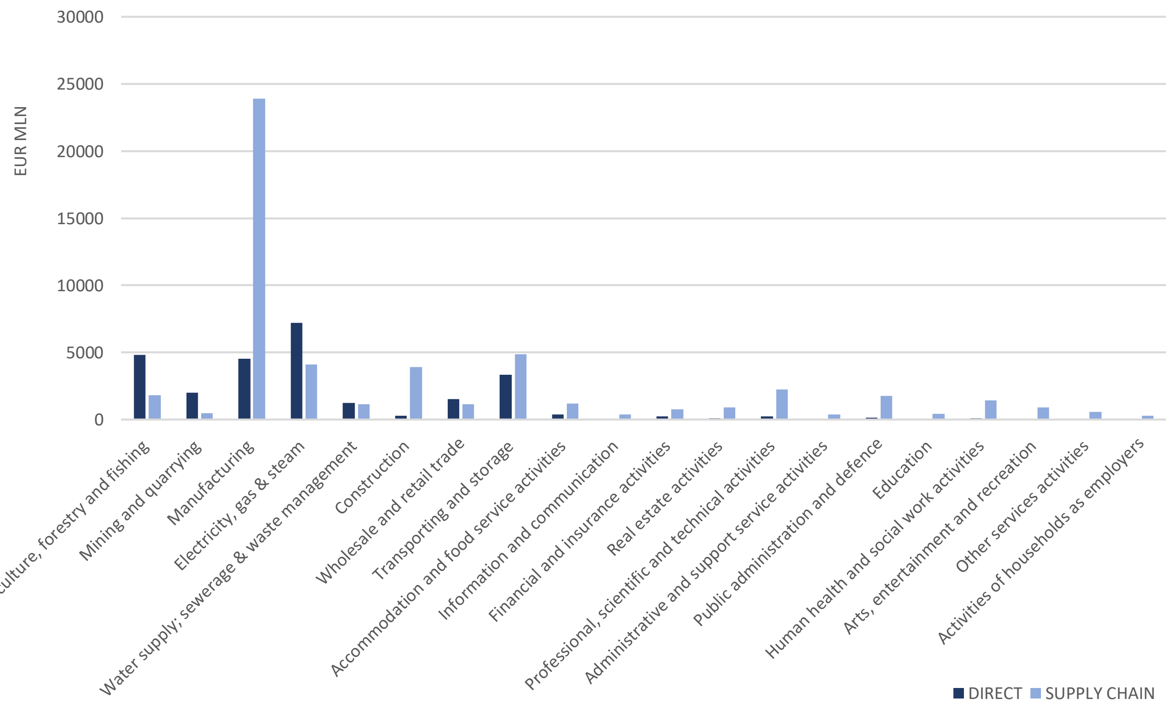

Figure 2. The total direct and supply-chain environmental and social damage costs for the Dutch economy (in million euros).

The total damage costs are driven mostly by GHG emissions (70%), followed by pollution (23%) and water use (7%). Within GHG emissions carbon dioxide is the costliest form of emissions with a total cost of 44 billion. This is mostly due to the enormous output of carbon dioxide emissions, not because of the high monetary value of the substance. Other externalities with a high contribution are methane (EUR 8 bn), nitrous oxide (EUR 5 bn), water consumption (EUR 4 bn) and particulate matter (EUR 3.5 bn). The different externalities per economic sector are shown in figure 3.

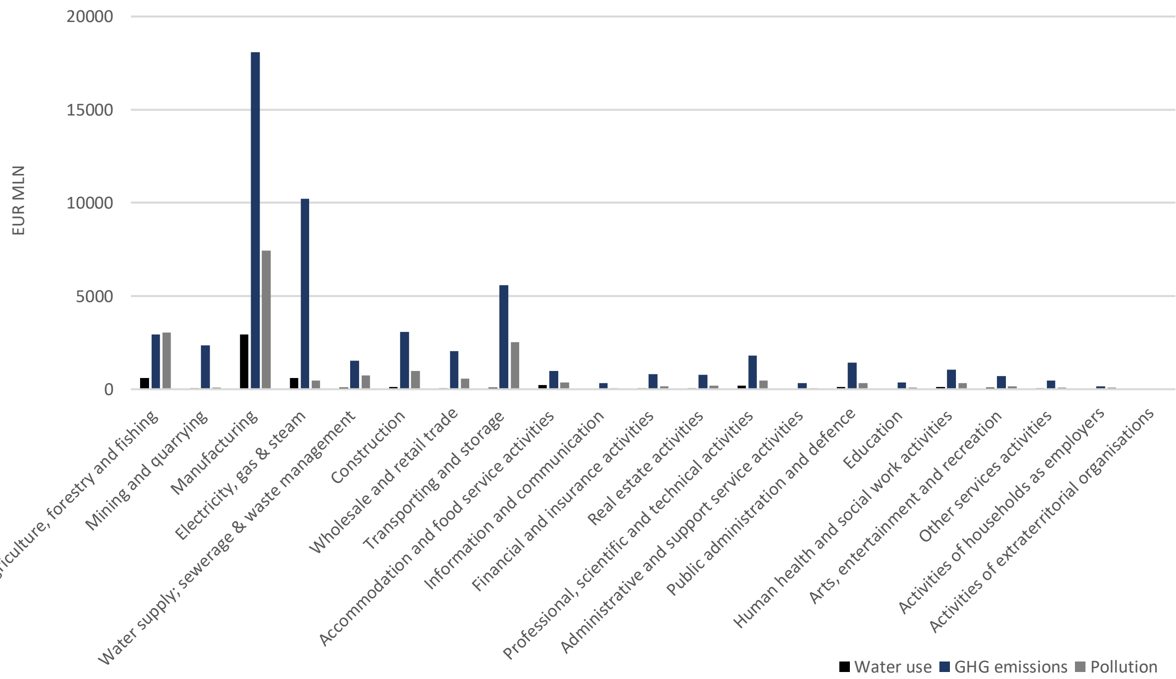

Figure 3. The total environmental and social costs of the Dutch economy for each externality (in million euros).

The potential impact on the different economic sectors

The monetary pricing of environmental externalities presumably has a large impact on a select number of economic sectors. Within this research the impact ratio has been used to give an indication on the impact of the environmental and social damages on the profitability of the different economic sectors of the Netherlands. In total, five of the 13 economic sectors have an impact ratio above 100%. De average profits of the sectors are then too low to compensate for the added environmental and social costs. These sectors are: The electricity producing sector (1490%), the waste and sewage treatment sector (385%), the manufacturing industry (140%), transport (133%) and agriculture (108%). All impact ratios including the direct and supply-chain impacts are shown in figure 4, where we once more highlight that there are data limitations on the mining sector.

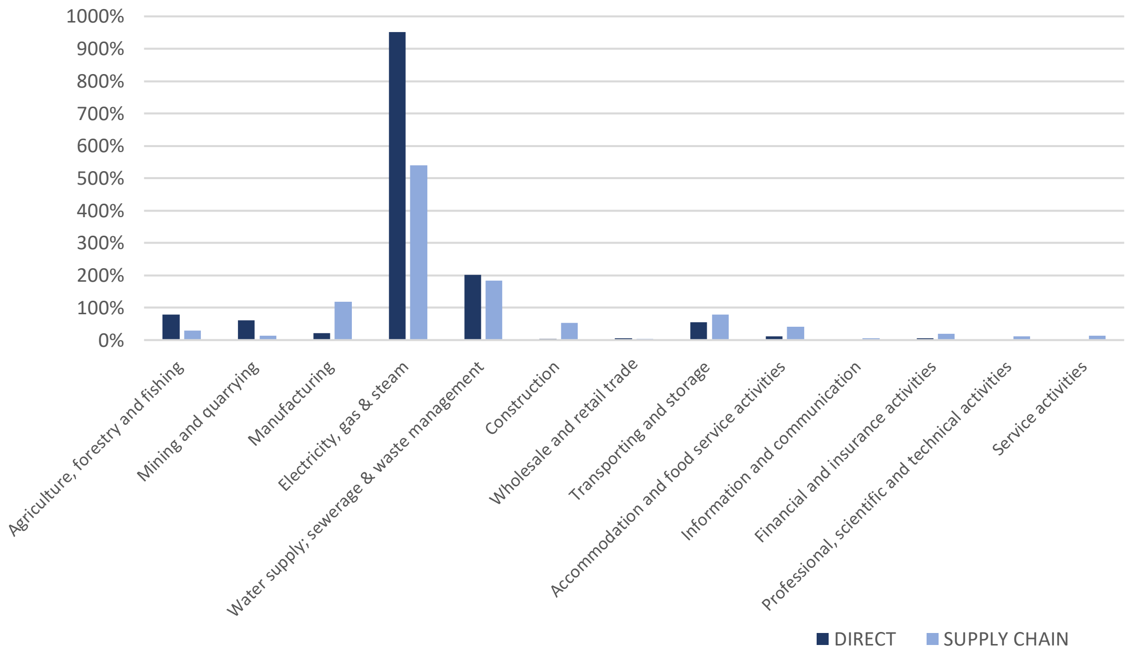

Figure 4. The impact ratio of Dutch economic sectors (in %).

Policy recommendations and next steps

The research shows that assets in many sectors within the Netherlands or within supply-chains of these sectors risk devaluation or might even become stranded within the not so far future. The research suggests that constructing a political climate that incentivizes companies to change towards more sustainable business practices is needed. In order to avoid sleepwalking into a next economic crisis it is especially important for financial institutions to be aware of the presence of these risks. This form of risk contagion from environmental risks in non-financial sectors through financial assets to financial institutions is something that should be researched more into the future. It is suggested that at least some form of portfolio analysis of financial institutions should be implemented as both physical and social environmental risks are real and are expected to expand over next decade. Tools like those presented within this research could help financial institutions to look better into their portfolio's and eliminate investments with high impact ratio's or be held more accountable for these investments in terms of the risks associated with them. In general, it would help these institutions to evaluate ESG risks more specifically on sector and perhaps on company level in the future. As for next steps, this research will be published as a DNB Working Paper.

Abstract

Environment-related risks are often poorly understood, regularly mispriced and can ultimately lead to the stranding of assets. This knowledge gap has already resulted in significant over-exposure to environmentally unsustainable assets throughout economic and financial systems. The emerging risks related to the environment represent a large discontinuity and should be compensated for by altering and reassessing values across a wide range of sectors. There is thus a need for new government regulations to counter them, but these government regulations can also itself be a driver of stranded assets. Therefore, this research conducted a scenario analysis into the implementation of monetarily pricing the respective output of externalities for all economic sectors of the Netherlands, followed by what kind of impact this will have on the profitability of these sectors. Monetarily quantifying the global supply-chain of the Dutch economy lead to the conclusion that this impact would be substantial, with large sectorial deviations. Some sectors will feel limited effects of such a regulation, while other will struggle to survive, possibly generating stranded assets along the way, making the sectors very susceptible to these future regulations. It is found that especially *the electricity, gas and steam producing sector* and *the water supply, sewerage and waste processing sector* would become sectors with a high percentage of total losses. It is also found that current economy of the Netherlands is unsustainable, creating physical environmental risks within many economic sectors. The research thus suggests that constructing a political climate that incentivizes companies to change towards more sustainable business practices is needed, and more research should be done into looking how this can be made practice in the future.

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1. Introduction

Environment-related risks have risen the global agenda dramatically over the last few years. The 2019 publication of the World Economic Forum on global economic risks ranked extreme weather events, failure to implement sufficient climate change mitigation and adaption and natural disasters among the top 5 risks most likely to occur within the next 10 years (WEF, 2019). These environment-related risks are created due to biodiversity losses, resource depletion, climate change, water scarcity and other environmental changes which are already impacting socioeconomic development (WEF, 2019). These environment-related risks also pose large economic challenges as seen in the fast-emerging topic of 'stranded assets'. Stranded assets are defined as assets that have suffered premature or unanticipated write-downs, devaluations or conversion to liabilities (Caldecott & McDaniels, 2014; Caldecott et al., 2014). The environment-related risks are often poorly understood and regularly mispriced, which has resulted in significant over-exposure to environmentally unsustainable assets throughout economic and financial systems (Caldecott et al., 2014). Stranded assets gained worldwide attention with the introduction of the 'Carbon Bubble', a hypothesized bubble in the valuation of fossil-fuel based companies. These companies are valuated under the assumption that all fossil fuel reserves owned will also be consumed, but this would exceed the global carbon budget by nearly 5 times, which is set to reduce the chance of exceeding the 2 degrees warming of the earth (Carbon Tracker Initative, 2015). Climate change regulations will possibly leave a large sum of fossil fuels unburnable, substituting to a loss of value of the fossil fuel sector of 28$ trillion dollars over the next two decades (Kepler Cheuvreux, 2014). Indirect financial exposure could also eat up between 40% and 280% of banks total capital (Rubin, 2015).

Since 2011, the concept of stranded assets has gained a wider range of interest to be engaged on the topic, such as those concerned with risks due to environmental damages and their respective social consequences, looking beyond the fossil fuel sector. These emerging risks related to the environment represents a large discontinuity and should be compensated for by altering and reassessing values across a wide range of sectors (Caldecott et al., 2014). Recent developments very clearly illustrate that environment-related risks, and not just related to unburnable carbon, can have a significant impact on assets today, and are likely to increase in significance over time (Caldecott, 2017; Caldecott et al., 2017). If anything, evidence shows that these risks are more material in the short and medium term, than the risks of stranded assets within the fossil fuel sector (Caldecott, 2017; Caldecott et al., 2017). Examples of this are for instance the major credit risk exposure of Indian banks to agricultural and power generation sectors within India situated within high water stress areas, or the impending liability of the agricultural sector due to water and land pollution making agricultural land less viable or sometimes even useless (Caldecott et al., 2013; Singh, 2019).

These physical environmental challenges give the need for new government regulations to counter them, but Caldecott (2017) also states that these government regulations can in itself be a driver of stranded assets. Setting a price on the damages done by sectors to the environment and society at large can for instance result in implications for the international competitiveness of economies, especially if only done domestically. This can be examined when looking at other environment-related regulations across different countries (Silajdzic & Mehic, 2017). But it is seen that these government regulations are gaining popularity, giving the need for more insight into the possible consequences of implementation.

One regulation like this is the internalization of negative environmental externalities, which is based on the pre-existing Polluter Pays Principle (PPP). The PPP was set up in 1972 by the Organisation for Economic Cooperation and Development (OECD), stating that *"the polluter should bear the expenses of carrying out the measures decided by public authorities to ensure that the environment is at an acceptable state".* As of recent years, the internalization of negative externalities has again gained more interest by policy and research, as statistical quantitative analysis into sector specific output of environmental pressures is getting more detailed and inclusive. Furthermore, these environmental pressures can now be linked to the impact that they have on the environment and society at large, including the respective monetary costs that this impact is associated with. This monetary method of valuation can facilitate the optimization of financial, social and environmental value (Schoenmaker, 2017). Subsequently, by having market prices reflect external costs of business practices, economic benefits of a firm now must exceed these costs. This will provide firms with new incentives and opportunities to develop more sustainable business models and technologies in order to reduce impacts cost-efficiently (Andersen, 2017).

Multiple institutions and scientific platforms are shaping awareness into the effectiveness associated with the internalization of environmental externalities by monetary valuation of environmental pressures. For example, The International Monetary Fund states that *'carbon pricing should be front and centre in implementation mitigation pledges in both advanced and emerging markets economics. It increases the price of energy from fossil fuels, creating incentives for mitigation. Furthermore, it reduces demand for energy-consuming products, promoting innovation.'* (IMF, 2017). Apart from damages to the environment and society related to carbon output, there are more environmental pressures that create damages. The global assessment report on biodiversity and ecosystem services (IPBES) takes this into account by stating that *'a key constituent of sustainable pathways is the evolution of global financial and economic systems to address environmental impacts such as externalities of economic activities, from local to global scale'.* Furthermore, they state that *'introducing and improving standards and systems, including relevant regulations, aimed at internalizing the external costs of production, extraction and consumption is a central aspect of sustainable development'* (Dziba et al., 2016).

That internalization of negative environmental externalities is gaining popularity within policy is also seen within the Netherlands, where the Dutch government recently announced a carbon tax towards companies within their national climate agreement (Meijer, 2019). As of 2018, the Netherlands is also actively promoting a full transformation of the national economy to become 100% circular by 2050 (IenM & EZK, 2016), with the first target of the program being a 50% decrease of primary resources' (e.g. minerals, fossils and metals) by 2030 (IenM & EZK, 2016). What makes this interesting for this research is the fact that the Dutch government makes the following statements regarding their ambition to increase circularity within the economy: *"A market incentive is needed that promotes the efficient use of resources, because resource-efficiency promotes both sustainability as increased production process efficiency on the use of these resources. Also, making companies more efficient with their resource use could help with decreasing the emission output of these respective companies"* (IenM & EZK, 2016). More importantly they also state the following: *"Setting a price on the negative externalities a company imposes on society promotes the creation of closed circular business models"* (IenM & EZK, 2016). These statements are very much in line with the type of approach explained above and gives this research an interesting geographical scope of focus.

As these regulations become more popular, the side effects of implementation should not be underestimated. Within the fossil fuel sector, divestment campaigns are already threatening to erode the social licence of some targeted companies, which could induce stranded assets and all the financial and economic consequences following that (Ansar et al., 2013; Bergman, 2018). It is thus important to know the effects of future regulations beforehand to give insight into which sectors will be impacted the most. As of now, the impact of the internalization of negative environmental externalities on the economy has not been research yet for the Netherlands, except for the carbon footprint. This knowledge gap is where this research will try to contribute, setting up a scenario analysis into the implementation of monetarily pricing the respective output of externalities not limited by carbon for all economic sectors of the Netherlands, followed by what kind of impact this will have on the profitability of these sectors. Scenarios can help firms, investors and policy makers increase the resilience of assets by making them better prepared for inherently hard to predict future events. This brings us to the research question of this paper: *What is the impact of internalization of negative environmental externalities on the profitability of Dutch economic sectors?*

To answer the research question, two sub-questions must be answered first; *what is the total physical output of environmental pressures of the Dutch economy?* and, *what are the environmental and social damage costs associated with this total output?* These questions will be analysed in three steps, each answering one question: First, an analysis into the total physical output of environmental pressures is done for all economic sectors of the Netherlands, including their supply-chain. Second, the environmental and social (E&S) damage costs are linked to the environmental pressures to monetarily quantify the total costs associated with the total physical output of each economic sector. Thirdly, as to answer the main research question, a quantification of the percentage of these economics sectors annual earnings at risk will be given.

To conduct this research, an environmentally extended input-output (EEIO) model has been used to calculate the total environmental output of all Dutch economic sectors. It is possible to include the supply-chain, because an EEIO model traces the flows of goods and services between all sectors of the world (Wiedmann, 2009). Preliminary research has been done into calculating the global supply-chain of the Dutch economy (Vollebergh et al., 2017; H. C. Wilting & van Oorschot, 2017), looking at the biodiversity footprint or the output and pricing of domestic pollutants of Dutch economic sectors. This study will add to these existing studies by implementing a newer dataset to calculate the global supply-chain of the Netherlands and including both the direct and the supply-chain E&S damage costs over a range of environmental pressures. Ideally, one would want to present a complete sector footprint by including all the negative environmental externalities of a sector. Sadly, this is not possible due to various data limitations. The environmental externalities have been selected by matching the different databases used, ending up with a total of 30 environmental pressures, which can be separated in three main categories; Air, water and land pollution, GHG emissions and water usage. Environmental externalities like land and resource use are not considered due to a multitude of reasons. For one, land use transformation over time is still hard to quantify towards specific sectors worldwide, making data available on it limited. Also, the environmental externalities of resource use like GHG emissions and pollution contributing to the extraction and use of these resources have already been considered. Including resource use in the analysis would create the possibility of double-counting externalities.

As an explorative research for the University of Utrecht and the Dutch Central Bank the objective of this paper is to add to the empirical knowledge of the impact of internalization of negative environmental externalities within national economies in terms of possible stranded asset creation. To do this, a new quantitative approach to linking E&S damage costs to EEIO analysis results on environmental pressures has been constructed, which to our knowledge has never been done on a national level before. In terms of further insights into contribution, this paper opens a lot of possibilities into further research into this topic, possibly inducing a more data driven approach to setting regulation on negative environmental externalities. Furthermore, concerning the environmental pressures, the results of this paper can be used for policy prioritisation by governments and individual sectors to increase responsibility for supply-chain impact, but also to eliminate the most prominent, and new to this research, most costly environmental pressures. This supply-chain insight could help economic sectors mitigate the risk of stranded assets by reducing the losses further upstream, improving resource efficiency or perhaps changing the complete supply-chain by geographical resource allocation. Moreover, it can also help the Dutch government to have more insight into what specific economic sectors bear the greatest environmental impacts both directly and within their supply-chain, and with that, which economic sectors induce higher environment-related risks when it comes to regulation on pricing these impacts. This could also open a discussion on if this is a fair distribution of responsibilities (e.g. service sectors gaining the profits but not bearing the responsibilities of production), something which will be highlighted more within the discussion section of this paper. The results of this research could ultimately be linked to the investment made within these different sectors and asset classes to warn financial institutions on possible exposures to future stranded assets.

This paper will first take a deeper look into the theoretical background of stranded assets. Secondly, the policy background on internalization of negative externalities will be looked at extensively. Thirdly, the methodology of this paper will be described in detail. Lastly, the results will be shown, followed by a discussion and conclusion.

2. Theoretical background

Within this section we will first discuss the theoretical background of stranded assets, followed by the theory of internalization of negative externalities.

2.1 Stranded assets

The theory of stranded assets was created by environment-related risk ratios, including physical climate change impacts and the societal responses to this climate change, which has risen up the agenda dramatically (Caldecott, 2017). The topic itself is a relatively new literature, deriving from the first half of the 2010's. Given the speed at which is have become an important topic, the scientific literature on the topic is surprisingly under-developed, primarily because of the long publication processes of journals (Caldecott, 2018). The topic does have a high diversity over a wide range of disciplines, from macroeconomics (Batten et al., 2016; Campiglio et al., 2015) to finance (Battiston et al., 2017; Campiglio, 2016) and law (Barker et al., 2016), making it a multi-disciplinary topic of interest. But different scientific disciplines also bring confusion within communicating often very similar and overlapping concepts. That is why Caldecott et al., (2013) has introduced a 'meta' definition of stranded assets to encompass all different definitions, *'stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities'*.

While the topic of stranded assets is mostly focussed on the rise of environment-related risks that can strand assets, the concept of asset stranding is not novel. In fact, it has happened often due to economic development. Schumpeter already coined the term of 'creative destruction' in 1942 in his 'essential fact about capitalism', which is the idea that value is created, as well as destroyed, as a dynamic process that drives forward innovation and economic growth (Schumpeter, 1942). Schumpeter build this idea on the earlier works of Kondratiev, (1926) and the idea of 'long waves' within an economic cycle (Perez, 2010).

The dynamics of creative destruction has been studied often since then, particularly in how and why technological innovation and diffusion results in technological revolutions (Caldecott et al., 2017). This eventually led to Perez (1985), giving rise to the idea of 'techno-economic paradigms (TEPs). TEPs capture the idea of technological innovations that overlap, making them strongly inter-related and interdependent, resulting in technological revolutions. Perez (2002) studied five occurrences of such TEPs over time: The Industrial revolution (1771-1829); the Age of Steal and Railways (1829-1875); the Age of Steel, Electricity, and Heavy Engineering (1875-1908); the Age of Oil, the Automobile and Mass Production (1908-1971); and the Age of Information and Telecommunications (1971-present).

Each TEP is led by the emergence of new sectors, while at the same time stranding assets in old sectors. For example, within the Industrial Revolution mechanically produced cotton from England became superior to India's cotton textile sector (Broadberry & Gupta., 2005); the Age of Steam and Railways replaced canals and water transport with railway networks (Bagwell & Lyth., 2002); the Age of Steel, Electricity, and Heavy Engineering saw the introduction of the steam engine, introducing steam ships which made sailing ships obsolete (Grübler & Nakićenović., 1991); the Age of Oil, the Automobile and Mass Production reduced the use and need for public transportation like trains as one could now own a car for a relatively cheap price (Wolf, 1996); and the Age of Information and Telecommunications has resulted in the widespread adoption of digital communication and sharing of information, leading to the end of the many devices and services like type writers, instant cameras, physical copies of music and movies in terms of DVDs and CDs and many more (B. Caldecott, 2017; Ryan, 2013; Shanklin, 2000). All these examples show that with each TEP, companies, brands, physical infrastructure, machinery, human capital and more became stranded over time.

But stranded assets of TEPs can be linked to ratios related to innovation and commercialization of new technological developments, as part of the concept of creative destruction on which it is based (Caldecott, 2017). Stranded assets as a concept on the other hand, is different in the way that some causes of asset stranding are not linked to the principle of creative destruction, but increasingly more environment-related (Caldecott, 2018). In other words, the combination of physical environmental change and the social responses to this change are quantitively and qualitatively different from previous drivers seen above (Caldecott, 2017). Moreover, there is a fundamental difference from a geographic, sector and asset class perspective, as environment-related risks are stranding assets simultaneously over all these perspectives, and perhaps even more quickly than previous TEPs, and that this is an accelerating trend (Caldecott, 2017).

For usage of the theory of asset stranding, the scope of risks that can cause the actual stranding of assets was analysed. This ultimately resulted in a typology for the different environment-related risks associated with asset stranding, shown in figure 1 (Ben Caldecott et al., 2013). The typology shows a total of 6 different risk classes, separated in physical and societal risks. This is due to the concern of both the physical environmental changes and the societal responses to such environmental change. The typology also allows a wider range of interest to be engaged into the topic, such as stranded assets due to water stress or pollution, looking beyond the narrow view sector view of just fossil fuels, into sectors like agriculture and manufacturing. Ultimately, the theory of stranded assets could identify where stranded assets will take place in the future and mitigate these risks by making capital less likely to flow towards assets that are incompatible with environmental sustainability and more to those which are (B. Caldecott, 2017). As seen within figure 1, government regulations are one of the causes of stranded assets, but it might also be the most important tool for preventing stranded assets from occurring. One way of doing so is by the implementation of regulation that internalizes negative externalities. As this is research into the consequences of internalization of negative environmental externalities to stranding assets in the future, the concept of environmental externalities will be elaborated on further within the next section

	Class	Description
PHYSICAL	**Environmental challenges and change**	For example, climate change, water stress, and biodiversity loss.
	Changing resource landscapes	Price and availability of different resources, such as oil, gas, coal and other minerals and metals. For example, Peak oil and the shale gas revolution.
SOCIETAL	**New government regulations**	Introduction of carbon pricing (via taxes and trading schemes), subsidy regimes (e.g. for fossil fuels and renewables), air pollution regulation, disclosure requirements, the 'carbon bubble' and international climate policy.
	Technological change	For example, falling clean technology costs (e.g. solar PV, onshore wind), disruptive technologies, and GMO.
	Evolving social norms and consumer behaviour	For example, fossil fuel divestment campaign, product labelling and certification schemes, consumer preferences.
	Litigation and changing statutory interpretations	For example, court cases, compensation payments, and changes in the way existing laws are applied or interpreted.

Figure 1: Typology of Environment-related Risk. Source: Ben Caldecott et al. (2013).

2.1 Environmental externalities

External effects have been studied by economists ever since the days of Marshall and Pigou (Van den Bergh, 2002). Positive externalities arise when an action by an individual or a group confers benefits to others. As these actions will not be considered within this research, they will not be elaborated on further. Negative externalities arise when an action by an individual or group produces harmful effects on others (Cornes & Sandler, 1996; Sankar, 2006). Pollution is for instance a negative externality. A ratio discharging untreated waste into a river results in the negative externality of pollution, making consumers bear not only the health or water purification costs but also the costs of environmental degradation. Generating a negative externality thus results in a higher social cost than private cost.

This divergence between private costs and social costs results in an inefficiency in resource allocation (Sankar, 2006). Producers of externalities have no economic incentive to take into account the effect of their actions on others. When a negative externality occurs, the marginal social costs (MSC) will be higher than the marginal private cost (MPC), hence the private optimal level of output will be higher than the socially efficient output (Sankar, 2006; Thi et al., 2016).

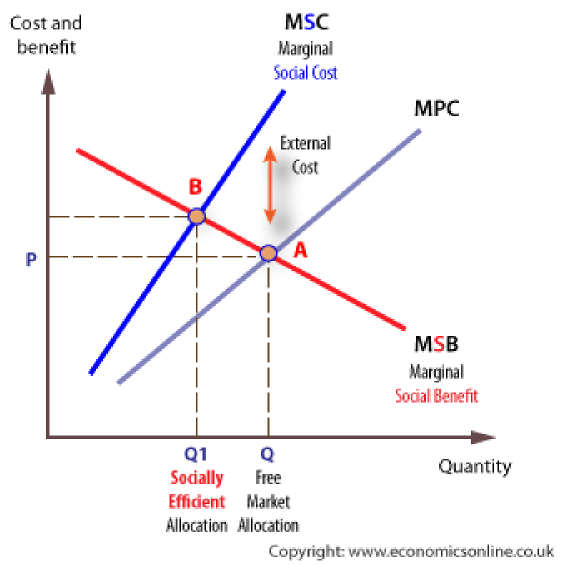

Figure 2: This figure shows the standard negative externalities graph as described by the theory. Retrieved from: Economics Online (2019).

To illustrate this, figure 2 is shown. An external cost like for instance the costs of pollution from industrial production makes the MSC curve higher than the MPC curve. The socially efficient output is where MSB=MSC, shown here in Q1, but this is often not the case due to free market allocation or Q. This is because for environmental resources such as air, water, living creatures including human beings and plants property rights are not well-defined (Sankar, 2006). Users of these resources consider them often as “free goods” or an “unpaid” ratio of production. This results in negative externalities being a market failure. The non-existence of markets for environmental goods and services underestimates their social value, even though the users of these resources are often dependent on them (Sankar, 2006). Therefore, government intervention is needed to internalize these externalities so that social efficient levels of output and private levels of outputs will be the same.

The government regulation of internalizing externalities is on the rise due to the increased possibilities of calculating the social costs of product systems. Bear in mind that the social costs also include environmental costs. Examples of this are: The societal life cycle costs model of Goedecke et al., (2007); the accounting for externalities within a cost-benefit analysis of Nguyen et al., (2013); the eco-design method of Lim et al., (2013); the ecosystem service valuation ESV model by De Groot et al. (2012).

The theory of negative externality is the foundation of environmental economics (Sankar, 2006). The importance of taking into account the external costs when setting a price on a product, service or process has been universally recognized by environmental and economic scholars (Thi et al., 2016). There are a few possible ways to internalize these external costs. We will shortly review two contributions to the theory by Pigou (1920) and Baumol & Oates, (1988). Pigou suggested that the solution for correcting the negative externality is to impose a per unit tax on the output of the firm generating the negative externality, also known as the Pigouvian tax. This per unit tax should equal the difference between the marginal social costs and the marginal private costs, corresponding to the socially efficient output. Imposition of such a tax would raise the price and reduce demand, helping to internalize the environmental costs in the decisions of producers and consumers of the product.

Baumol and Oates highlight the information problem in implementing such a tax. To solve this problem, he suggests a two-stage approach: First, decide on the environmental standards based on available scientific knowledge or/and social preferences, and second, pursue these standards by either granting permits or charging violation of these standards. Given the standards and information about the pollution level baselines, tradable permits/quotas can be distributed, and prices of the permits can be determined by the market forces.

Both contributions are often already used within policy regulations worldwide, both successfully and not (Sankar, 2006). But, exploring the perfect policy tool for accounting for external costs of economic sectors is beyond the scope of this research. This research will find its contribution to the theory in exploring the impact of moving from a free market allocation towards a socially efficient allocation on different economic sectors. This could however give more insight into what policy tool would work within the Netherlands.

3. Method

This section describes the steps taken to answer the research question on the effects of internalization of negative externalities on the profitability of Dutch economic sectors. Three crucial steps will be taken. Firstly, an environmental footprint of the Dutch economy will be determined based on a global supply-chain analysis across 30 externalities broken down by sector. Secondly, a monetary value of the environmental footprint will be determined by attaching a price to each of the externalities. Lastly, the impact ratio will be determined by expressing the value of the environmental footprint as a percentage of the profits of the sector, using combined data from Statistics Netherlands and the Dutch Central Bank on sector profits. These three different steps will be explained in detail over the coming sections.

3.1 Global supply-chain analysis

In this section the environmentally extended input-output (EEIO) analysis will be discussed which has been used for conducting a global supply-chain analysis of the Dutch economy. As stated within the name of the analysis, the environmental aspect is an extension on the primary analytical framework of an input-output analysis, which has been developed by Professor Wassily Leontief in 1936, for which he received the Nobel Prize in Economic Science in 1973 (Suh, 2009). The fundamental function of an input-output analysis is to analyse the interdependence of different industries within an economy (Suh, 2009). Input-output (IO) tables show where supplies of different kinds of goods and services originate from, both from domestic economic sectors and imports, and how those supplies are allocated between various intermediate or final uses, including exports (OECD, 2019b; Tukker et al., 2009). One general assumption that often occurs when analysing results contributing to the supply-chain is that these results contribute to foreign inputs. However, this is generally not the case, as a company within the Netherlands can also have most of their supply-chain constructed of companies which are also situated within the Netherlands.

Firstly, the dataset used will be explored. Secondly, the actual data analysis will be explained, followed by its limitations.

3.1.1 The dataset

The global supply-chain analysis of the Dutch economy has been performed by using a global, detailed Multi-Regional Environmentally Extended Input Output (MR EE IO) database: the Exiobase MREEIO database. Exiobase is an international input-output table that can be used for the analysis of environmental impact associated with the consumption of product groups (Stadler et al., 2018). The database was developed with support from the European Union, by harmonizing Supply and Use Tables (SUT's) of 43 countries with each 164 economic sectors, compromising 95% of the global GDP (Exiobase, 2019; Tukker et al., 2014). Added to this are 150 smaller countries which have been combined in five "rest of the world" groups by continent. This sector interconnectedness of production and consumption for the entire global economy is combined with estimations on emissions and resource extractions specifically for each of the 163 identified economic sectors. The database covers environmental pressures in the following categories: emitted substances, waste supply and usage, land use, water use, and resource use. The 163 identified economic sectors are classified under the NACE classification codes (Nomenclature statistique des Activités économiques dans la Communauté Européenne) which is the standard classification code for economic sectors within the European Union. For this research, the most recent version of the database has been used, of the year 2015.

3.1.2 The environmentally extended input-output analysis of the Dutch economy

This section will go deeper into the specifics of the global supply-chain analysis done for this research. For the purposes of explaining this analysis this paper follows the general EEIO methodology outlined by Kitzes (2013) and applied it to the Exiobase MREEIO database. Before going into the specifics of the analysis it is important to note one essential aspect of EEIO analyses. An EEIO analysis analyses the environmental impacts associated with the final consumption of product groups. This means that it counts all emissions required for a given sector to sell goods and services to end consumers. The EEIO analysis can thus be interpreted as a process of reallocating responsibility for a known quantity of emissions from a producer-orientation to a consumer-orientation. For instance, the total production-based emissions of sector A is 10 tons of CO_2. The results of an EEIO analysis could for instance be that 6 of those 10 tons of CO_2 are actually being emitted to support the sales of goods and services of sector B to final consumers and are thus allocated as such. In theory, if sector B did not exist, sector A would only have emitted 4 tons of Co2 to meet consumer demands. This simplification of the analysis is crucial to understanding the results.

For the purposes of clarifying the analysis, the example of only one specific Dutch sector (the electricity sector) and one specific environmental pressure (tons of CO_2) is used. Naturally, this analysis has been done for all 163 industries and 30 environmental pressures, using the same methodology.

Within Exiobase, the analysis starts with the technical coefficient matrix of economic sectors, commonly denoted as the A matrix. This matrix shows how much inputs and outputs any given sector requires of any other sector in the world, for each dollar output that it created. Because it is a matrix, this can be shown for the global economy, in a single table. A limitation to this from a supply-chain perspective is that the A matrix only shows the direct inputs of an economic sector, not considering all the other economic sectors in the lower layers of the supply-chain. For instance, it is possible to see that the electricity sector of the Netherlands requires \$0.42 of inputs of the coal sector and \$0.17 of inputs from the gas sector for its final output of \$1, but it does not show what these sectors again need to generate this input for the electricity sector. The mathematical operation to compute the input of these other layers as well is called the Leontief inverse. The Leontief inverse is commonly used within an EEIO analysis, as it calculates all the layers of dependency of different sectors within the supply-chain. As this paper is not purposed to explaining specific mathematical operations, this will be left out of this methodological section and the calculation will be a given. For a complete explanation of the mathematical operations of an EEIO analysis, including the Leontief inverse, the handbook of input-output economics by Suh (2009) is suggested.

The result of this last step gives us the technical coefficient matrix L, showing the inputs and outputs of all economic sectors in the world but now also including the total supply-chain. Using the same example as earlier, it is now seen that there is also need for equipment from the manufacturing sector used for coal mining of \$0.13 as a second-tier supplier, for which again \$0.03 of the metal sector is needed to construct this equipment as a third-tier supplier, all for that 1\$ output of the electricity sector. This ultimately comes down to a fractional contribution of each global sector for generating the 1\$ output of the electricity sector. The fractional contribution of all these global sectors is then multiplied by the total output of the electricity sector, showing us the total amount of inputs generated by all global economic sectors for the total output of the electricity sector. Within the example this would mean that the total output of the electricity sector would be for instance \$1000, of which \$1000 x 0.03 = \$30 of total input of the metal sector is needed while \$1000 x 0.13 = \$130 of total input is needed from the manufacturing sector. This is the point where the general input-output analysis is completed, and the calculation of the environmental footprint begins.

To calculate the final output of environmental pressures contributing to the total output of the electricity sector, two things are needed. First, the total input of all global economic sectors is needed for the output of the electricity sector. This we now have. Second, the emission intensity vector is needed. The emission intensity vector is the amount of emissions (within this example tonnes of CO_2) that is emitted to produce $1 of output of any given sector. This emission intensity vector is calculated by taking the total emissions produced by any given sector and dividing this by the total output of this sector. The result of this calculation would for instance give a CO_2 output of 5 tonnes per 1$ output of the metal sector. Having this emission intensity vector of the metal sector, combined with the total input of the sector needed for the total output of the electricity sector, makes it possible to calculate the final environmental output of CO_2 within the metal sector, specifically for the electricity sector. This is done by multiplying the emission intensity vector of the metal sector times the total input it produces for the electricity sector, which is: 5 x 30 = 150 tons of CO_2. Thus, the total CO_2 output of the metal sector, needed to produce equipment for the coal sector, which again is needed to produce electricity is 150 tons of CO_2.

The steps taken within the example are done for every economic sector giving inputs into the total output of the electricity sector and when added up, this results in the total tons of CO_2 emissions needed for the total output of the Dutch electricity sector. We now have the total environmental footprint regarding CO_2 emissions of the electricity sector of the Netherlands. Because Exiobase has data available on the total direct CO_2 emissions for each sector in each country, there is a possibility for dividing the direct and supply-chain emissions by simply subtracting these direct emissions from the total CO_2 emissions which have just been calculated. This gives us the interesting result of not only the total CO_2 emissions of the electricity sector in the Netherlands, but also how much of this is generated by direct consumption, and how much is generated by indirect/supply-chain consumption.

This global supply-chain analysis has been standardized to include not only the electricity sector within this example, but all 163 economic sectors of the Netherlands and all 30 different environmental pressures by using MATLAB. Ultimately this shows us the total environmental footprint of all Dutch economic sectors, separated in direct and supply-chain footprints.

3.1.3 Limitations of the analysis

Before going into the specific limitations, it is important to mention that performing a global supply-chain analysis will always pose some limitations, mostly since calculations using a global EEIO table will never give 100% accurate data results due to the data being on one of the highest levels of abstraction. That being said, Exiobase as of now, is the best available source for global EEIO analysis, due to its high level of granularity when it comes to environmental pressures, number of countries and economic sectors, combined with a high level of detail of the data itself (Ton, 2019; H. Wilting, 2019). But it is also important to mention some limitations that are unavoidable when conducting an EEIO analysis, and these will be discussed below. First, we will discuss some general limitations of performing an EEIO analysis, followed by the limitations which are specified towards the actual analysis and using the Exiobase EEMRIO database.

3.1.4.1 General EEIO analysis limitations

Firstly, a more general limitation of EEIO analysis is the fact that input-output tables may not capture all the activities within the economy. For instance, impacts directly related to consumers that do not involve any purchases from economic sectors (e.g. burning wood generated from one's own property). This limitation should be taken into consideration, as "off the book" activities like for instance land clearing, small scale mining operations etc. can have a high environmental impact. These activities especially occur in low-income countries (Kitzes, 2013). Unfortunately, this limitation is unavoidable. Increased data quality over time will decrease this limitation in the future.

Secondly, and perhaps the most important limitation of EEIO is known as homogeneity, which assumes that each sector in the economy produces a single, homogeneous good or service. This means that there is no classification towards the output of specific products, but instead, sector averages are used when it comes to output of products and the environmental impact it produces. Intuitively, this problem becomes smaller when more sub-sectors are specified within the dataset, as the number of different products produced by these specific sub-sectors becomes smaller. For instance, the environmental output of the manufacturing sector says less about which product specifically causes this output, than the environmental output of dairy farming, of which the environmental output is clearly related to the farming of cattle for dairy, even though even this cannot be 100% confirmed. Ideally, there should such a high level of granularity that each sector represents one unique product created within the economy, although this level of detail is never realized. This means that only assumptions can be made on which products cause the environmental output, and this assumption becomes better with higher sector granularity.

3.1.4.2 Specific limitations of the analysis using Exiobase

Firstly, Exiobase identifies 163 different economic sectors for each country within the Exiobase database. A limitation of this is that even though these economic sectors have been identified, the mining sector in general, which comprehends in total 15 of the total of 163 economic sectors is mostly left blank for all countries. This can be related to the general limitation of EEIO analysis that mining industries in foreign countries are often "off the book" activities. But as of yet, no explanation for this has been given by the developers of the Exiobase database. This does mean that results associated with the mining sector will underestimate the true overall environmental impact, including industries which rely heavily on the input of minerals and metals.

Secondly, data on environmental pressures occasionally lacks consistency with other sources. This can be seen when for instance comparing Exobases' emission data specifically of the Netherlands with CBS data (CBS is the main statistical office of the Netherlands) or the Emission Registration Database (ERD) created by several large organisations for the central government of the Netherlands (Ton, 2019; H. Wilting, 2019). One explanation for this could be the accuracy of the Exiobase database is limited by the quality of data collection and standardization of this data collection by different nations. The inventories of environmental impacts of different nations, often reflect a mix of empirically measured and modelled estimates, both of which can introduce biases and uncertainties. That being said, it is not possible to substitute Exiobase data for CBS data specifically for the direct output of Dutch industries, and not do this for all other countries as well. This would impair the data consistency and comparability of the analysis. Also, Exiobase is still the best database from an EEIO perspective, which is essential when conducting a supply-chain analysis.

3.2 Environmental footprint valuation of the Dutch economy

The completion of the first step of the analysis results in having a complete dataset on the environmental footprint of all Dutch economic sectors, separated in direct and supply-chain footprints. This gives the opportunity to set prices on the Environmental and Social (E&S) damage costs of the environmental pressures selected for this research. This section will first look deeper into the data provided by TruCost, including the valuation methodologies that have been used for the different negative externalities. Secondly, we shortly specify how this research got to the 30 environmental pressures considered. Thirdly, we will look deeper into the specific steps taken to get to the result of the E&S damage costs associated with the environmental footprint of the Dutch economy. Lastly, the limitations of this step within the analysis will be considered.

3.2.1 TruCost data and valuation methodology

TruCost data provides the E&S damage costs for the different environmental pressures provided by Exiobase. TruCost has been used as the main data provider for pricing negative externalities related to the environmental pressures researched within this paper due their data quality. TruCost provides E&S damage costs on a high granular level, making it possible to set prices on specific environmental pressures derived from Exiobase, without making extensive assumptions or combining these environmental pressures into one. To do this, TruCost has developed an extensive methodology on the monetary valuation of environmental pressures. Appendix 8.2, 8.3 and 8.4 describe all these methodological steps, retrieved directly from TruCost documents. The following sections will give a short summary to this for explanatory purposes.

Within this research, three negative externalities have been considered; GHG emissions, pollution and water consumption. Each of these pressures have their own valuation methodology. GHG emissions have been valuated using the Social Costs of Carbon (SCC) methodology, which reflects the full global costs of damages caused by GHG emissions over their lifetime within the atmosphere. These economic costs arise from for instance, changes in agricultural and forestry output, costs from changes in energy demand, property loss due to sea level rise, coastal storms and forest fires and heat related illnesses and diseases.

Within the quantification methodology of water consumption, a separation has been made into the human health impacts and the environmental impacts. The health impacts are estimated using the Disability Adjusted Life Years (DALYs) lost per unit of consumed water. This has been done by linking the impacts associated with malnutrition due to lack of water irrigation, and the spread of deceases due to lack of domestic water. These parameters are country specific and depend on variables like share of total water withdrawals used for agricultural purposes, human development and per-capita water requirements to prevent malnutrition and water stress. From this, the total quantity of DALYs lost can be calculated. The DALYs lost are then valued by the value of a statistical year (VOLY), which is stated as just in excess of $46.500.

The impacts of water consumption on ecosystems is measured based on net primary productivity (NPP). NPP is defined as the rate of new biomass production that is available for consumption and is used by TruCost as a measure of how well an ecosystem is functioning. Based on this TruCost calculated the percentage difference of ecosystem availability between pre- and post-water consumption at a country level. This was applied as a percentage to the average value of one square meter of natural ecosystem in a given region.

Within the valuation methodology of pollution, again a separation has been made into the human health impact, and the impact on the natural environment. The impact of pollution on human health has again been calculated using DALYs. To calculate the quantities of DALY's lost due to pollution, TruCost used the USES-LCA 2.0 combined with literature reviews for some specific types of pollution. This model, originally developed in the context of life cycle assessment (LCA) studies, calculated the quantities of DALYs lost due to emissions of over 3,300 chemicals to: freshwater and seawater, natural, agricultural and industrial soil and rural, urban and natural air. Once these DALYs have been quantified, the same valuation methodology has been applied to these DALYs as stated above.

For the calculation of the impact of pollutants on ecosystems TruCost assessed the link between biodiversity, measured species richness (IUNC, 2015), net primary activity (NPP), and ecosystem value. Finally, TruCost calculated the percentage difference in pre- and post-change of ecosystems at a country and substance level and applied this percentage to the average value of one square meter of natural ecosystem in a given region.

3.2.2 Matching the environmental pressures

30 environmental pressures have been considered within this research. The environmental pressures have been selected by matching them to the environmental pressures available within the TruCost valuation database, as having a price for these environmental pressures is essential for the final output of the analysis. Out of the 35 environmental pressures listed under the main categories of GHG emissions, pollution and water usage within Exiobase 30 have a clean match with TruCost valuation data. The five environmental pressures missing were: benzo(a)pyrene, benzo(K)fluoranthene, indeno(1,2,3-cd)pyrene, dioxins and furans (PCDD/F) and trisodium phosphate. All five environmental pressures missing were indicators of air pollution. The specific indicators and sub-indicators can be seen in appendix 8.1. The environmental pressures that have not been considered are lined in red. The EEIO analysis has been run for these environmental pressures, but as no valuation data was available for them, they have been left out of the final analysis. What could be seen within the EEIO analysis, is that all five these indicators have very little effect on the total air pollution footprint.

With the final list of matching environmental pressures ready there are still two more steps left. First, the units of analyses were matched to calculation purposes. For calculating greenhouse gas emissions (in tons of output) to their respective CO_2 equivalents, the IPCC Fifth Assessment Report of 2014 (AR5) has been used (International Panel Climate Change, 2014). Second, the E&S damage costs calculated by TruCost were constructed in dollar prices. As this research is conducted on the Dutch economy, these prices had to be converted to Euro's to ultimately match the E&S damage costs to the profits gained by individual economic sectors in the Netherlands. This was done by using the exchange rate as given at the time the research was conducted. The exchange rate as of 11-06-2019 was one dollar to 0.88 euros. This exchange rate was used for all environmental pressures used within this research.

3.2.3 Calculating the environmental and social damage costs of the Dutch economy

After matching the environmental pressures, it makes it possible to match the environmental footprint of the Dutch economy to the E&S damage costs associated with this output. This was done by multiplying the total E&S damage costs specifically for one environmental pressure to the environmental footprint of Dutch industries regarding this specific environmental pressure as calculated within the first step of the analysis. This results in a final price associated with the output of each specific environmental pressure over all 163 identified industries within the Netherlands.

3.2.4 limitations of implementing environmental and social damage costs

As for the methodological limitations of this step, the E&S damage costs are average damage costs. But these costs have often been sourced on a national level or even on a regional level. As this level of granularity is impressive, it cannot be utilized within this research as this would bring forth an extremely more complex analysis when including supply-chains of industries within the analysis. This makes the results on valuating sector footprints more general, as environmental externalities of for instance water consumption could prove more expensive in regions with higher water stress levels. Another limitation is the fact that some biases or data assumptions could be present within the TruCost data for some environmental pressures due to the lack of comparability. This is because some of the environmental pressures considered have not been valuated before.

3.3 Impact ratio

Although the total E&S damage costs of the Dutch economy can inform policy development on itself, it ignores differences in the size of the economic sectors and thus the extent to which these economic sectors would be able to bear the burden of E&S damage costs associated with them. Therefore, this paper introduces the metric of the impact ratio: The E&S damage cost as a percentage of the total profits of a sector.

Before going deeper into the analysis, itself, first, we will look deeper into the data that is being used for calculating the total profits of each Dutch economic sector. Secondly, the data alterations needed to implement this data into the current dataset on E&S damage costs will be discussed. Thirdly, an explanation of the analysis itself will be given, followed by the limitations of this specific step within the analysis.

3.3.1 Statistics Netherlands and the Dutch Central Bank datasets

To perform the last step within the data analysis, datasets on the profits gained by each Dutch economic sector are needed. These datasets are obtained from Statistics Netherlands (CBS) and De Nederlandsche Bank (DNB). CBS is the national statistical office of the Netherlands which reports yearly on the total profits of non-financial economic sectors gained over a specific year. These profits are reported as profit before tax, which as a means of consistency will also be used for this research. DNB is the central bank of the Netherlands which tracks the same data on profits before tax as CBS, only specifically for the financial sector of the Netherlands.

The profit before tax selected within these datasets are of the average of the annual profits of 2014 to 2016. The timeframe of three years has been chosen to account for annual fluctuations in profits gained within specific years. A longer timeframe would expectedly distort the analysis as changes within the economic sectors in terms of sector growth or decline might become substantial.

3.3.2 Matching the economic sectors

Having the economic sectors of the current analysis match the datasets of CBS and DNB is essential for comparison. CBS, DNB and Exiobase all use the European union's NACE sector classification standard NACE codes consist of a letter which entails a specific industrial sector followed by up to 6 digits, which increase in detail with each digit added. For example, the NACE code A stands for: agriculture, forestry and fishing, which is divided into A.02 forestry and logging and so on. The NACE classification standard has two versions: The NACE version 1.1 and the more updated version, NACE version 2, which only matches on the 1-digit level.

As Exiobase sector classification is identified in NACE version 1.1, while CBS and DNB data is identified in NACE version 2, a conversion of industrial classification between these two versions also had to be made. But, since data CBS and DNB data is only available on 1-digit level, there was a limited mismatch within the sector conversion. The only major issue resumed under the sub-sector of *"Other business activities"* (M.69) which was a collective of the sector professional, scientific and technical activities (M) and *the sector administrative and support service activities* (N) in NACE 1.1, while this was grouped under NACE 2 as only being the first (M). Due to majority of the sub-sector being (M) in NACE 1.1, the total sector has been contributed to sector M within the final economic sector conversion. This can be considered an assumption. This finally resulted in 21 main economic sectors being considered within this final step of the analysis.

Furthermore, since public organisations do not generate profits, these sectors have been left out the final step of the analysis. Also, due to the common nature of the sectors N (as stated above) and S (*other service activities*), and their relatively low environmental impact, the two economic sectors have been grouped together.

3.3.3 Calculating the impact ratio

As stated above at the beginning of this section, the metric of the impact ratio will be used within this paper. This is to normalize the E&S damage costs of economic sectors, to facilitate comparisons. The metric takes the total E&S damage costs associated with a specific sector and divides it by their total profits generated within the fiscal year of 2014 to 2016. The formula used to calculate the final impact ratio is shown below.

$$Impact\ ratio\ (\%) = \frac{\text{E\&S damage cost (EU€ Mn)}}{\text{Total profit before tax (EU€ Mn)}}$$

The resulting metric is a proxy for an economic sectors annual earnings at risk, should the sector be held accountable for their negative environmental and social impact. The economic sectors annual earnings at risk gives a clear representation of how internalization of negative externalities would affect individual sectors of the Dutch economy differently.

Two different impact factors have been considered within this paper, the main impact ratio according to the profits of the sectors, and the added impact ratio according to revenue, showing the environmental efficiency of the different economic sectors of the Netherlands. The main impact ratio divides the E&S damage costs to the total profits before tax and shows us the impact of such costs on the profitability of the individual economic sectors of the Netherlands, which is in line with answering the main research question. The added impact ratio of E&S damage costs according to total revenue of the economic sectors does not show the direct impact of the internalization of negative externalities on the different economic sectors because the total revenue of economic sectors is much higher. This is because no costs have been subtracted yet, making the impact ratio also much lower. It does show the environmental efficiency of these economic sectors, which is an interesting result. The environmental efficiency is the total E&S damage costs per euro of revenue generated and thus gives a clear representation on how environmentally efficient a given sector is when conducting its business processes.

3.3.4 Limitations of calculating the impact ratio

As mentioned before there are some limitations to this step of the analysis as well. Firstly, when matching NACE 1.1 to NACE 2, on the 1-digit level the industries remain largely the same. But, when looking deeper into the NACE 1.1 sub-sectors and the sub-sectors to which they correspond to in NACE 2, there is more differentiation. This means that some small parts of the 1-digit industries within the NACE 1.1 classification should in fact be contributed to another sector in the NACE 2 classification. This mostly applies to services related to a main sector (say mining for instance). The service industries related to mining are included within the mining sector in NACE 1.1, while these service industries are included within the sector of *other service activities* within NACE 2. These minor sub-sector differences are no major limitation, but on a more granular level could impact the results. Secondly, while the financial sector has been taken into consideration by DNB data, not the complete sector is included. This is because the DNB only has data on profit before tax for banks, pension funds, investment companies and insurers. As this covers most of the financial sector within the Netherlands, there are other companies within the Netherlands that classify as such. Thirdly, as a more general limitation, both profits and revenues can fluctuate over time, as this is already compensated for by considering three-year averages, these fluctuations can still have effect on the impact ratio. This is especially applicable to the financial sector. For instance, within the fiscal year of 2015, pension funds of the Netherlands have endured significant losses (approximately 56 billion euro's). This major cut on profits is not compensated for within 2014 or 2016 (combined profit of less than 10 billion), while in 2017 pension funds made a total profit of 85 billion. These high profit fluctuations have not been as extreme in other economic sectors but should be taken into consideration.

4. Results

The results of this thesis have been divided in the three different methodological steps. This has been done to create a complete image of not only the impact of pricing negative externalities within Dutch economic sectors (step 3), but also showing the environmental pressures it derives from (step 1) and the total costs which are associated with this impact (step 2). The main results will be shown in graphs, aggregated to sectors[1]. As the results of this research are extensive, some of the more detailed result tables have been moved to the appendix.

4.1 The total output of environmental pressures of the Dutch economy

First, the total output of water consumption will be shown. Second, the total output of GHG emissions will be shown. Lastly, the total output of pollution of the Dutch economy will be looked at in more detail. These outputs cannot be further aggregated as each has a different unit of analysis.

4.1.1 The total water footprint of Dutch economic sectors

This total water footprint of the Dutch economy is broken down into: water consumption and water withdrawal. Water withdrawal describes the total amount of water withdrawn from a surface or groundwater source, while water consumption is the portion of the withdrawn water which is permanently depleted from its source. This water is no longer available because it is evaporated, got consumed by people or livestock or got transpired or used by plants. Water withdrawal might be considered less impactful because the water is returned to watershed after being used by for instance households or sectors, but research shows that the water quality is often impacted (Ridgway et al., 2016). This result interlinks with the results of water pollution discussed further on. As shown in figure 3, almost 75% of the total water footprint of the Dutch economy classifies as water consumption, with just over 25% classifying as water withdrawal.

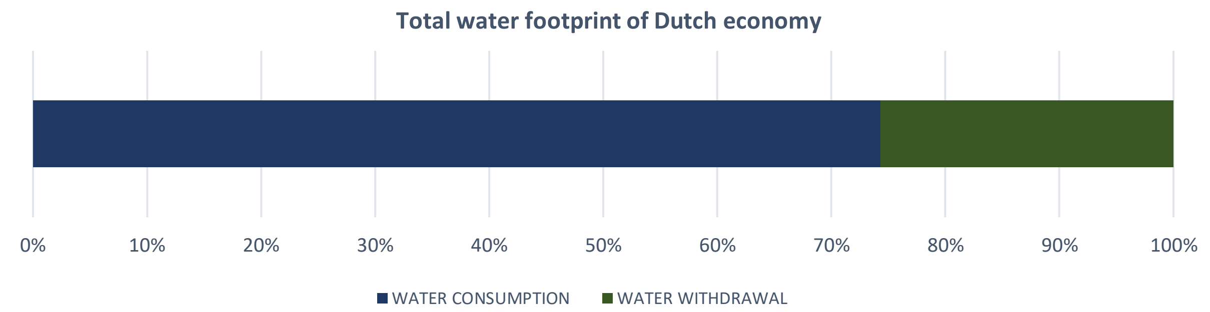

Figure 3: The total water footprint of the Dutch economy, divided in water consumption or water withdrawal. The unit of analysis is cubic hectometre.

[1] Results on a higher granularity are possible if requested, as the results within section 4.1 and 4.2 are available for all 163 sectors.

Analysing the whole Dutch economy considering its water footprint resulted in a total footprint of 103 trillion litres of water, of which 18% is consumed directly by the sectors, and 82% is consumed within the supply-chain. Figure 4 shows the total water consumption and withdrawal combined for all economic sectors of the Netherlands, divided by either domestic, or supply-chain consumption and withdrawal in cubic hectometres. As seen in figure 4, by far the largest share of the water footprint of the Dutch economy resides within the economic sector of *manufacturing*, accounting for 53% of the total Dutch water footprint. Other mentionable sectors are: *the electricity, gas and steam sector* and *the sector of agriculture forestry and fishing*, both accounting for 11% of the total footprint. Within the water footprint of *the manufacturing sector*, 92% of the total footprint contributes to the supply-chain, with only 8% of the footprint being due to direct consumption and withdrawal of water.

In terms of direct usage, *the sector of electricity, gas and steam production* contributed to 47% of the direct water footprint, with *the agriculture, forestry and fishing sector* having a share of 25%. Notable is the fact that 93% of the water footprint of *the electricity, gas and steam production sector* contributes to water withdrawal, not consumption, as it is being used as for instance cooling water or to generate steam for energy production, not consuming the water source itself, but possibly degrading the water quality.

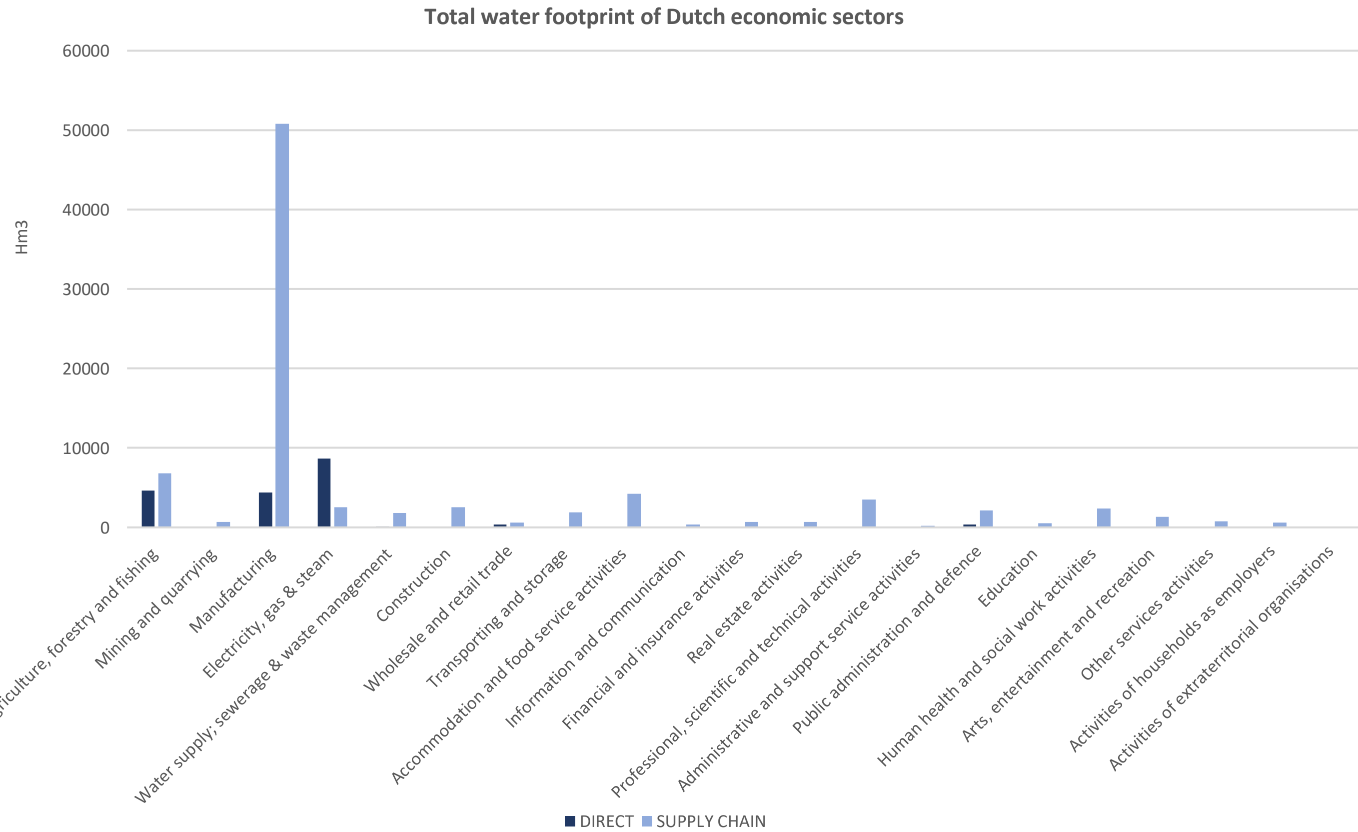

Figure 4: The total water usage of Dutch economic sectors, separated in direct and supply-chain usage. The unit of analysis is in cubic hectometres.

As the results show that the manufacturing footprint contributes to more than half of the total water footprint of the Netherlands, this sector is scoped in further as seen in figure 5. The manufacturing sector consist of 59 sub-sectors, of which the top 10 sub-sectors have been shown considering their water footprint. The other sectors are combined within 'rest'. The figure shows that 51% of the total water footprint of the manufacturing sector is due to the *processing of food products n.e.c.*[2] sector, with over 99% of this footprint residing within the supply-chain of the sector. The processing of food products is the transformation of agricultural products into something that can eventually be eaten. As the Dutch population consumes most of its food processed in somewhat way, the bulk of the water footprint for food consumption ends up within this specific sector. Note that as mentioned within the method section, this is a consumption-based analysis, making the economic sector of food processing accountable for a large sum of the water being used within the primary production process of raising cattle or producing crops. Furthermore, the sector concludes with not elsewhere classified, making it a bulk sector of the total of food processing done within the Netherlands. In total, the water footprint of processing of food products accounts for 27% of the total water footprint of the Dutch economy.

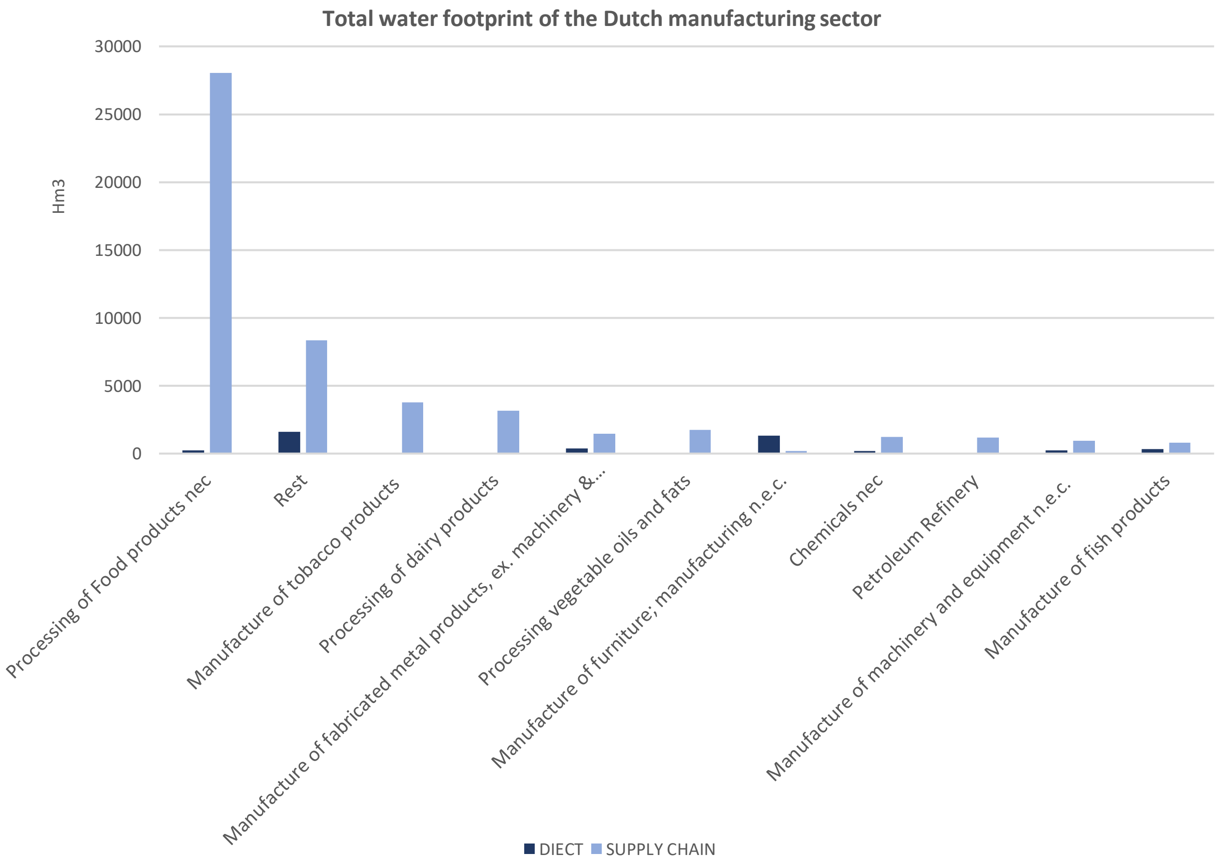

Figure 5: Water usage specifically for the manufacturing sector of the Netherlands, separated in direct and supply-chain usage. The unit of analysis is in cubic meters.

[2] N.e.c. = not elsewhere classified

4.1.2 The total GHG emissions of Dutch economic sectors

Within this research, 6 different GHG emissions are considered: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFC's), perfluorocarbons (PFC's) and sulphur hexafluoride (SF_6). Figure 6 shows the total GHG emissions for all Dutch economic sectors, separated by these different GHG emissions. The respective CO_2 equivalents for each emitted substance are considered within this graph as stated by IPCC (2014). As seen within figure 6, carbon dioxide has the largest contribution to the total output of GHG emissions, with a contribution of 79.4%. Methane comes in second with 13.9%, nitrous oxide third with 3.7%, HFC's fourth with 2%, PFC's fifth with 0.9% and SF_6 last with 0.2% of the total.

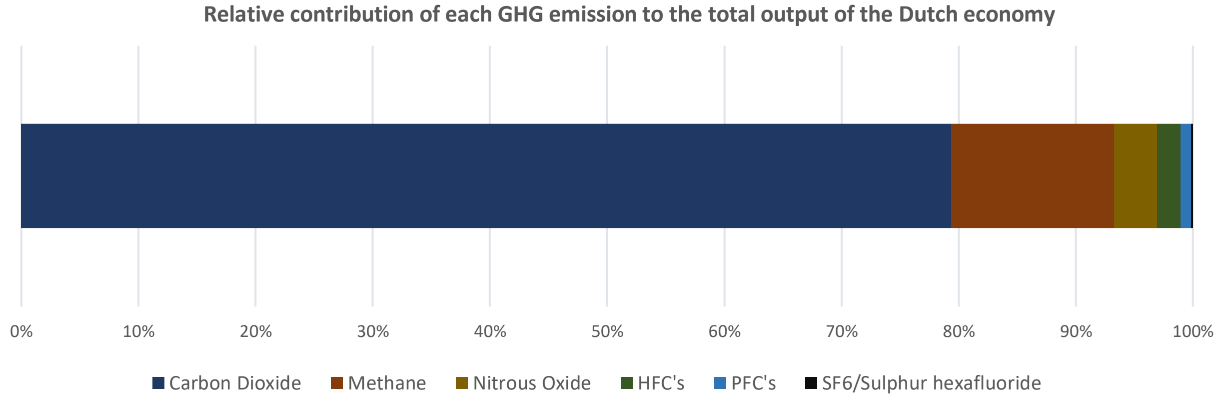

Figure 6: The total GHG emissions for all Dutch economic sectors, separated by the different GHG emissions considered within the analysis. The unit of analysis is in kilotons of Co2 equivalents kilotons of Co2 equivalents.

In total, the Dutch economy emits 4.8 billion CO_2 equivalents (CO_2e). 63% of these GHG emissions are emitted over the supply-chain of the different economic sectors, while 37% is emitted directly by the sectors themselves. The relative contribution of each economic sector to the total is shown in figure 7. The figure shows that the highest contribution of GHG emissions comes from the *manufacturing sector*, taking up 32.8% of the total GHG emissions of the Dutch economy. *The electricity, gas and steam producing sector* comes second with 18.5% of the total GHG emissions emitted. The relative share of total output of *the transportation and storage sector* (10.2%), *the construction sector* (5.6%) and *the agriculture, forestry and fishing sector* (5.3%) is also not to be overlooked.

There is also more direct output of GHG emissions compared to the water footprint. Of all the direct emitted GHG emissions by Dutch sectors, 33% is due to *the electricity, gas and steam producing sector*, with *the manufacturing sector* coming in second with 19.5%. As is shown in figure 6, carbon dioxide dominates the total GHG output. This is the case for almost all sectors shown in Figure 7, with some exceptions. Within *the agriculture, forestry and fishing sector*, both methane (34%) and nitrous oxide (20%) is relatively high. Within *the manufacturing sector*, 68% of all emissions account for CO_2, with methane (19%) and HFC's (10%) also taking a large share. The table showing the specific GHG output for each sector in percentages to the total is shown in Appendix 8.5.

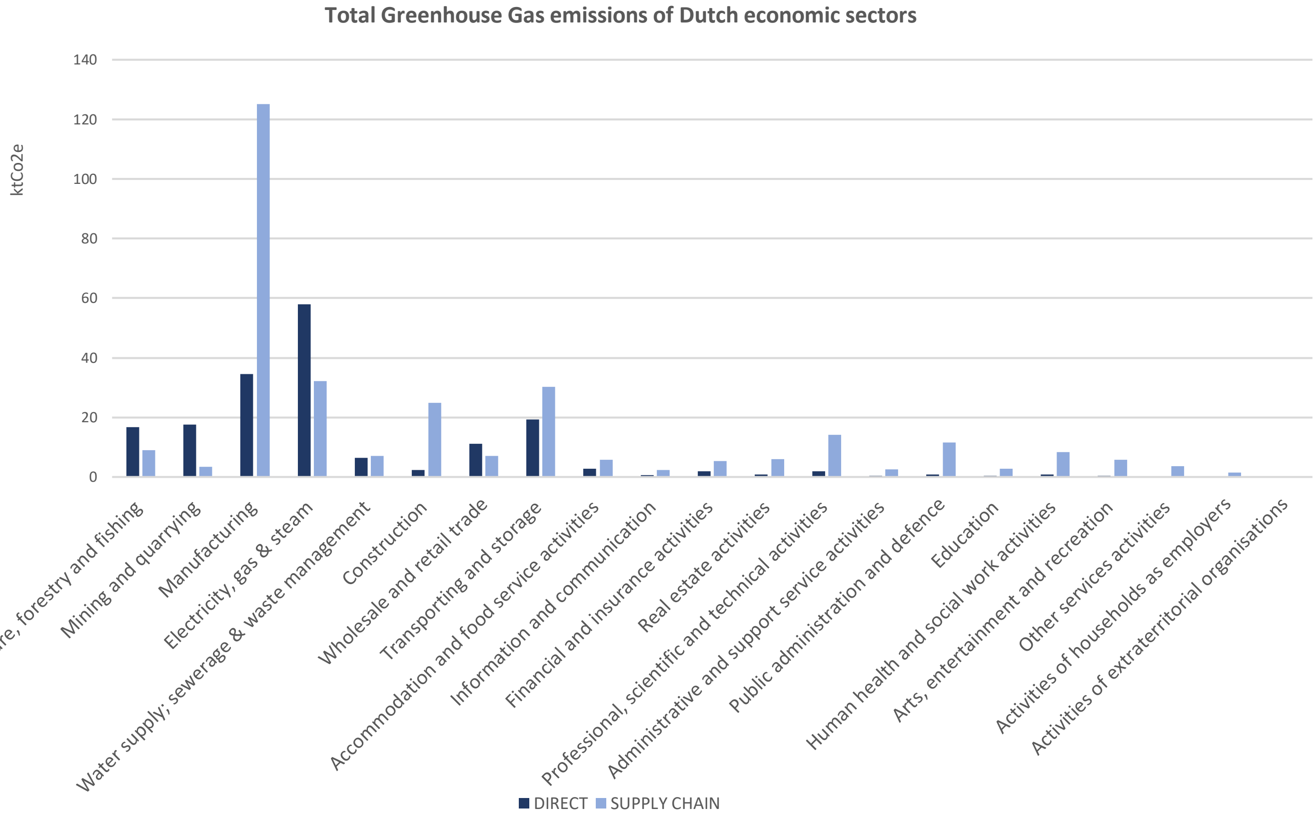

Figure 7: The total GHG emissions for all Dutch economic sectors, separated in direct and supply-chain usage. The unit of analysis is in

To expand on the initial sector results, the high polluting sectors of *the electricity, gas and steam* and *manufacturing* have been researched more intensively. *The electricity, gas and steam sector* consists of 15 sub-sectors in total. More than 55% of the total GHG emissions come from only two of them: The sub-sectors of *steam and hot water supply* and the sub-sector of *the manufacturing and distribution of gas*. As *the manufacturing sector* has so many different sub-sectors, figure 8 shows the top 20 sub-sectors with the highest respective GHG emission output, again for both direct and the supply-chain. The figure shows that the total GHG output of *the manufacturing sector* comes from a multitude of sub-sectors. The highest GHG emissions result from the sub-sector of *petroleum refinery* (21%), *the processing of food products n.e.c*. (16%), *the chemical sector* (8%), *the dairy processing sector* (8%), *the manufacturing of fabricated metal products* (7%) and *the manufacturing of machinery and equipment sector* (7%). Overall, the supply-chain contribution of these sectors dominates the total output, except for *the chemical sector* of which 60.5% of its total output comes from direct GHG emission output, 22,4% of the total direct output of the manufacturing sector.

As mentioned above, within *the manufacturing sector* only 68% of the total GHG emissions are from the output of CO_2. This shows that carbon dioxide is not dominating all the 20 sub-sectors with a high GHG output. This is mostly due to three sub-sectors: The contribution of methane to the total GHG output is high within *the dairy processing sub-sector* (45% of sub-sector), *the petroleum refinery sub-sector* (40%) and *the food processing sector* (26%). Furthermore, within *the food processing sector* 16% of the total output contributed to nitrous oxide. For more details on the specific GHG output of all manufacturing sub-sectors, appendix 8.6 shows a table in percentages of the total output.

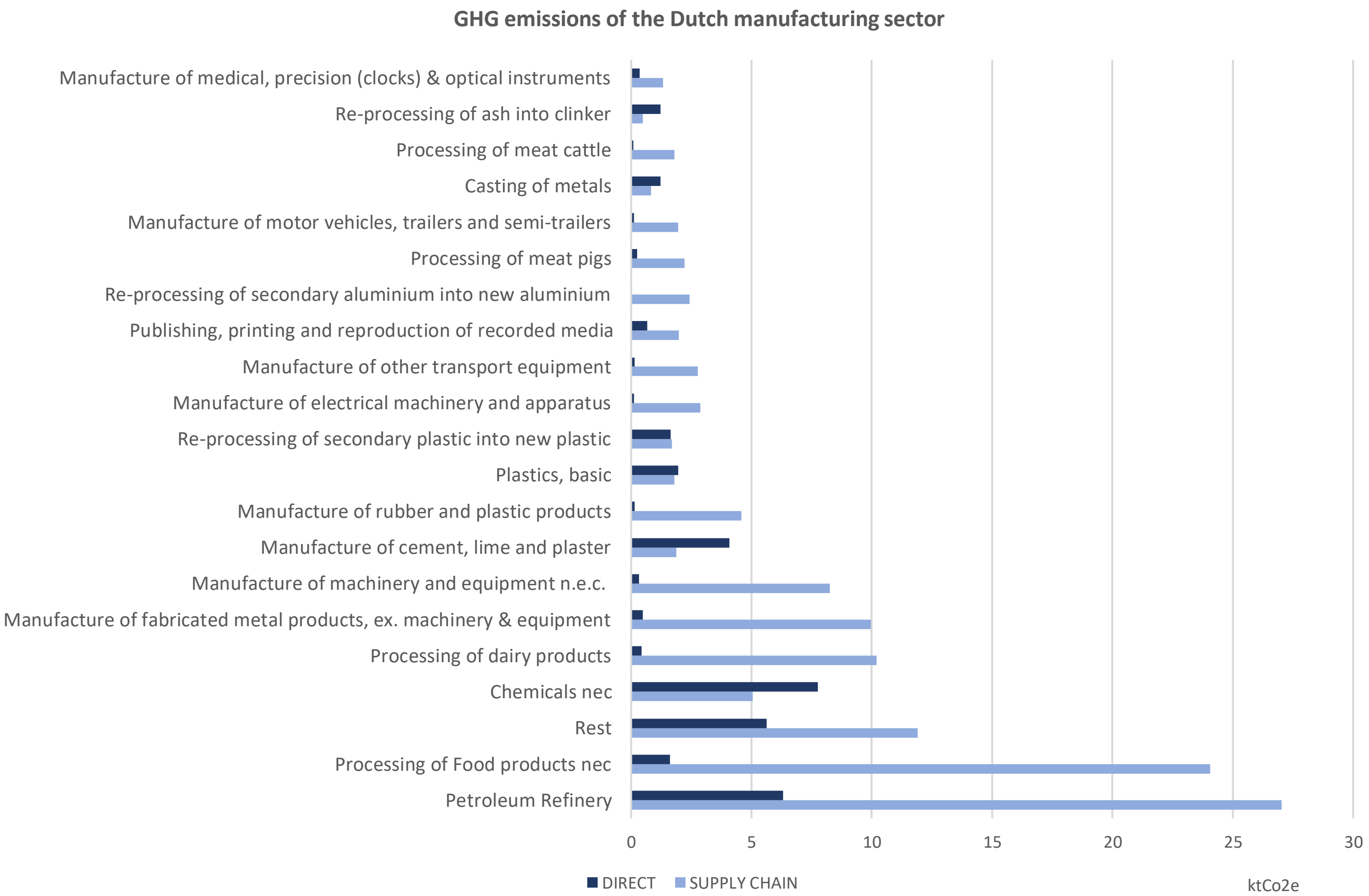

Figure 8: total GHG emissions for the manufacturing sector of the Netherlands, separated in direct and supply-chain usage. The unit of analysis is in ktCO_2e.

4.1.3 The total air, water and land pollution of Dutch economic sectors

The last environmental pressure is pollution. The total air, water and land pollution generated by the Dutch economy is 7.9 million tons. Within air pollution, this is excluding GHG emissions. Figure 9 shows the in total 18 different environmental pressures considered and their relative contribution to the total. As is clearly seen, there are 8 types of pollution dominating the results, being: Carbon monoxide (40%), nitrogen oxides (19%), ammonia (13%), sulphur dioxide (10%), volatile organic compounds (6%), nitrogen to water (6%), phosphorus to land (3%) and particulate matter (3%). All the other types of pollution combined only contribute to 0.4% of the total pollution output.

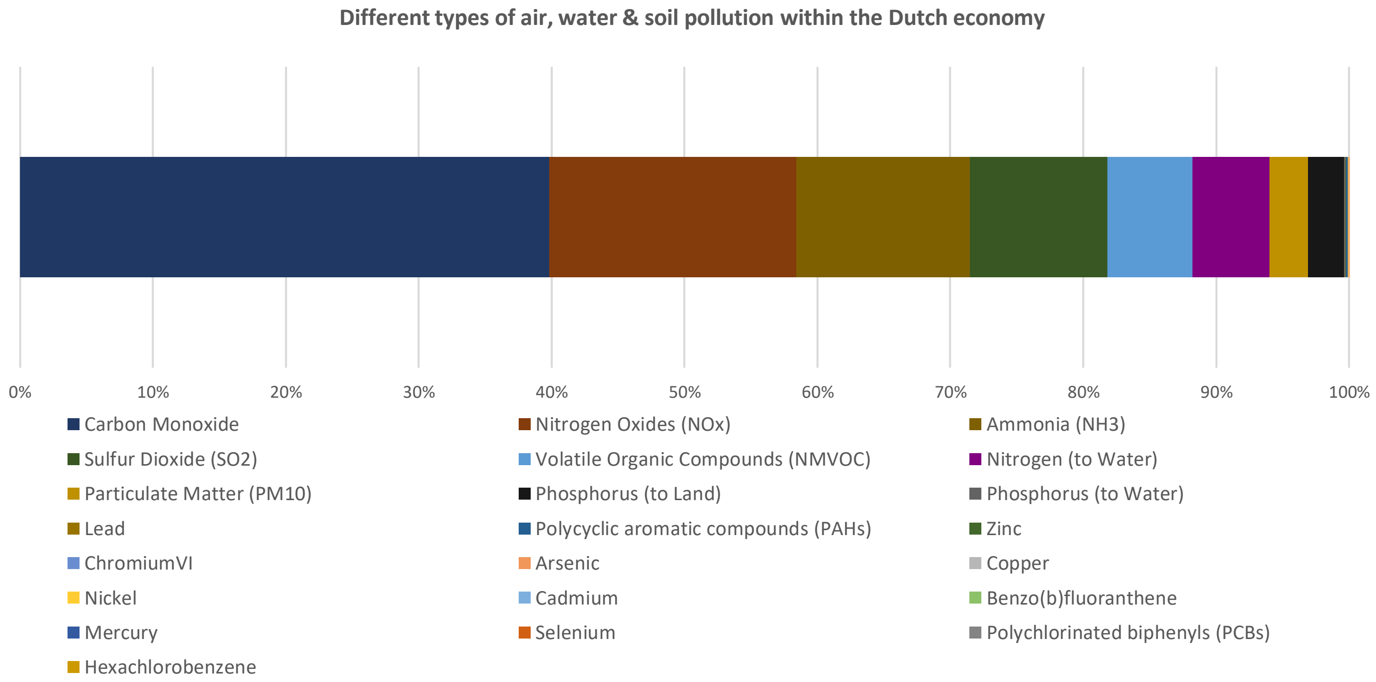

Figure 9: The total air, land and water pollution the Dutch economy, separated in the different pollutants considered within this research. The unit of analysis is in tonnes of physical output of the pollutant.

The next step is to look at how this pollution is divided in direct output of the economic sector, and supply-chain output. This is shown in figure 10. Of the total 7.9 million tons of pollution generated by these economic sectors, 72% is produced within the supply-chain, and 28% directly by the industries. Figure 10 also shows us that again, the manufacturing sector has the highest total output, which is 43% of the total. Second comes *the transporting and storage sector* which accounts for 12% of the total, and third *the agriculture, forestry and fishing sector* with 10%. Within *the manufacturing sector*, the supply-chain contributed to 90% of this total output of pollutants, while t*he transporting and storage sector* has an even distribution of 43% direct and 57% supply-chain. *The agriculture, forestry and fishing sector* is the highest direct pollutant of the Netherlands with 82% of its pollution output contributing to it, taking up 30% of the total direct pollution output of the Netherlands. The specific types of pollution contributing to these different quantities of direct and supply-chain output can be seen in Appendix 8.7.

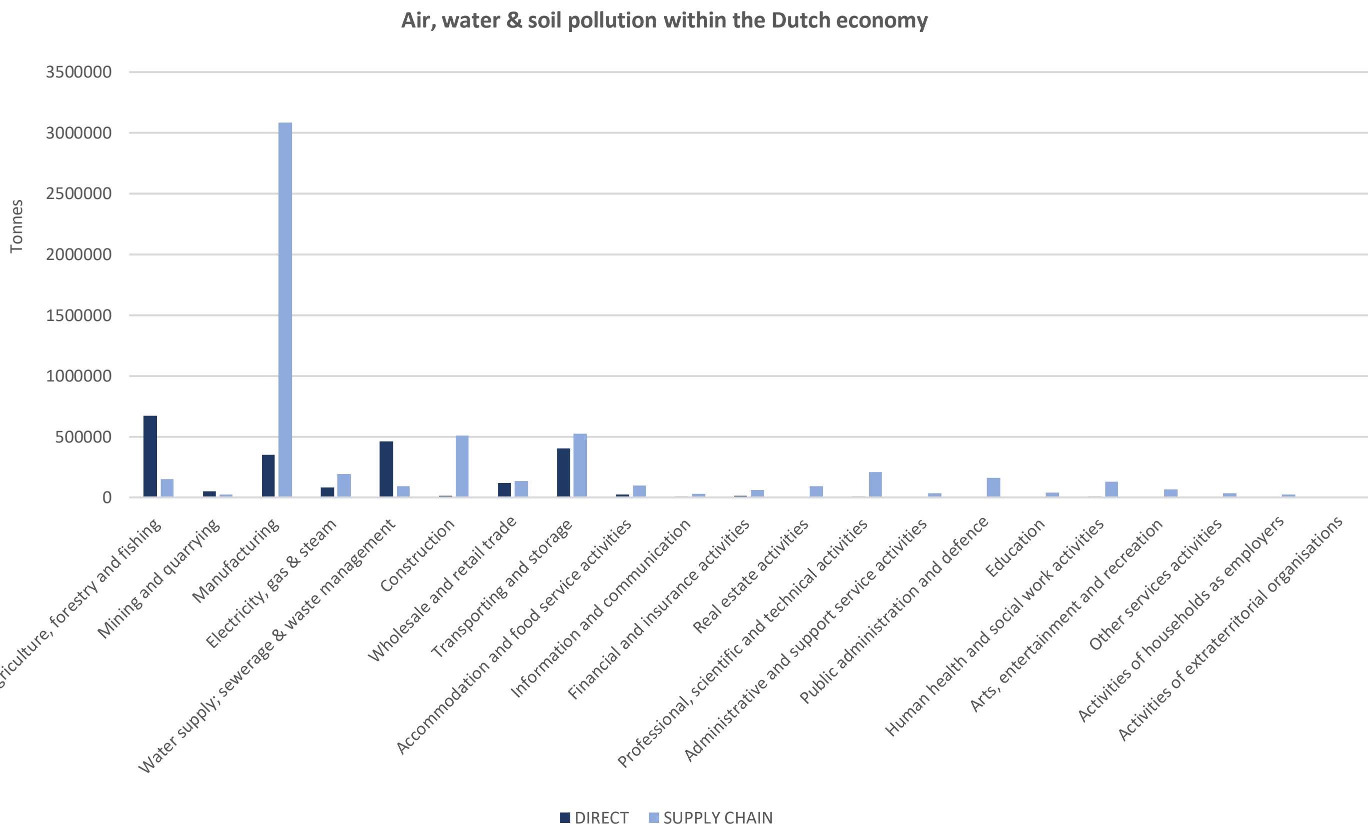

Figure 10: The total air, land and water pollution for all Dutch economic sectors, separated in direct and supply-chain usage. The unit of analysis is in tonnes of physical output of the pollutant.

As *the manufacturing sector* again has a high output of environmental pressures it is highlighted in figure 11. Figure 11 shows us the total output of pollution generated by each sub-sector of *the manufacturing sector*, divided in direct and supply-chain output. Noticed at first sight is the fact that for almost all sub-sectors, the supply-chain is the main contributor of pollution output. This makes sense as 90% of *the manufacturing* output of pollutants contribute to the supply-chain as mentioned above. The two most polluting manufacturing sub-sectors are *the processing of food products* and *the production of fabricated metal products* with a total of 19% and 14% of *the manufacturing sector* total respectively. *The re-processing of secondary aluminium sub-sector* is the only sector with a high direct output of pollution with 76% of its total output, contributing to 41% of the total direct output of the manufacturing sector. The respective pollutants responsible for each output for the top 20 sectors of figure 11 are shown in appendix 8.8.

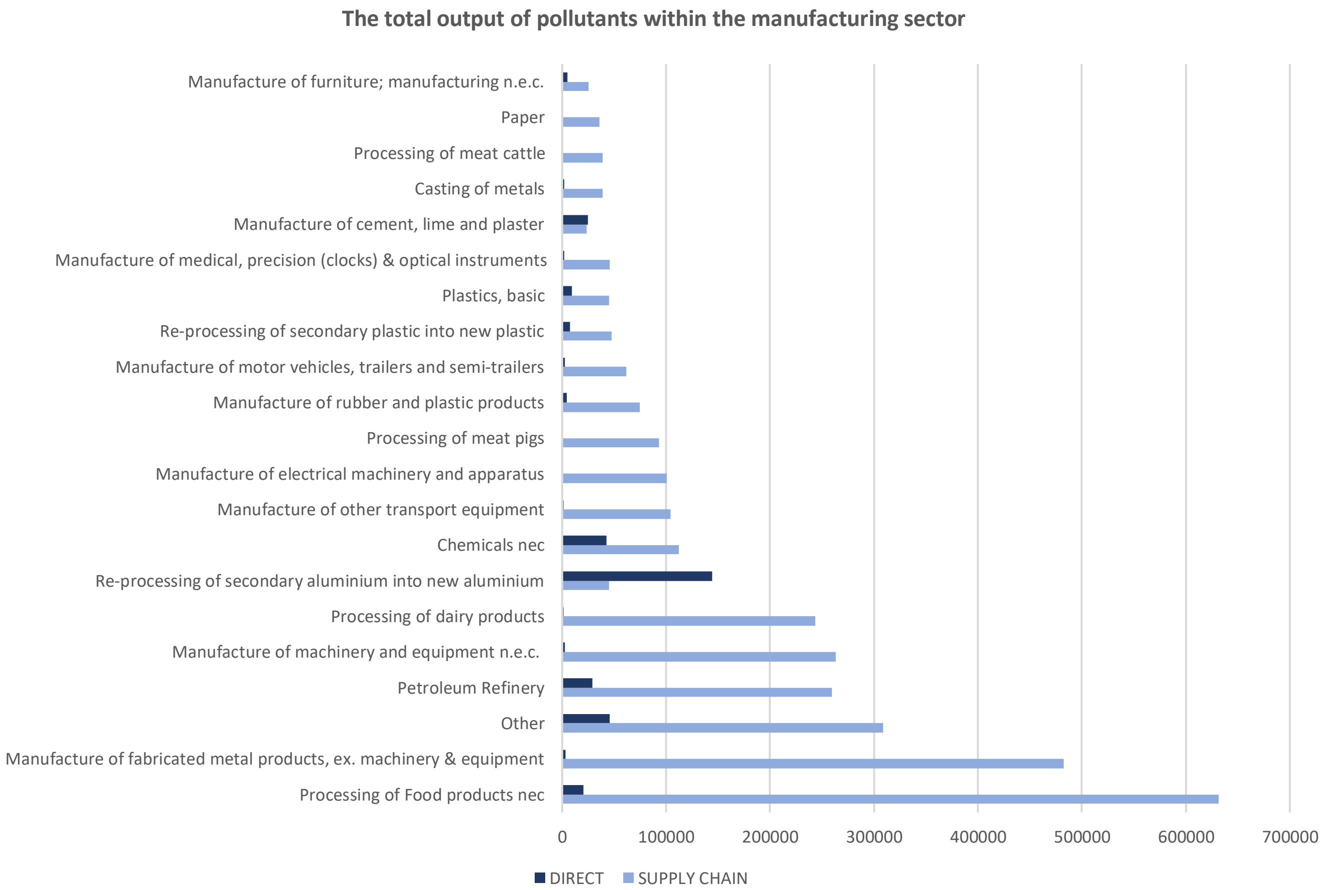

Figure 11: the total output of pollutants for the manufacturing sector of the Netherlands, separated in direct and supply-chain usage. The unit of analysis is in tons of output.

4.2 The total environmental and social damage costs of the Dutch economy

With the total environmental footprint calculated and shown in the previous section, including the differentiation of this footprint to the economic sectors of the Netherlands, this section will now substitute the quantitative output with monetary output of the different environmental pressures. Whereas for the footprint several units of analysis are needed, monetization enables to compute totals per sector. Before looking at specific sectors, first the total costs of the negative environmental externalities in general and for each individual environmental pressure is shown.

The total E&S damage costs of all negative environmental externalities considered for the Dutch economy is 78.8 billion euros. This amounts to 10.7% of the Dutch GDP. Figure 12 shows the total costs associated with each environmental pressure over all sectors, combined with the total costs of each main environmental pressure being; GHG emissions, pollution and the water footprint. The figure shows that GHG emissions contribute to 70% of the total E&S damage costs, with a total of 55 billion euros. The total pollution generated by the Dutch economy relates to 23% of the total costs, being 18.3 billion euros. The lowest costs are associated with the water footprint, taking up 7% of the total costs, or 5.5 billion euros.

The high contribution of GHG emissions to the total E&S damage costs is due to carbon dioxide, which is by far the costliest environmental pressure of the Dutch economy. Carbon dioxide by itself contributes to 55% of the total E&S damage costs (43.6 billion). Relatively speaking, this is not due to the high E&S damage costs associated with the substance carbon dioxide as it is in the lower half of E&S damage costs per quantity of physical output. It is thus the cheer quantity of output of the substance that results in it being the costliest. Other substantial contributors to the total E&S damage costs are methane (9.7%), ammonia (6.2%), nitrogen oxides (6.1%), water consumption (5.2%), particulate matter (4.3%) and sulphur dioxide (3%). There are also 17 environmental pressures within the figure that combined only result in 0.32% of the total E&S damage costs.

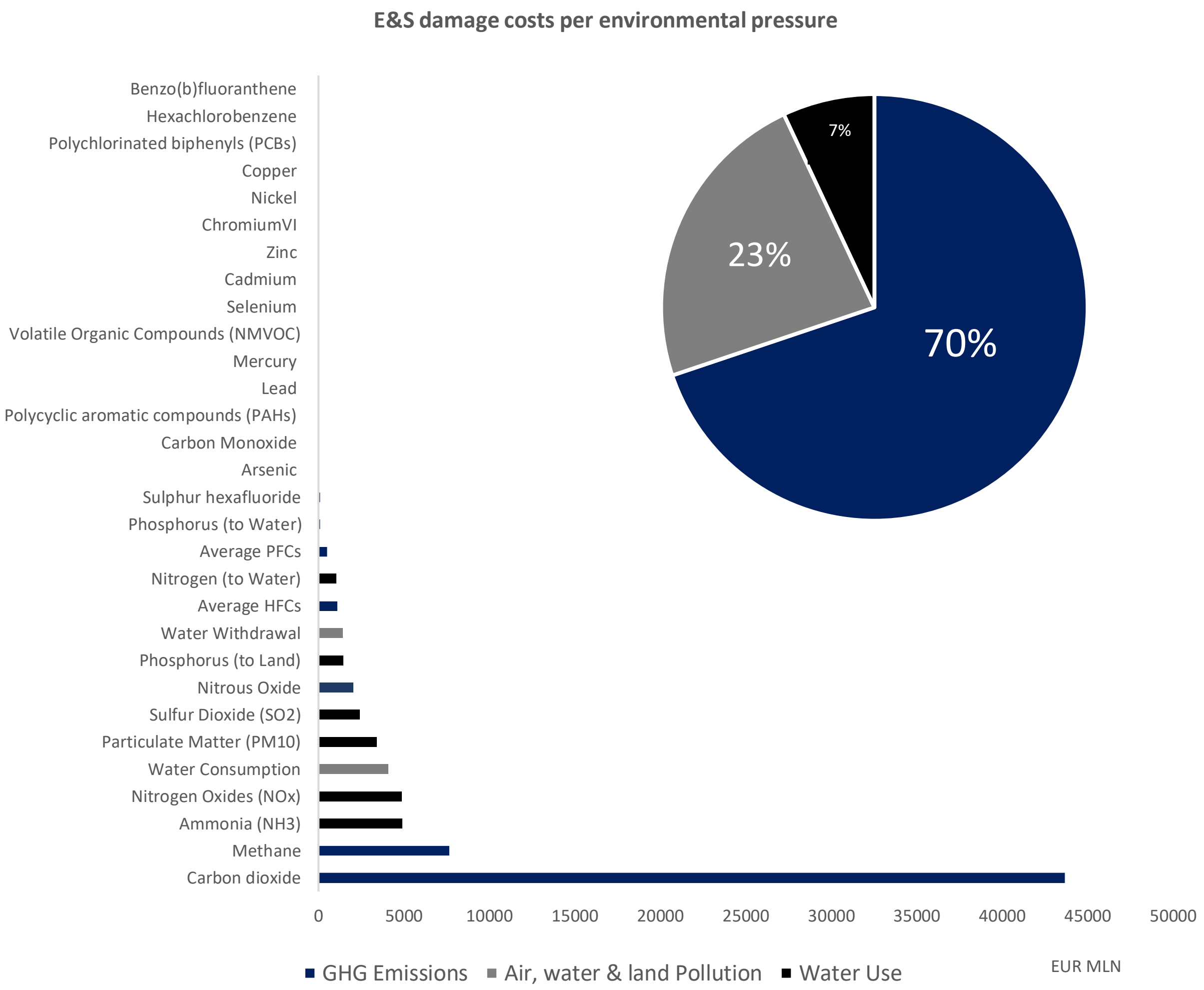

Figure 12: This figure shows the total E&S damage costs for each environmental pressure considered within this research. The pie chart shows the percentage contribution of the three negative externalities to the total E&S damage cost.

Knowing the total E&S damage costs, and the highest contributors concerning environmental pressures to these costs, we can now show how these costs distribute over the different economic sectors of the Netherlands. This is shown in figure 13. Figure 13 shows the distribution of these costs over the different economic sectors, separated by the relative contribution of each of the three negative externalities. The costs associated with the water footprint is 5.5 billion in total, of which *the manufacturing sector* takes the highest share with 53.3% of the total. Second is *the agriculture, forestry and fishing sector* with 11% and third *the electricity, gas and steam sector* with 10.8%. The costs associated with GHG emissions are 55 billion in total, of which again *the manufacturing sector* takes the highest share, in this case 32.8%. The second highest share of costs are related to *the electricity, gas and steam sector* (18.6%) and third *the transporting and storag*e sector (10.2%). The costs associated with air, water and land pollution are 18.3 billion euros. *The manufacturing sector* again takes the highest share of 40.6% of the total costs. Second is *the agriculture, forestry and fishing sector* with 16.7% and third, *the transporting and storage sector* with 13.9% of the total costs. As can be seen, costs associated with GHG emissions are the highest in every economic sector, except for *the agriculture, forestry and fishing sector*, where pollution costs are slightly higher. Furthermore, the manufacturing sectors almost takes double the share in E&S damage costs compared to the other sectors.

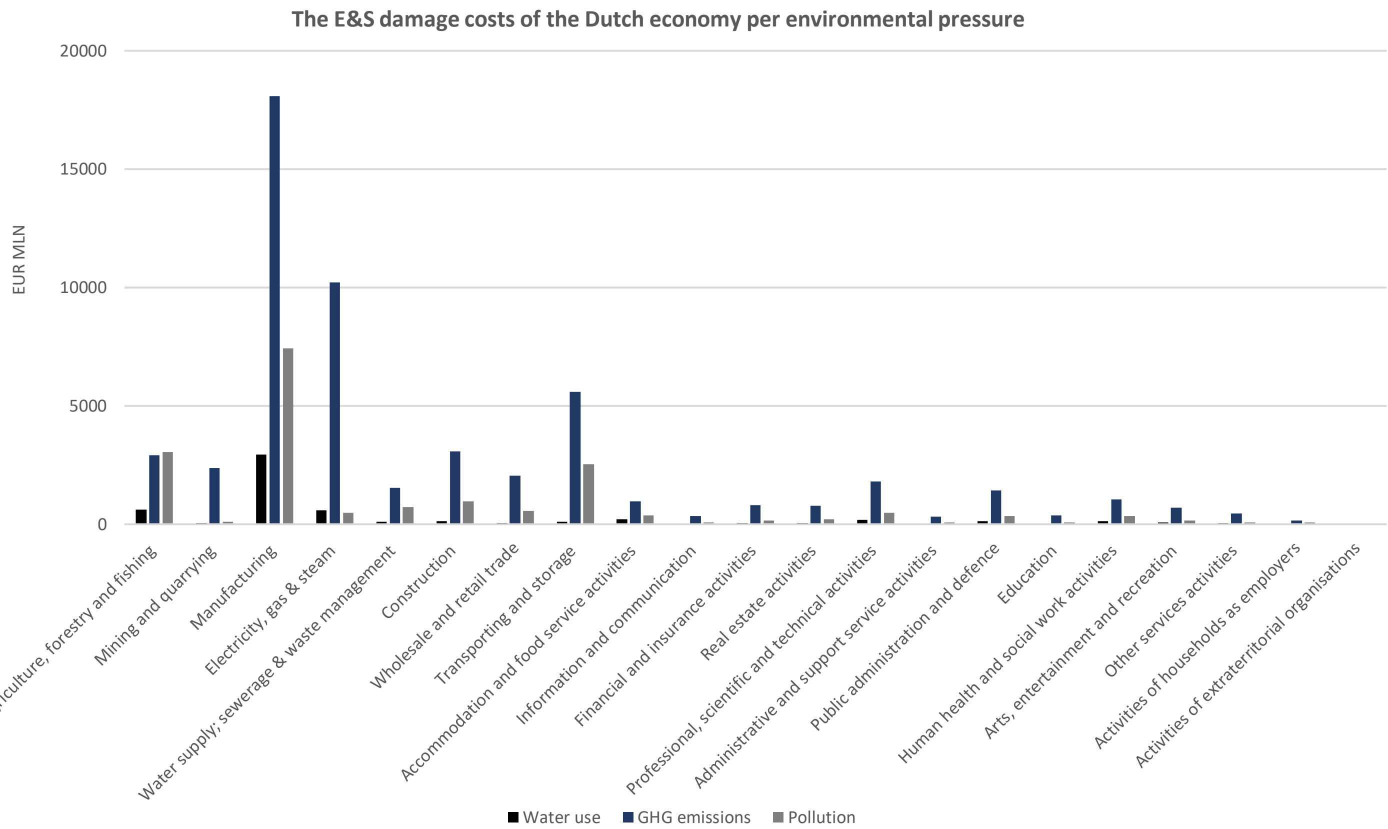

Figure 13: This figure shows the contribution of the three negative externalities to the total E&S damage costs, specifically for each economic sector considered within this research.

In total highest total E&S damage costs are related to *the manufacturing sector* with an E&S damage costs of 28.4 billion euros, a share of 36.1% of the total E&S damage costs of the Dutch economy. *The electricity, gas and steam sector* comes in second place with a total of 11.2 billion euros in E&S damage costs, a share of 14.3% of the total E&S damage costs. Third is the sector of transporting and storage with a share of 10.4% of the total costs, or 8.2 billion euros.

Figure 14 shows how these costs are divided between the direct costs and the indirect or supply-chain related costs of the different economic sectors. The figure shows that a significant part of the costs shown above are related to the supply-chain of the different sectors. The direct E&S damage costs of the Dutch economy is 26.3 billion, while the indirect or supply-chain related E&S damage costs are 52.5 billion. *The manufacturing sector* has the highest supply-chain related costs of 23.9 billion euros, contributing to 84% of the total costs of the sector. Second is *the transporting and storage sector* with 4.9 billion, which is 59% of the total costs of the sector. The direct costs are highest within the *electricity, gas and steam sector* with 7.2 billion euros which is 64% of the total costs of the sector. The second highest direct costs are related to *the agriculture, forestry and fishing sector* with 4.7 billion, resulting in 73% of the total costs of the sector. Notable is the fact that *the manufacturing sectors'* direct E&S damage costs are lower than the E&S damage costs of both *the electricity* and *agricultural sector.* Furthermore, the direct costs are more concentrated in a few sectors, while the supply-chain costs are more diffused over all sectors.

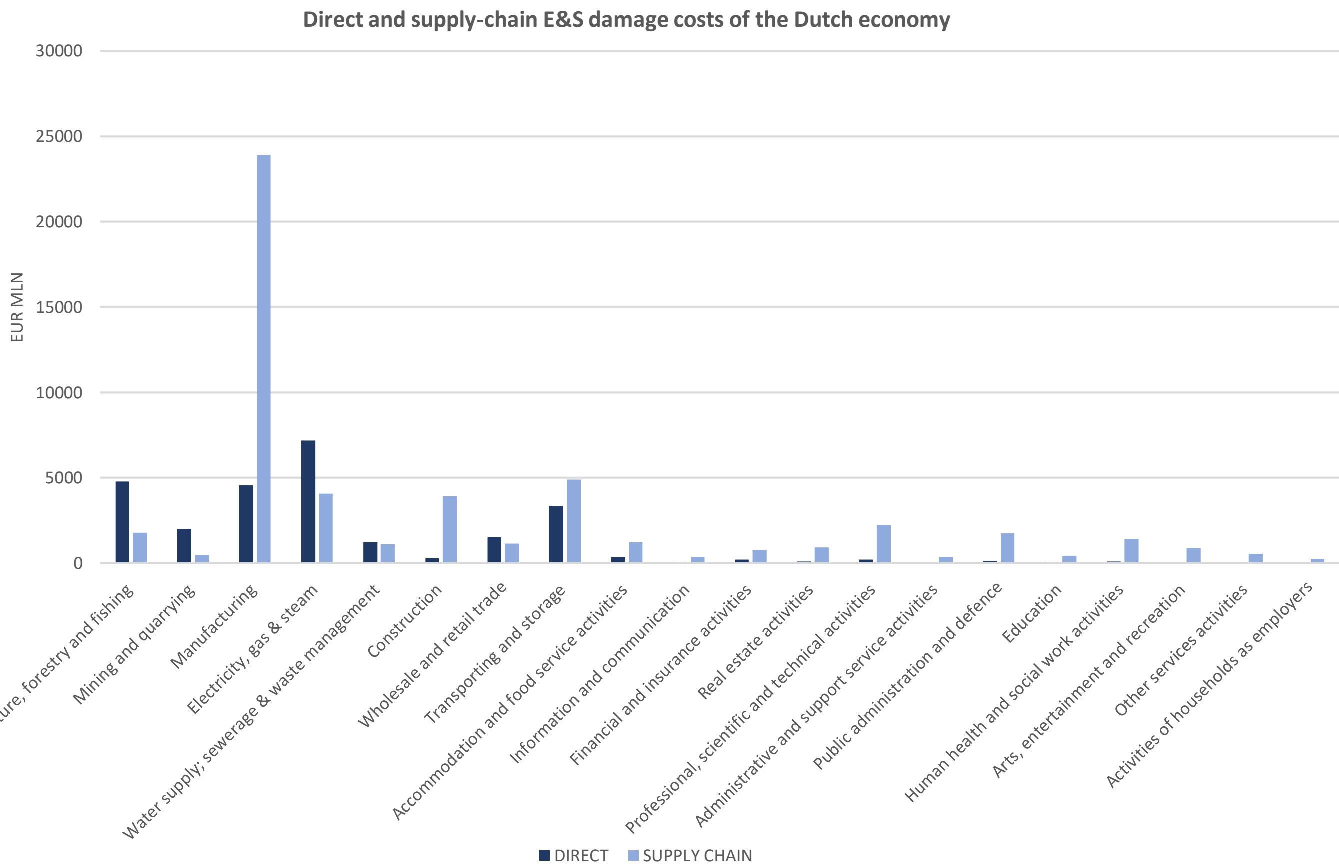

Figure 14: The total E&S damage costs for the Dutch economy, separated by the direct and indirect or supply-chain costs in million euros.

As a final result, table 1 shows us the top 10 most expensive negative externalities for each economic sector of the Netherlands, including the highest two environmental pressures (EP's) that contribute to these costs, either through supply-chain output or direct output of the pressure. The table shows us that GHG emissions in *the manufacturing sector* contribute to the highest E&S damage costs within the Netherlands, with supply-chain output of carbon dioxide and methane mostly being responsible for these costs. Regularly occurring sectors within the top 10 are *the manufacturing sector*, *the transportation and storage sector* and *the agriculture, forestry and fishing sector* and are thus associated with the highest E&S damage costs of the Dutch economy. One odd sector in this list is the sector of mining and quarrying, as most of this sectors output data is missing within Exiobase. As only 4 out of 15 sectors have data available within the mining sector, the 2.36 billion in E&S damage costs due to GHG emissions is almost exclusively due to the extraction of natural gas (92%), with the extraction of sand and clay (3%) and the mining and extraction of chemicals (2%) and petroleum (3%) taking a small share of the total output.

Table 1: A top 10 of negative externalities of the economic sectors of the Netherlands. The table includes the total E&S damage costs of the negative externality specifically for the sector contributing to the output of this externality. Furthermore, it includes a top two of environmental pressures (EP's) contributing to the output of the negative externality, including the direct and supply-chain output of these EP's

Rank	Negative Externality	Sector	E&S damage costs (MLN)	Highest EP share	Direct	Supply-chain	Second highest EP share	Direct	Supply-chain
1	GHG	Manufacturing	18081.8	Carbon Dioxide (68.3%)	29.7%	70.3%	Methane (22.2%)	1.3%	98.7%
2	GHG	Electricity, gas & steam	10211.4	Carbon Dioxide (97.1%)	65.3%	34.7%	Methane (2.0%)	28.1%	71.9%
3	Pollution	Manufacturing	7423.7	Ammonia (31.8%)	0.0%	100.0%	Nitrogen oxides (19.2%)	14.5%	85.5%
4	GHG	Transporting and storage	5599.6	Carbon Dioxide (88,8%)	43.5%	56.5%	Methane (9.4%)	0.7%	99.3%
5	GHG	Construction	3090.3	Carbon Dioxide (86.4%)	9.8%	90.2%	Methane (8.1%)	0.2%	99.8%
6	Pollution	Agriculture, forestry and fishing	3057.2	Ammonia (57.4%)	93.2%	6.8%	Nitrogen oxides (13.9%)	82.5%	17.5%
7	Water	Manufacturing	2931.2	Water consumption (86.3%)	2.9%	97.1%	Water withdrawal (13.7%)	8.0%	92.0%
8	GHG	Agriculture, forestry and fishing	2922.3	Carbon Dioxide (43.8%)	42.0%	58.0%	Methane (34.4%)	81.8%	18.2%
9	Pollution	Transporting and storage	2532.1	Nitrogen Oxides (52.7%)	52.9%	47.1%	Sulphur dioxide (23.8%)	42.7%	57.3%
10	GHG	Mining and quarrying	2363.0	Carbon Dioxide (69.4%)	79.4%	20.6%	Methane (19.4%)	92.9%	7.1%

4.3 The total impact of pricing negative externalities of the Dutch economy

Now that we have the total E&S damage costs calculated for each economic sector of the Netherlands it is possible to calculate the impact ratio using the total generated profit before tax of each of these economic sectors. As stated within the method section, public sectors have not been considered within this section of the results, as they do not generate profits. As we have seen in the last section, the total E&S damage costs of the Dutch economy is 78.8 billion euros for the year 2015. The average total profit before tax generated by the Dutch economy between 2014-2016 was 112.7 billion Euros. A simple calculation of a direct payment of these costs would, ceteris paribus, results in a total loss of profit of 70% for the Dutch economy as a whole. Of this 70% profit loss, 47% is associated with E&S damage costs generated within the supply-chain of the economic sectors, while 23% is due to direct E&S damage costs.

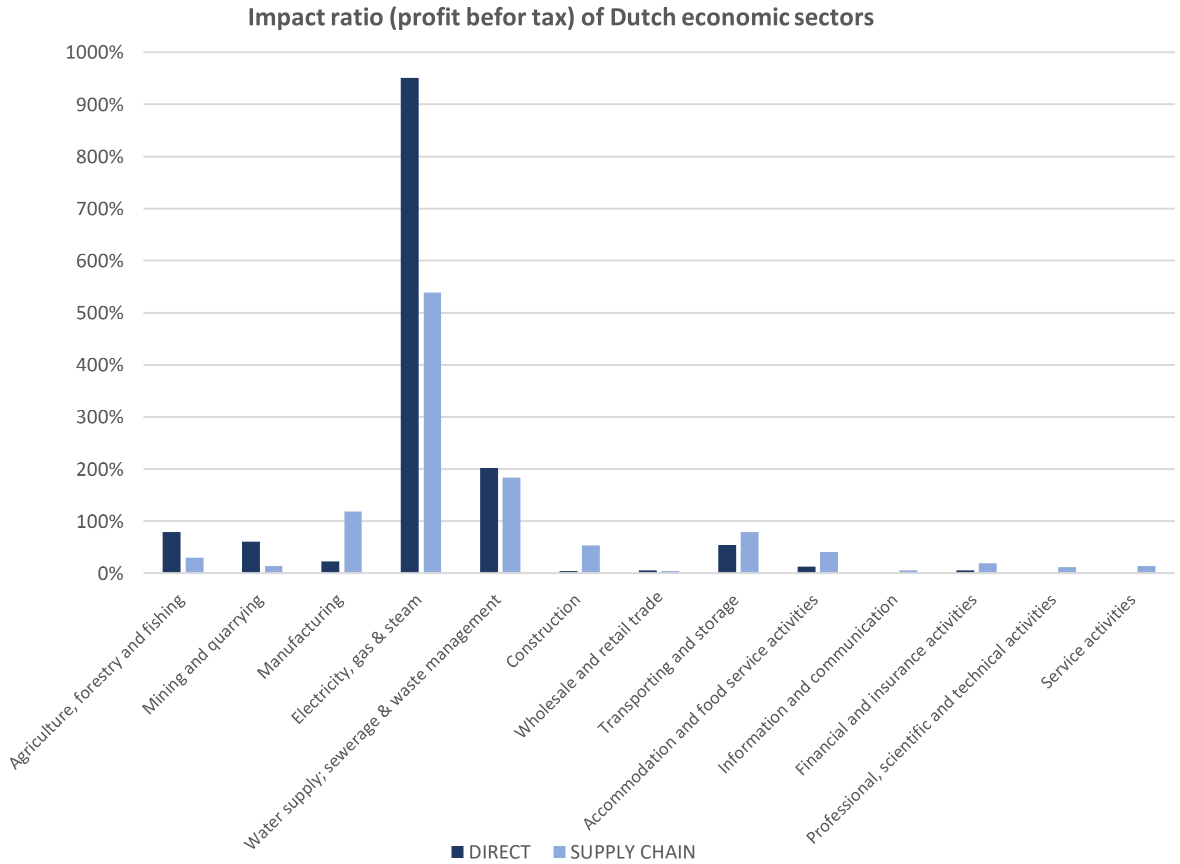

Figure 15: The impact ratio of Dutch economic sectors concerning profit before tax. The impact ratio has been given in percentages of total loss of profit. The impact ratio has been divided in direct of supply-chain impacts.

The results of the impact ratio for the specific economic sectors is shown in figure 15. In total there are five economic sectors out of 13 with an impact ratio higher than 100%: *the electricity, gas and steam sector* (1490%), *the water supply, sewerage and waste sector* (385%), *the manufacturing sector* (140%), *the transportation and storage sector* (133%) and *the agriculture, forestry and fishing sector* (108%). It clearly shows that *the electricity, gas and stream sector* is not at all capable in bearing the costs of its environmental footprint. The sector would lose 950% of its total profits when all the negative externalities from their direct sector processes would become regulated, ceteris paribus. This would be almost 1490% if the complete supply-chain would be taken into account too. It is not the only sector with a high impact ratio; *the water supply, sewerage and waste sector* would stand to lose a total of 385% of its profits due to E&S damage costs, of which 202% would be due to negative environmental externalities due to direct sector processes, and 183% due to supply-chain processes. The sector does not have a high environmental footprint compared to the other sectors, but the sector does not generate high profits either. Furthermore, the result shows us that pricing negative environmental externalities for direct sector processes would only impact two of the sectors in such a way that it would generate losses, which makes for an interesting point of discussion.

Another finding is the fact that even though *the manufacturing sector* of the Netherlands had the highest E&S damage costs of all sectors, its impact ratio is relatively low. Of its total impact rate of 140%, 118% is due to negative environmental externalities within the supply-chain, and only 22% due to direct sector processes. A more detailed impact ratio of all aggregated sub-sectors of *the manufacturing sector* is shown in figure 16. The figure clearly shows that *the manufacturing of food products sub-sector* (1413%) contributes largely to the supply-chain impact ratio of *the manufacturing sector* in general.

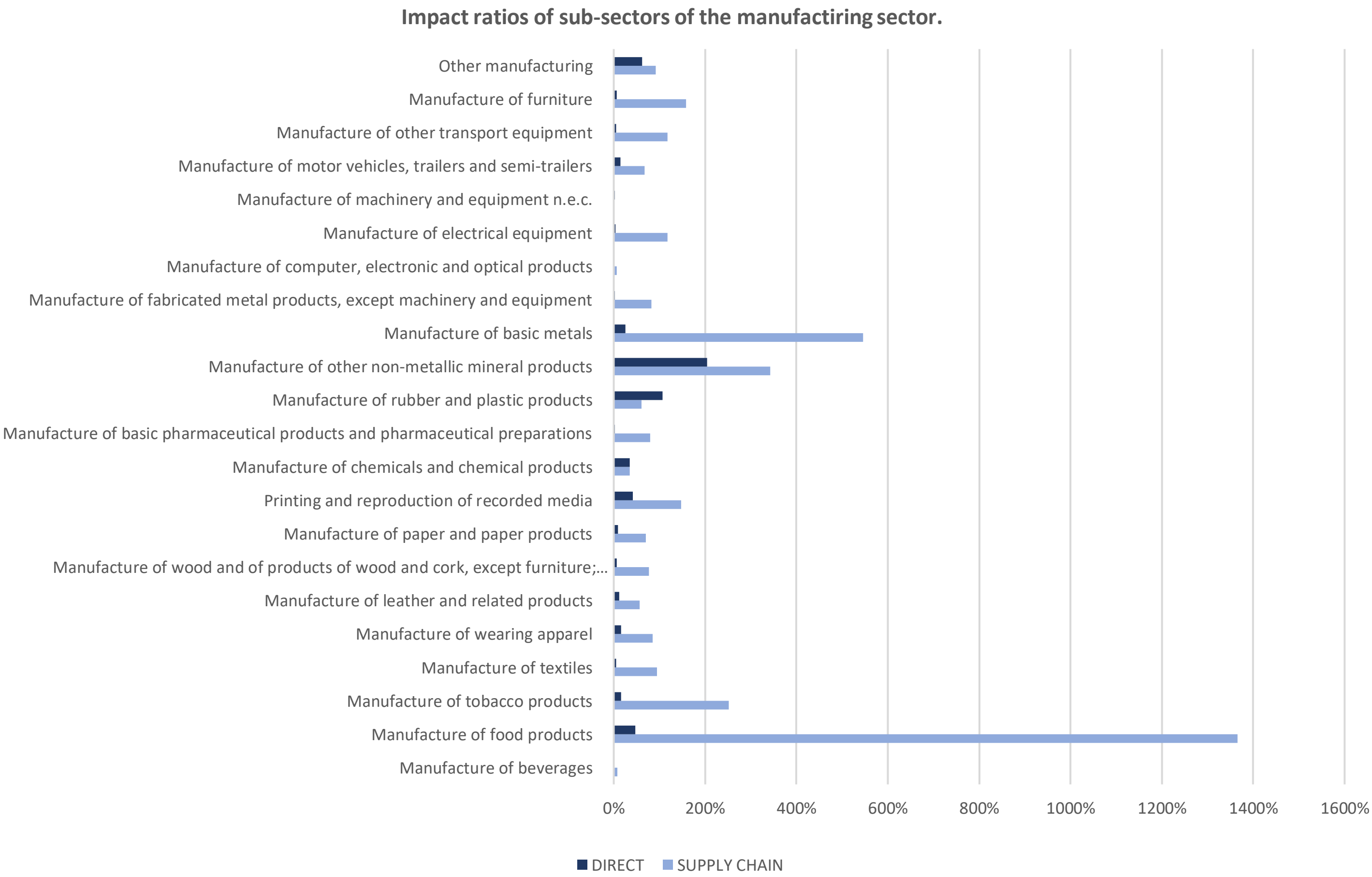

Figure 16: This figure shows the impact ratio of sub-sectors in the manufacturing sector, divided in direct and supply-chain impact ratios.

Furthermore, the sub-sectors of *the manufacturing of basic metals* (571%) and *the manufacturing of non-metallic mineral products* (548%) have high impact ratios. The fact that the total impact ratio of *the manufacturing sector* is relatively low could be due to the presence of high profit generating sectors compared to their E&S damage costs like for instance the sub-sector of *the manufacturing of beverages* (8%), *the manufacturing of computer, electronic and optical products* (6%) and *the manufacturing of machinery and equipment* (2%). Bear in mind that the mining sector is a data-gap within the Exiobase database, possibly affecting the impact ratio of sectors and sub-sectors. One sub-sector that is completely missing from the graph is the sub-sector of *petroleum refinery*. This is because this sub-sector sustained a total loss of over one billion euros over the financial years of 2014 to 2016. With no profit available, no impact factor can be calculated, but it can be clearly stated that this sector would not sustain a regulation on its respective E&S damage costs as the output of externalities is high compared to other manufacturing sub-sectors as shown in section 4.1.

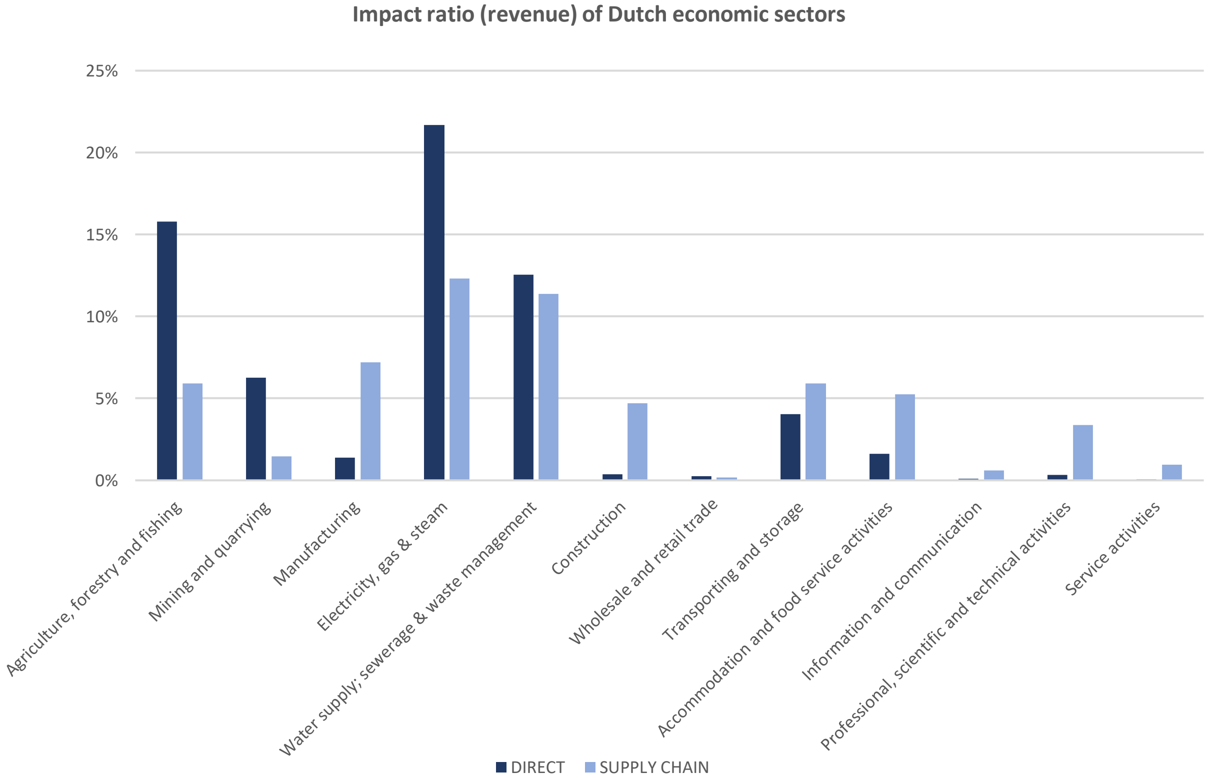

Figure 17: The impact ratio of Dutch economic sectors concerning total revenue generated. The impact ratio has been given in percentages of total loss of profit. The impact ratio has been divided in direct of supply-chain impacts.

To get a sense of the 'environmental efficiency' of different sectors, the impact ratio for revenue will also be shown in figure 16. Revenue is here used a measure of the size of the sectors. The result of this shows a total loss of revenue of 6% for the Dutch economy.

The environmental efficiency can be shown as the total E&S damage costs per euro output of the sector. The figure shows us that even though the E&S damage costs of *the manufacturing sector* were the highest, due to the quantity of output of this sector, the relative E&S damage costs per euro output of the sector is only 9 cents per euro output, or 9% per euro output. These numbers become higher when looking at sectors like *agriculture, forestry and fishing* (22%), or *water supply, sewerage and waste* (24%), ceteris paribus. As for *the electricity, gas and steam sector*, apart from the fact that it has the highest potential loss of profit before tax, it is also the least efficient concerning the amount of E&S damage costs for each euro output. For each euro of revenue generated it would lose 34% in costs associated with E&S damages, making the products generated not very environmentally efficient.

5. Discussion

This research is conducted to answer the research question of the impact of internalization of negative environmental externalities on the profitability of Dutch economic sectors by answering the two sub-questions of what is the total physical output of environmental pressures of the Dutch economy and, what are the E&S costs associated with this total output? This section of the paper will discuss the results to the individual sub-questions further within the next sections, followed by a discussion on the research question. These sections are ordered in order of occurrence of the topic, being the physical output of negative externalities, the monetary output of negative externalities and lastly the impact ratio of economic sectors of the Netherlands.

5.1 Physical output and usage of environmental pressures within the Dutch economy

The first sub-question regarding the total physical output of environmental pressures of the Dutch economy is answered successfully for the three main environmental pressures considered within this research. First, the water footprint will be discussed. Secondly, the total physical output of GHG emissions and lastly, the total physical output of pollutants.

The water footprint of the Dutch economy is 103 trillion litres of water. 75% of this footprint is due to water consumption, while 25% is due to water withdrawal. The sheer amount of water consumption poses a threat as the water is lost from its original water body, and the regenerative capacity of these water bodies cannot keep up with the unsustainable usage of this water, impacting ecosystems and the biodiversity within it (OECD, 2019a). But it could also have an economic impact; having such an extensive demand for water can pose a possible threat to current economic processes as water scarcity is an increasingly growing problem (OECD, 2019a). With 82% of the total water footprint being due to water use within the supply-chain of economic sectors, this threat becomes even more unpredictable. The sectors that are most responsible for the consumption of water are the food and beverage producing sectors. These sectors, including the agricultural sector and all the subsectors associated with the processing of food and beverages accounts for 46% of the total water footprint of the Netherlands. This can be considered substantial, making the sector highly dependent on an increasingly scarcer resource. The impact of this dependency should be studied more intensively and, if possible, with higher granularity in further research.

Results show that the Dutch economy emits 4,8 billion tons of CO_2e over all its economic processes of which 63% is due to the supply-chain of economic sectors, and 37% due to direct emissions. The results show us that overall, the fossil fuel sector and the overall fossil-fuel dependency of the Dutch economy takes a large share of this total output, either directly from the production of electricity and petroleum refinement, or indirectly due to manufacturing and transportation. These results show that the Dutch economy is still heavily dependent on fossil-fuel energy domestically, making the current energy transition within the Netherlands even more challenging, but also more impactful. Cutting back on fossil-fuel consumption can be considered the most substantial driver of GHG emission decrease.

Of all GHG emissions emitted, almost 80% of the total is due to the output of carbon dioxide. From this perspective it stands to reason that political action is primarily focussed on the output of carbon dioxide worldwide. But focussing on carbon dioxide alone will not bring us to a net-zero emissions economy. For instance, the food producing sectors also play a substantial part in the total output of GHG emissions, partly due to methane gases (CH_4) which are mostly associated with the farming of cattle and the production of meat. The overall political action towards mitigating the output of these non-CO_2 GHG emissions have been lacking and should be considered more. Clarke et al., (2014) and Gernaat et al., (2015) both show us that non-CO_2 GHG emissions are expected to have an increasingly larger share of the total GHG emissions in stringent mitigation measures. Even with these ambitious CO_2 reduction measures, which also reduces CH_4 emissions due to the reduction of fossil fuels, agricultural CH_4 emissions are projected to constitute an increasingly larger share of anthropogenic CH_4 emissions in mitigation scenarios, and remains the largest mitigation bottleneck in a 2100 2˚C climate policy case (Harmsen, 2019; Harmsen et al., 2019). It is also stated that many of these non-CO_2 mitigation measures provide low-cost opportunities to reduce total GHG emissions, with a wide range of options available in many sectors (Harmsen, 2019). These findings, together with the findings of this research should increase political incentive to tackle these non-CO_2 GHG emissions.

Consequentially, it is shown by PBL (2018) that due to the primary focus on carbon dioxide, current results on environmental pressures have a higher share of carbon dioxide compared to other substances, as carbon dioxide levels have been measured more consistently and substantially over the past decades. This means that the other non-CO_2 GHG emission trends are often lacking global statistics and are thus much more uncertain (PBL, 2018).

The total output of pollutants within the Netherlands is 7.9 million tons. These contain in total 18 different types of pollutants which are often very different from each other. In the results it is seen that of these 18 pollutants, 4 pollutants alone, account for 82% of the total being; Carbon monoxide (40%), nitrogen oxides (19%) ammonia (13%) and sulphur dioxide (10%). These four substances are highlighted in more detail, but all substances are relevant to consider when looking at the environmental footprint of economic sectors. Carbon monoxide is a substance produced by the incomplete combustion of carbon containing fuels like gasoline, natural gas, oil coal and wood. In the atmosphere the substance is spatially variable and short lived, having a role in the formation of ground level ozone, but when exposed to in high dosages, it is a toxic substance to animals and humans alike. Carbon monoxide poisoning is the most common type of fatal air poisoning in many countries (Omaye, 2002). The output of carbon monoxide is high in almost any sector due to the indirect use of electricity and transport services, but the quantity of output is highest within the manufacturing sector. This is mostly due to the supply-chain of *the petroleum refinement sub-sector* and *the sub-sector of steel production*, both associated with a high output of incomplete combustion of fuel.

The output of ammonia in the Netherlands has a whole other sectorial source. Air based ammonia output is mostly associated with the use of fertilizers and can be seen to be especially high within *the agricultural sector* and *the sector of food processing*. Through the air, ammonia is deposited on land or water, leading to eutrophication and acidification of both soils and water bodies (Krupa, 2003). The combination of a high nitrogen oxide output and sulphur dioxide output is potentially very harmful for the environment in the Netherlands. Both are derived from the burning of fossil-fuels and the combination of both substances in the air is the leading cause of acid rains (A. Singh & Agrawal, 2008). Furthermore, nitrogen oxide influences tropospheric ozone and the creation of smog which effects human health.

Overall, nitrogen levels due to for instance ammonia, nitrate, nitrous oxide and other forms of nitrogen have been a long-lasting problem within the Netherlands, with it having one of the highest nitrogen emission densities in the world (Domburg et al., 2005). This is largely due to the economic sectors shown within the results, but also because the Netherlands is a small country at the delta of several large European rivers which brings along agricultural pollution. The in 2015 introduced policy on reducing nitrogen levels (PAS) within the Netherlands was researched by Heer et al., (2017) and was concluded to be a comprehensive approach to the current nitrogen issue. But as of the 29th of May 2019, this policy has been revoked due to it not being in line with the current European Union's habitat directive (Raad van State, 2019). This shows us that there are active policy contributions towards decreasing nitrogen output, but not successfully. The results of this research could possibly provide new insights by providing a new regulatory approach to the nitrogen problem.

As shown, each pollutant has a different effect on the environment and human health. These differences will be accounted for when adding a monetary value to them.

5.2 The monetary output of environmental externalities within the Dutch economy

Having the total environmental footprint of Dutch economic sectors creates the possibility of answering the second sub-question of the research: what are the E&S damage costs associated with this total output? This is calculated to be 78.8 billion euros, amounting to 10.7% of the total Dutch GDP. As seen within the results, GHG emissions contribute to a total of 70% of these total costs. Carbon dioxide alone accounts for 55% of the total E&S damage costs the Dutch economy, making it by far the costliest form of pollution within the Netherlands. This result supports the already impending carbon tax reform for economic sectors in the Netherlands. But the results also show us that this tax would ignore 45% of all E&S damage costs inflicted on nature and society by other environmental externalities. Even within GHG emissions other substances like methane and nitrous oxides have high damage costs associated with the output of them and thus should be considered as well. We will only shortly discuss GHG emission costs specifically as there are no real differences between output and costs as the output is scaled to CO_2e and the E&S damage costs are linked to the output of CO_2e. Thus, as already seen within the output of GHG emissions, the costs associated with this output, are largely due to the strong fossil-fuel relations within these sectors.

23% of the total E&S damage costs result from the output of pollutants by Dutch economic sectors. Within the environmental pressure of pollution there is a large differentiation in output of the different substances and the respective costs. This is because as discussed above, each type of pollutant has very different environmental and social (health) effects and should thus be priced accordingly. This resulted in ammonia (6.2%) now having the largest share of E&S damage costs of all pollutants, followed by nitrogen oxides (6.1%) and particulate matter (4.3%). What is interesting to note is the fact that carbon monoxide, which takes a share of 40% of the total physical output of pollutants, is not a pollutant with a high E&S damage cost. This is mostly since it is a short-lived substance, while other substances can have a prolonged impact on both the environment and human health. The results also find that there are in total 17 environmental externalities that combined only result in 0.32% of the total E&S damage costs, which are all externalities associated with pollution. It could be concluded that these environmental externalities are not worth taking into consideration for large scale policy action. This does not mean that high local concentrations of these pollutants are to be ignored. Even though their global impact is limited, local high concentrations of for instance carbon monoxide can still lead to large environmental and human health implications and should in that case be taken into consideration.

The highest E&S damage costs are largely associated with substances which are by-products of fossil-fuel combustion, and with the polluting sector of food production and agriculture. The former strengthens the argument of an energy and transportation transition towards sustainable alternatives. The latter is, as mentioned before, a finding which should be highlighted more, as the production of food has a significant impact on the environment and humans alike.

The different types of pollutants should not be underestimated and at least be taken into consideration when introducing future policy on the internalization of negative externalities, as they can be linked to both severe biodiversity losses and human toxicity. This finding is also reflected in the monetary value of these specific substances. Even though GHG takes the highest share of costs associated with its output, this is mostly due to the massive quantity of output, not because of its high monetary value. This means that the E&S damages per unit of physical output of the different pollutants are often considerably higher than within GHG emissions and should thus again, not be underestimated. Furthermore, one could argue that measuring and modelling specific types of pollution has not been done on such an extensive level as GHG emissions, especially compared to carbon dioxide as shown above. But, better measurements of different environmental externalities would be beneficial and often necessary to implement possible future regulation of internalizing them.

The costs of water consumption and withdrawal account for 7% of the total E&S damage costs of Dutch economic sectors. This percentage could be perceived as being low, but water consumption and withdrawal has one of the lowest E&S damage costs of all negative externalities considered. The quantity of water consumption by economic sectors of the Netherlands is excessively high, as already mentioned before, but the fact that it is listed in fifth place in total E&S damage costs with such a low monetary value compared to the other pressures confirms this finding.

The prices that have been used within this research reflect the E&S damage costs of environmental externalities within the year 2018. If these environmental externalities are not controlled and regulated now, these prices will possibly only become higher and higher due higher quantities of output and with it, increased damages over time. It is thus argued that early policy action could prevent higher E&S damage costs in the future.

5.2 The impact ratio of Dutch economic sectors

With both sub-questions answered the main research question of the impact of internalization of negative environmental externalities on the profitability of Dutch economic sectors can be answered. To do this, the impact ratio has been used. This impact ratio gives an indication on which industries would be affected by the internalization of negative externalities by looking at how much the E&S damage costs affect the current profitability of economic sectors in the Netherlands and should be considered as such. Furthermore, the impact ratios are sector averages, which could have strong deviations over specific companies. Moreover, some economic sectors (like education and healthcare) have not been considered within this step as they do not operate from a profit-driven perspective.

The impact ratio shows us a total loss of profit of 70% of the total Dutch economy, of which 47% is due to supply-chain costs and 23% due to direct costs of the sector, showing that the Dutch economy could bear a regulation on the internalization of negative externalities. But this statement is oversimplified. Due to sector deviations in impact ratios, the overall impact of an implementation of a regulation like this on the Dutch economy will become far more complex. Therefore, this research focusses more on sector specific results. This shows us that *the electricity sector* would lose almost 1500% of its total profits, making the implementation of a direct tax particularly challenging. The research concludes in the fact that the economic impact of internalizing negative environmental externalities using a direct tax would be large within the Netherlands, with five of the in total 13 economic sectors losing all generated profits. These high impact ratio's show us that a direct application of this regulation would not work. Instead, different kinds of policy applications of the internalization of negative externalities should be considered, like for instance regulation with a more progressive character like a gradual implementation or other forms of internalization could work better. This will be further discussed in the policy implications section.

The two sectors with a particularly high E&S damage cost compared to their respective economic performance are *the electricity sector* as stated above, and *the water supply, sewerage and waste processing sector.* But both these industries perform a vital task for the national economy (producing electricity and processing waste). This means that there will always be demand for these services, thus the willingness to pay for them will be high, both from a consumer and sector perspective. In economic terms, these sectors have a low elasticity of demand. The demand for these basic and vital tasks is very rigid, making for the possibility of large price deviations if needed by for instance policies like the internalization of negative externalities. This gives them overall more pricing power towards their customers and thus more flexible in a changing climate. That being said, looking at the impact ratio of revenue it is seen that both these industries are also least environmentally efficient when it comes to their business processes, which means they produce the most environmental externalities per euro output of product. So even though a part of these high profit losses can be sustained due to a low-price elasticity of demand, there should still be a strong incentive towards restructuring these sectors to not become stranded assets in the future.

Even the sectors which have a lower impact ratio to their name could be impacted substantially. The potential impact might generate instability and insecurity as permanent changes in the profitability profile of the sector could disrupt the expectancy of investors to certain levels of profits. An example is a pension fund which promises the people that a certain retirement benefit would be given to its respective attendees. If a certain return on investment is not managed by the companies it invests in because of decreasing profits within the sector, the fund might consider withdrawal from the investment completely. This would have a limited impact on the pension fund due to its diversification of investments over different sectors, but the divestment of the pension fund in a specific sector due to its decreasing economic performance could have large consequences for the overall economy. This could be an interesting topic for further research, especially as the effects of divestment campaigns are already seen within the fossil fuel sector where it is threatening to erode the social licence of some targeted companies (Ansar et al., 2013; Bergman, 2018).

Another interesting point of discussion derived from this research is the fact of attribution. As the financial sector, the healthcare sector, the wholesale and trading sector and many different service providing sectors are dependent on the primary production sectors like manufacturing, agriculture and the electricity sector, there attribution for this output is not seen within the results of this research. Overall the attribution of these sectors to their environmental output is often limited to their own output, while a service company selling contracts on phones and laptops should perhaps also be held accountable for a small part of the E&S damage costs of the production of these phones themselves. The same goes for the financial sector. As the impact ratio of the financial sector is low, their actual impact in terms of investments within all these sectors is a lot higher. Tools like these presented within this research could help financial institutions to look better into their portfolio's and eliminate investments with high impact ratio's or be held more accountable for these investments in terms of the risks associated with them.

6. Conclusion

This research has been conducted to get more insight into the effects of the increasingly popular policy tool of the internalization of negative externalities by answering the following research question: *What is the impact of internalization of negative environmental externalities on the profitability of Dutch economic sectors?* The research concludes that it would have a substantial impact on the general Dutch economy, with high sectorial deviations of impact. Some sectors will feel limited effects of such a regulation while other will struggle to remain profitable, possibly generating stranded assets along the way, making the sectors very susceptible to these future regulations. But it is also seen that current economy of the Netherlands is unsustainable, creating physical environmental pressures and associated risks within many economic sectors. The research thus suggests that constructing a political climate that incentivizes companies to change towards more sustainable business practices is needed, and more research should be done into looking how this can be made practice in the future.

Limitations & further research

In total, 30 environmental pressures have been considered within the analysis. For an EEIO analysis Exiobase is the most comprehensive database available, but it should be mentioned that lot more environmental pressures exist and have been monetized. More research towards implementing these missing environmental pressures within the Exiobase database should be done to make monetary EEIO analyses like these more inclusive. One of these missing environmental pressures that could have profound effect on the results is the environmental pressure of land use transformation. It is known that this environmental pressure is devastating when it comes to loss of biodiversity, intensification of climate change effects and more (IPBES, 2012). This makes land use transformation one of the most essential missing environmental pressure within this research, and more research should be done to include this pressure in future research. Some research into this topic has shown that it is possible to include land use transformation on a higher granular level of individual companies or sub-sectors, showing potential ways to include this pressure within further research (TruCost, 2013).

Furthermore, data on these environmental pressures within Exiobase show deviations from nationally derived data as seen in sources like Statistics Netherlands. This is possibly due to a higher level of modelling done within the Exiobase dataset as it takes into account the global economy, compared to the more quantitative measurements made by a national statistical offices like Statistics Netherlands. As this is unavoidable when conducting a global supply-chain analysis, this should be taken into account when taking a more granular approach. Furthermore, collaboration between national and global statistical institutions would benefit the overall data quality.

A suggestion for further research would be to use the same methodological approach and apply it to different geographical settings in terms of different countries or different regions of interest. This would make geographical comparisons possible, creating new perspectives to the current results. Furthermore, the current analysis is a consumption-based analysis of the Dutch economy. Instead, a production-based analysis following the same approach of monetary valuation would also provide new insights into the discussion of a fair implementation of the internalization of negative environmental externalities.

In terms of the monetary valuation of negative environmental externalities, the recent interest and developments towards the subject are unprecedented. As seen within the introduction, policy support towards the subject has been growing enormously within the last decade, and valuation efforts to environmental externalities have not been lagging behind. As prices used within this research have been updated to the year 2018, it is expected that this will be done more frequently and extensively within the future, possibly including more and more environmental pressures in the process with more sound empirical approaches backing up the data. The UN statistical division of the SEEA or the Systems of Environmental and Economic Accounting has already started a project on natural capital accounting and the valuation of ecosystem services worldwide, with the first results expected in late 2020. It is thus expected that this research is the predecessor of more detailed and inclusive macro-economic analyses into the environmental performance of national economies in the future.

The current analysis gives a first indication on the impact of impending regulation on negative environmental externalities within the Netherlands. But, for the specific impact of this regulation a more detailed and granular analysis into specific sectors and even companies would be needed. Furthermore, as discussed above, other variables like the pricing power of sectors and price elasticity of demand should also be considered when analysing impacts of a tax towards specific sectors.

The research does clearly show that assets in many sectors within the Netherlands or within supply-chains of these sectors risk devaluation or might even become stranded in the medium term. In order to avoid sleepwalking into a next economic crisis it is especially important for financial institutions to be aware of the presence of these risks. This form of risk contagion from environmental risks in non-financial sectors to financial institutions through financial assets is something that should be researched more into the future. It is suggested that at least some form of portfolio analysis of financial institutions should be implemented as both physical and social environmental risks are real and are expected to expand over next decade. Tools like those presented within this research could help financial institutions to look better into their portfolio's and eliminate investments with high impact ratio's or be held more accountable for these investments in terms of the risks associated with them. In general, it would help these institutions to evaluate ESG risks more specifically on sector, and possibly within the future, on company level.

Policy and business implications

Government regulations on the internalisation of negative externalities are gaining popularity both worldwide and within the Netherlands. But, as Caldecott (2017) also stated, these government regulations can also itself be a driver of stranded assets. This research was conducted in order to give more insight into the possible consequences of these governmental regulations. It successfully showed us that the impact of such a regulation would be substantial, underlining the statement made by Caldecott (2017). But it also shows us that the current economy of the Netherlands is unsustainable, creating physical environmental risks within many economic sectors. The combination of risks associated with no change and the risks associated with too much change really shows the complexity of the concept of stranded assets. What is certain is the fact that the physical environmental challenges will only become larger, making unsustainable practices only more risk associated within the future. This means that society should avoid, or at least, deal with these environmental risks. This will be discussed in the next paragraphs, focussing on how this can be done.

The research thus shows us that direct implementation of a regulation like this might create shocks in the real economy and financial system alike. The political climate should thus be constructed in such a way that it is in the sectors' best interest to change. This can be done by gradual implementation of regulation by a combination of political and financial pressures on negative environmental pressures. High polluting economic sectors will need to mitigate the output of environmental externalities to avoid increasing liabilities due to stranded assets, but at the same time these changes should not be too radical, giving these sectors the time to implement these changes. This fine line of policy action will require much more research in order to set targets that are feasible for all parties involved. Furthermore, an unprecedented level of international collaboration is warranted. This, as mentioned within the introduction, is because of a potential loss of competitiveness of national economies when they are the only ones implementing this type of regulation. Subsequently, a national level of approach will give large multi-national companies large leverages over national economies, possibly opposing reforms or threatening to leave to a country with less strict policies.

But, one result does show us a more positive future application. This is the fact that the impact of a regulation of this type could have limited impact on the Dutch economy, when implemented for only the direct costs of externalities. This would only result in two sectors losing their respective profits and would limit the impact of the regulation substantially over all sectors. This is an interesting result to explore further within the future. Furthermore, as the supply-chain E&S damage costs are sector based, specific supply-chain E&S damage costs or even the respective output of environmental pressures are often not known within companies and reporting on them is often not mandatory. This would mean that regulation and legislation of the supply-chain impact of specific companies creates many policy implications and would, as of now, be challenging to implement. Alternatively, a first step would be for politics to incentivize companies to look deeper in their business processes and include their supply-chain impact.

One final policy application is to look at the internalization from the scope of individual externalities. Eliminating or substituting the most prominent, and new within this research, most costly environmental externalities would already make the Dutch economy much more sustainable. A good example of this is the impending carbon tax for companies. This type of policy is something that should be looked at more for the other substances researched within this analysis.

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8. Appendices

8.1 All environmental pressures considered

An overview of the environmental pressures within the main KPI categories. The KPI's which are coloured red are not considered within the analysis due to a lack of monetary units.

KPICategory	KPI	Monetary Unit	Unit of analysis
Pollution	Phosphorus (to Land)	$/tonne	tonne
Pollution	Nitrogen (to Water)	$/tonne	tonne
Pollution	Phosphorus (to Water)	$/tonne	tonne
Water Use	Water Consumption	$/m3	m3
Water Use	Water Withdrawal	$/m3	m3
GHGs	Carbon dioxide	$/tCO2e	tCO2e
GHGs	Average HFCs	$/tCO2e	tCO2e
GHGs	Methane	$/tCO2e	tCO2e
GHGs	Nitrous Oxide	$/tCO2e	tCO2e
GHGs	Average PFCs	$/tCO2e	tCO2e
GHGs	Sulphur hexafluoride	$/tCO2e	tCO2e
Air Pollution	Ammonia (NH3)	$/tonne	tonne
Air Pollution	Volatile Organic Compounds (NMVOC)	$/tonne	tonne
Air Pollution	Nitrogen Oxides (NOx)	$/tonne	tonne
Air Pollution	Particulate Matter (PM10)	$/tonne	tonne
Air Pollution	Sulfur Dioxide (SO2)	$/tonne	tonne
Air Pollution	Polycyclic aromatic compounds (PAHs)	$/tonne	tonne
Air Pollution	Arsenic	$/tonne	tonne
Air Pollution	Cadmium	$/tonne	tonne
Air Pollution	Carbon Monoxide	$/tonne	tonne
Air Pollution	ChromiumVI	$/tonne	tonne
Air Pollution	Copper	$/tonne	tonne
Air Pollution	Hexachlorobenzene	$/tonne	tonne
Air Pollution	Lead	$/tonne	tonne
Air Pollution	Mercury	$/tonne	tonne
Air Pollution	Nickel	$/tonne	tonne
Air Pollution	Polychlorinated biphenyls (PCBs)	$/tonne	tonne
Air Pollution	Selenium	$/tonne	tonne
Air Pollution	Zinc	$/tonne	tonne
Air Pollution	Benzo(b)fluoranthene	$/tonne	tonne
Air Pollution	Benzo[a]pyrene	-	tonne
Air Pollution	Benzo[k]fluoranthene	-	tonne
Air Pollution	Indeno [1,2,3-cd] pyrene	-	tonne
Air Pollution	PCDD/F	-	tonne
Air Pollution	TSP	-	tonne

8.2 TruCost valuation methodology of GHG emissions

After researching over 300 studies that attempt to put a price on carbon, TruCost's GHG emissions valuation was finally based on the social costs of carbon (SCC)(Ackerman & Stanton, 2010). This is because the SCC reflects the full global costs of the damage GHG emissions do over their lifetime within the atmosphere. Furthermore, the SCC can be used to monetize the global impact of GHG emissions, while this is not the case when using market prices found within emissions trading schemes (ETS) nor when using marginal abatement costs (MAC). The SCC is estimated by using Integrated Assessment Models (IAMs) to translate economic and population growth scenarios, and the resulting GHG emissions, intro changes in atmospheric composition and global temperature levels. More specially, the IAM's approximate the relationship between temperature changes and the economic costs of impacts. These economic costs arise from for instance, changes in agricultural and forestry output, costs from changes in energy demand, property loss due to sea level rise, coastal storms and forest fires and heat related illnesses and diseases. This also shows that even GHG emissions as environmental pressures also cause social impacts. The data of IAM's is based on the work conducted by the Interagency Working Group on the Social Costs of Carbon. Within this research, the "higher than expected" impact has been considered. This is to address material methodological omissions that arise during modelling and data limitations. Furthermore, these models naturally lag behind the latest scientific data and methods available.

8.3 TruCost valuation methodology of Water usage

The methodology on water usage from TruCost comprises of two steps: first, the impact on human health will be discussed, followed by the impact on ecosystems.

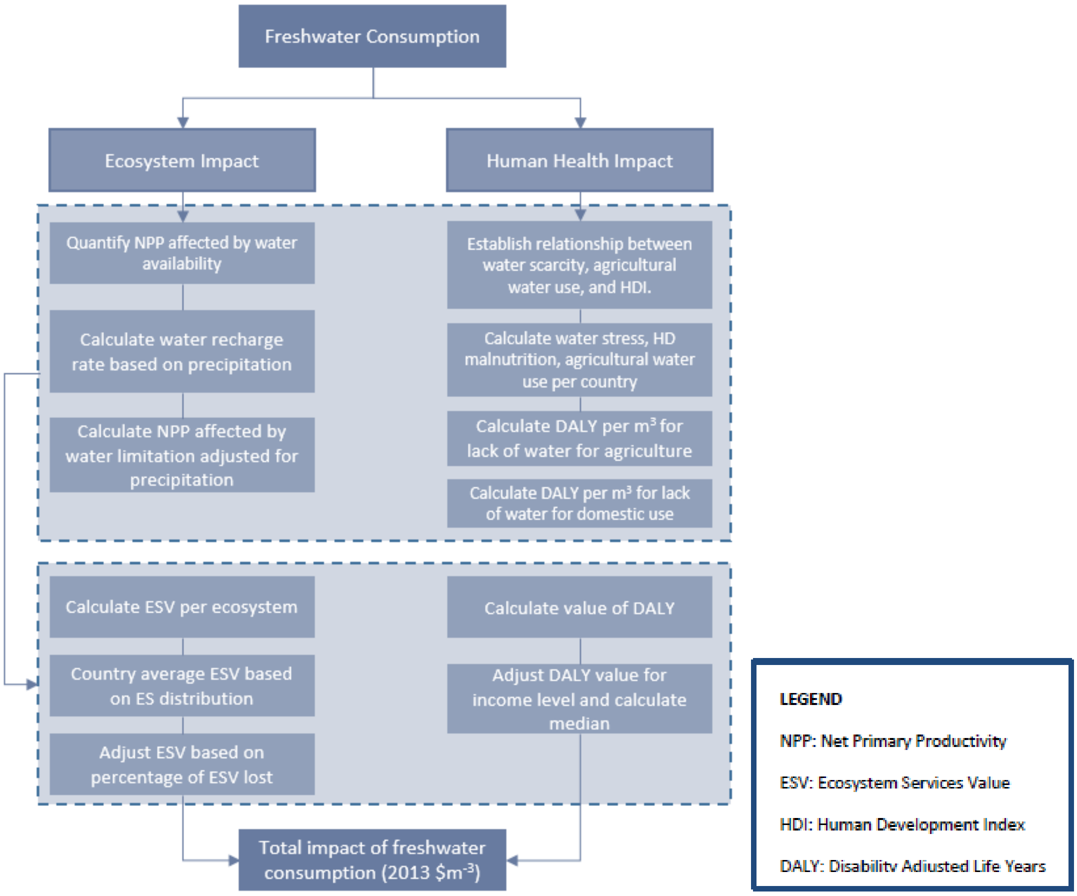


Figure 1: General overview of TruCost valuation process for water consumption. The first shaded box indicates the steps taken to quantify the environmental and human health impact of water consumption, while the second indicated the steps taken to value these impacts.

The quantification methodology for the human health impacts due to water consumption are developed using an estimate of the disability adjust life years (DALY) lost per unit of consumed water as reported within the Eco-indicator 99 (Goedkoop, 2015). This indicator has been further specified to; lack of water for irrigation and the lack of domestic water. The lack of water for irrigation can be linked to impacts associated with malnutrition. For this, the methodology developed by Pfister (2011) has been used. This parameter is country specific and depends several variables, including share of total water withdrawals used for agricultural purposes, human development and per-capita water requirements to prevent malnutrition and water stress. The lack of domestic water can be linked to the spread of diseases and for this data was sources from Motoshita et al., (2011) This model is based on a multi-regression analysis and covers health impacts related to incidences of diarrhoea and several other infections and diseases.

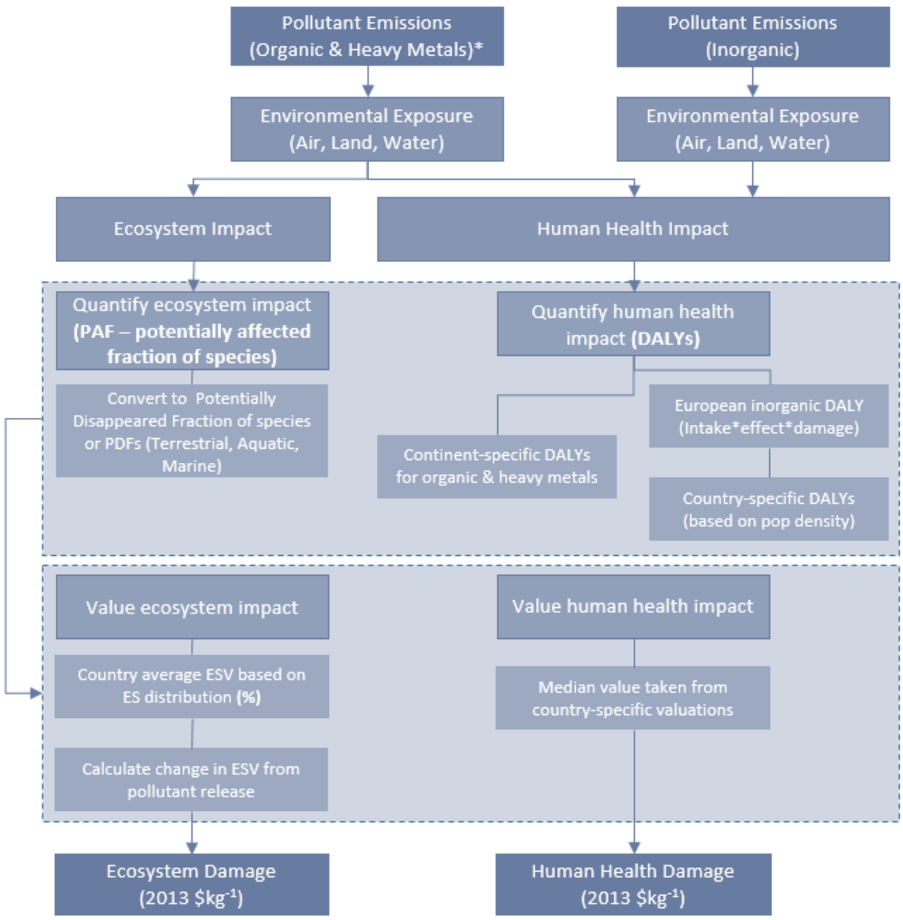
From this, the total quantity of DALYs lost can be calculated. To do this, TruCost uses the WTP technique utilized within the value of a statistical year (VOLY) method to value DALYs. This method encompasses most aspects related to illness and expresses the value of a year's life to the wider population. Furthermore, the results of a study conducted in the context of the New Energy Externalities Development for Sustainability (NEEDS) project by Desaigues et al., (2011, 2006) is being used to also consider the perceived effects of morbidity within the valuation of the DALYs. The value of life year used within this methodology is just in excess of $46,500.

The impacts of water consumption on ecosystems were measured based on net primary productivity (NPP). NPP is defined as the rate of new biomass production that is available for consumption and is used by TruCost as a measure of how well an ecosystem is functioning. The NPP is used within water usage as a proxy to measure impact on ecosystems, as it is closely related to the vulnerability of vascular plant species (Pfister, 2011). Furthermore, vascular plant specifies are primary products within the food chain and thus essential for a healthy functioning ecosystem. In addition, it is assumed by Bruyn et al., (2010) that damage to vascular plants is a representative of damage to all flora and fauns of ecosystems. As the objective is to biophysically model the fraction of NPP loss which is related to water availability, the metric is expressed as the percentage of one square metre of ecosystems that will be affected by the consumption of one cubic meter of water per year. This is since effects of water consumption on ecosystems is determined by local water availability.

A monetary value for the provisioning, regulating and cultural services by terrestrial ecosystem types was first calculated on based on the analysis of de Groot et al., (2012) This analysis calculated the minimum, maximum, median, average and standard deviation for each service provided by key terrestrial ecosystems. Based on this TruCost calculated the percentage difference between pre- and post-water consumption ESV at a country level. This was applied as a percentage to the average value of one square meter of natural ecosystem in a given region to align with the results of the biophysical modelling.

8.4 TruCost valuation methodology of air, land & water pollution

The methodology of valuating air, land and water pollution of TruCost again comprises of two steps: first, the impact on human health will be discussed, followed by the impact on ecosystems.



ESV: Ecosystem Services Value

DALY: Disability Adjusted Life Years

ES: Ecosystem Services

Inorganic pollutants include carbon monoxide (CO), sulphur dioxide (SO2), nitrous oxides (NOx), ammonia (NH3), particulate matter (PM), and volatile organic compounds (VOCs)

*Organic pollutants and heavy metals are grouped together due to the similarity in methodology, not

Figure 2: The general overview of TruCost valuation process for AL&W pollution. The first shaded box indicates the steps taken to quantify the environmental and human health impacts of these pollutants, while the second indicates the steps takes to value these impacts.

TruCost again uses the disability adjusted life years (DALYs) as a measure of the impact on human health from environmental impacts also from pollution. In order to calculate the quantities of DALY's lost due to AL&W pollution, TruCost used the USES-LCA 2.0. This model, originally developed in the context of life cycle assessment (LCA) studies, calculated the quantities of DALYs lost due to emissions of over 3,300 chemicals to: freshwater and seawater, natural, agricultural and industrial soil and rural, urban and natural air (EU, 2004). USES-LCA 2.0 considers the impact of cancer and non-cancer diseases caused by the ingestion of food and water, and the inhalation of chemicals. The followed output is the number of DALYs lost due to emissions of each pollutant to a specific media, at the continental level. Noted should be that organic substances and heavy metals have been grouped together, not due to their chemical properties, but due to their similarity in methodology. This methodology is different for sulphur dioxide, nitrogen oxide and particulate matter (PM10). As the USES-LCA2.0 does not estimate DALYs for these substances, TruCost conducted a literature review to find alternative methods to quantify the DALY impact of the emission of these pollutants. Once these DALYs have been quantified, the same valuation methodology has been applied to these DALYs as stated within the section of water usage.

For the calculation of the impact of pollutants on ecosystems TruCost linked the value of ecosystem services to biodiversity. This is been done in the following three steps:

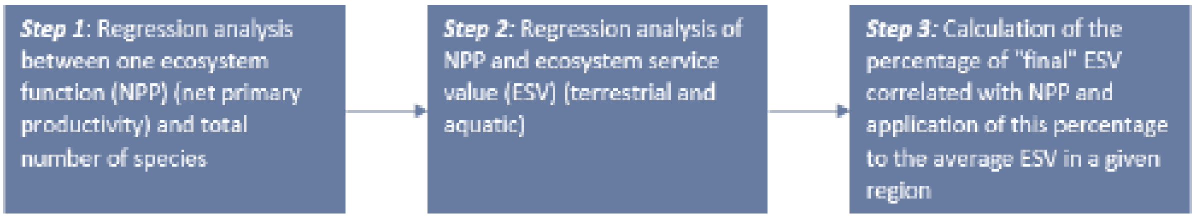
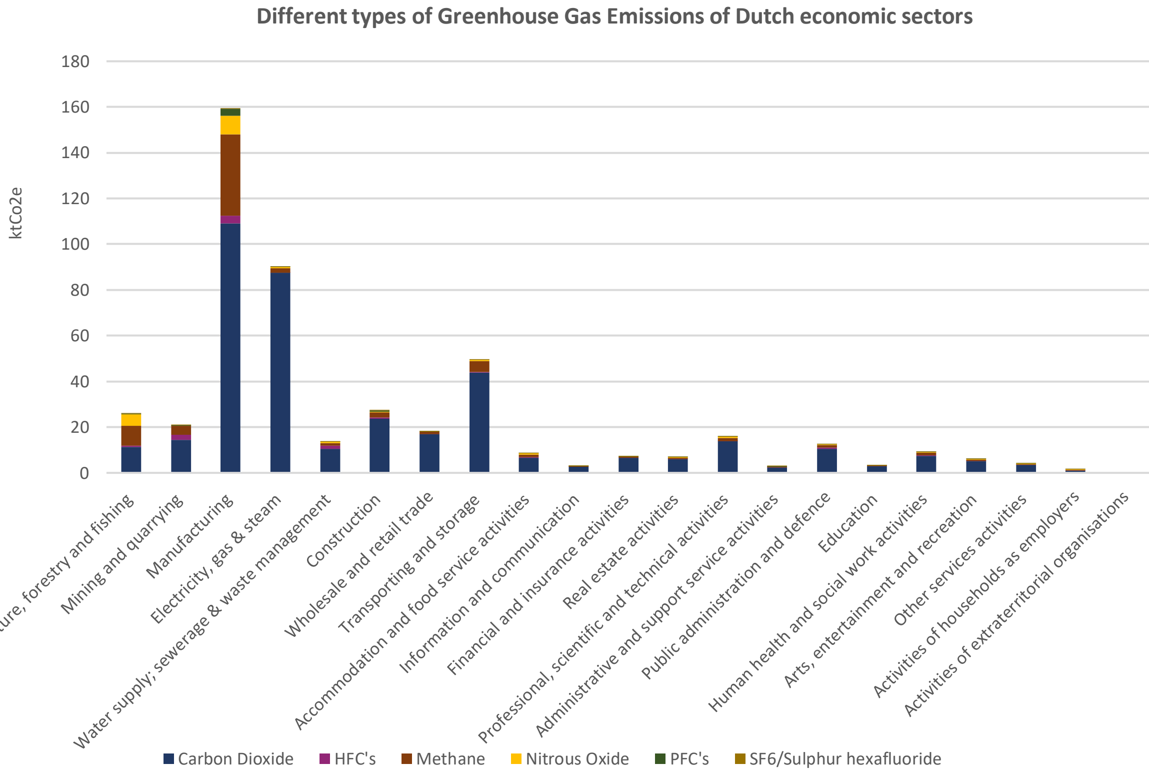


Figure 3: A flowchart of the methodological steps taken by TruCost to calculate the impact of pollutants on ecosystems.

Within this methodology, TruCost assesses the link between biodiversity, measured species richness (IUCN, 2015) net primary activity (NPP), and ecosystem service value (ESV) (de Groot et al., 2012). The monetary valuation was based on the same valuation as with water usage, using the ESV. Finally, TruCost calculated the percentage different in pre- and post-change of ESV at a country and substance level and applied this percentage to the average value of one square meter of natural ecosystem in a given region. This aligns with the results of the USES-LCA2.0, which calculates change of species richness, at a continental level.

8.5 percentage output of GHG emissions of all economic sectors



A table showing the percentage output of different GHG emissions over the total output of the sector.

	Carbon Dioxide	HFC's	Methane	Nitrous Oxide	PFC's	SF6
Agriculture, forestry and fishing	43,80%	1,91%	34,41%	19,61%	0,16%	0,11%
Mining and quarrying	69,42%	10,08%	19,41%	0,25%	0,54%	0,30%
Manufacturing	68,28%	2,20%	22,18%	5,26%	1,87%	0,21%
Electricity, gas & steam	97,08%	0,13%	2,00%	0,72%	0,06%	0,01%
Water supply; sewerage & waste management	77,47%	9,18%	9,77%	2,58%	0,66%	0,34%
Construction	86,44%	2,20%	8,14%	1,22%	1,69%	0,31%
Wholesale and retail trade	92,85%	0,35%	5,61%	0,93%	0,19%	0,06%
Transporting and storage	88,78%	0,60%	9,43%	0,98%	0,12%	0,09%
Accommodation and food service activities	77,40%	0,72%	14,31%	7,32%	0,16%	0,08%
Information and communication	88,02%	0,97%	8,41%	2,05%	0,43%	0,11%
Financial and insurance activities	90,91%	0,83%	6,44%	1,42%	0,31%	0,09%
Real estate activities	88,01%	1,59%	7,84%	1,53%	0,82%	0,22%
Professional, scientific and technical activities	86,32%	1,30%	8,95%	2,53%	0,75%	0,16%
Administrative and support service activities	81,16%	1,32%	15,65%	1,32%	0,38%	0,17%
Public administration and defence	84,47%	3,38%	8,96%	2,08%	0,86%	0,25%
Education	87,20%	1,51%	8,47%	1,64%	1,00%	0,17%
Human health and social work activities	81,28%	1,79%	12,78%	3,55%	0,35%	0,24%
Arts, entertainment and recreation	85,19%	1,09%	10,17%	3,04%	0,39%	0,12%
Other services activities	87,15%	1,03%	9,06%	2,31%	0,33%	0,12%
Activities of households as employers	65,36%	2,95%	23,74%	7,15%	0,29%	0,53%

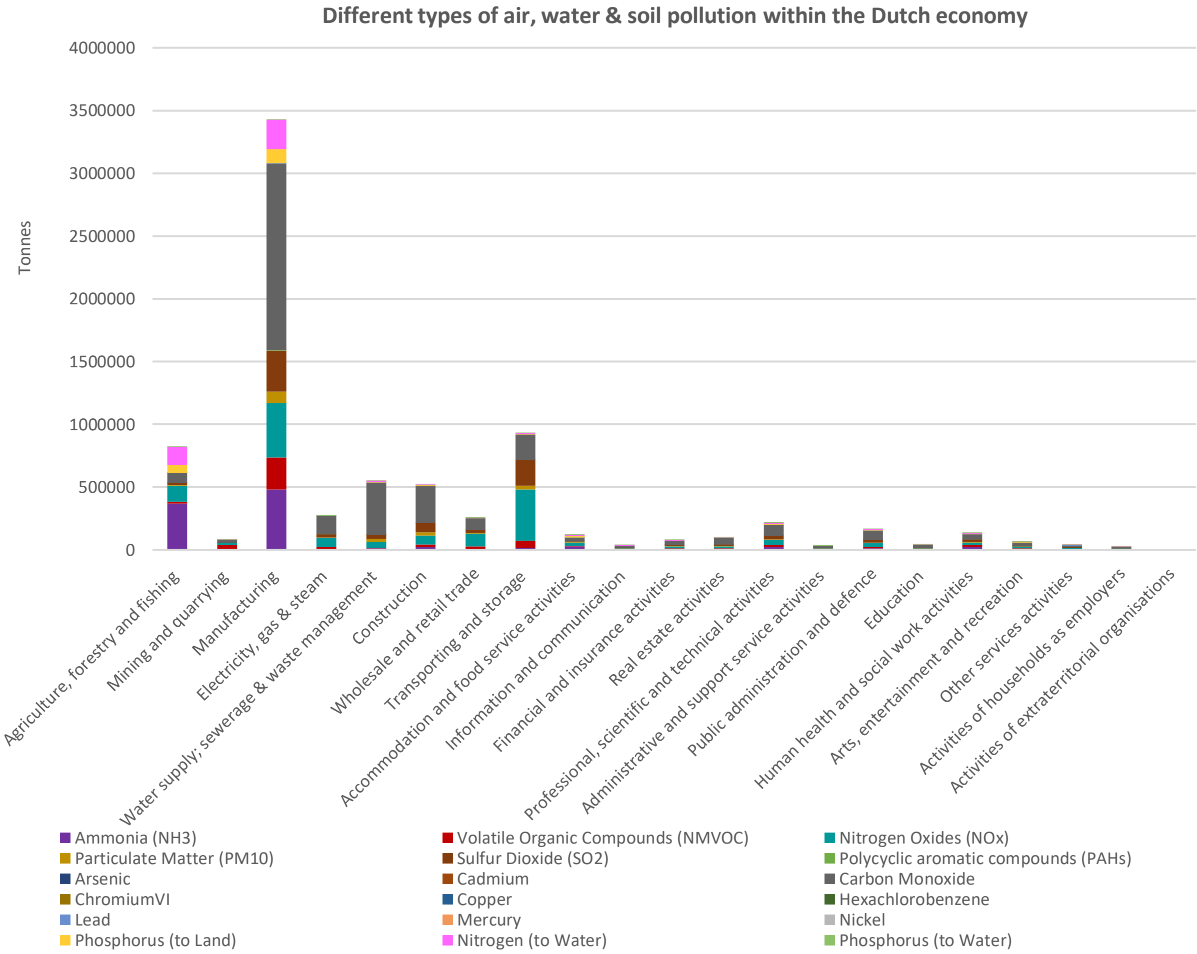
8.6 Percentage output of GHG emissions within the manufacturing sector

A table showing the percentage output of different GHG emissions over the total output of the sub-sector within the sector of manufacturing.

	Carbon Dioxide	HFC's	Methane	Nitrous Oxide	PFC's	SF6
Processing of meat cattle	55,57%	2,79%	40,66%	0,59%	0,20%	0,19%
Processing of meat pigs	55,10%	2,17%	26,38%	15,84%	0,31%	0,20%
Processing of meat poultry	86,01%	2,60%	8,51%	1,47%	1,24%	0,15%
Production of meat products nec	40,39%	1,33%	45,15%	12,80%	0,22%	0,11%
Processing vegetable oils and fats	76,10%	1,74%	10,99%	1,84%	9,00%	0,33%
Processing of dairy products	81,24%	1,38%	10,21%	1,56%	5,27%	0,33%
Processed rice	95,02%	1,61%	2,71%	0,28%	0,21%	0,16%
Sugar refining	81,62%	2,41%	12,12%	2,42%	1,14%	0,28%
Processing of Food products nec	85,60%	1,10%	9,48%	1,83%	1,84%	0,15%
Manufacture of beverages	84,92%	1,11%	9,22%	1,99%	2,60%	0,15%
Manufacture of fish products	75,91%	1,54%	14,09%	1,38%	6,78%	0,30%
Manufacture of tobacco products	81,59%	1,46%	11,80%	2,03%	2,79%	0,32%
Manufacture of textiles	88,19%	1,88%	7,54%	1,51%	0,74%	0,14%
Manufacture of wearing apparel; dressing and dyeing of fur	66,28%	0,95%	25,11%	7,34%	0,13%	0,20%
Tanning and dressing of leather	59,34%	1,57%	22,50%	16,24%	0,24%	0,11%
Manufacture of wood & products of wood and cork, except furniture	82,21%	1,44%	10,57%	1,53%	3,89%	0,36%
Re-processing of secondary wood material into new	82,69%	0,88%	8,34%	0,56%	7,41%	0,12%
Pulp	30,35%	0,82%	55,10%	13,56%	0,11%	0,07%
Re-processing of secondary paper into new pulp	96,01%	1,15%	2,26%	0,26%	0,18%	0,13%
Paper	81,92%	0,94%	8,07%	1,50%	7,39%	0,18%
Publishing, printing and reproduction of recorded media	61,59%	2,10%	27,97%	7,87%	0,26%	0,21%
Manufacture of coke oven products	81,74%	2,15%	9,52%	1,93%	4,39%	0,28%
Petroleum Refinery	77,61%	2,60%	16,00%	3,16%	0,32%	0,32%
Processing of nuclear fuel	73,84%	4,99%	10,77%	9,48%	0,63%	0,30%
Plastics, basic	84,71%	12,12%	2,11%	0,06%	0,59%	0,41%
Re-processing of secondary plastic into new plastic	97,65%	1,05%	1,17%	0,02%	0,07%	0,03%
N-fertiliser	79,16%	6,35%	10,55%	2,81%	0,73%	0,41%
P- and other fertiliser	57,23%	1,46%	26,93%	13,93%	0,30%	0,16%
Chemicals nec	81,54%	3,20%	11,28%	2,23%	1,28%	0,47%
Manufacture of rubber and plastic products	82,90%	1,52%	12,29%	2,30%	0,72%	0,27%
Manufacture of glass and glass products	88,35%	4,36%	5,78%	0,97%	0,35%	0,19%
Re-processing of secondary glass into new	76,92%	7,99%	11,02%	2,92%	0,83%	0,32%
Manufacture of ceramic goods	99,04%	0,03%	0,26%	0,67%	0,00%	0,00%
Manufacture of bricks, tiles and baked clay construction products	66,48%	2,14%	6,31%	24,77%	0,17%	0,12%
Manufacture of cement, lime and plaster	46,39%	9,80%	5,49%	37,42%	0,55%	0,35%
Re-processing of ash into clinker	82,61%	1,39%	12,67%	1,50%	1,41%	0,42%
Manufacture of other non-metallic mineral products n.e.c.	79,82%	1,34%	15,73%	2,66%	0,19%	0,26%
Manufacture of basic iron and steel & ferro-alloys	27,53%	1,13%	3,62%	0,47%	67,17%	0,08%

Re-processing of secondary steel into new steel	84,89%	2,60%	8,15%	1,12%	2,96%	0,28%
Precious metals production	85,12%	1,69%	10,23%	1,70%	1,04%	0,22%
Aluminium production	87,87%	1,35%	9,26%	1,16%	0,24%	0,13%
Re-processing of secondary aluminium into new aluminium	72,81%	2,26%	21,84%	2,44%	0,36%	0,30%
Lead, zinc and tin production	71,02%	11,25%	11,33%	4,28%	1,04%	1,08%
Re-processing of secondary lead into new lead, zinc and tin	80,07%	2,07%	13,27%	2,87%	1,52%	0,20%
Copper production	83,08%	3,67%	11,22%	1,52%	0,28%	0,23%
Re-processing of secondary copper into new copper	83,30%	4,38%	9,89%	1,34%	0,60%	0,50%
Other non-ferrous metal production	79,33%	2,52%	12,92%	4,30%	0,28%	0,64%
Casting of metals	84,84%	4,29%	9,29%	1,09%	0,28%	0,20%
Manufacture of fabricated metal products, ex. machinery & equipment	85,59%	1,65%	10,45%	1,15%	0,93%	0,22%
Manufacture of machinery and equipment n.e.c.	88,83%	1,62%	8,14%	0,69%	0,56%	0,17%
Manufacture of office machinery and computers	63,20%	1,37%	23,88%	11,25%	0,16%	0,15%
Manufacture of electrical machinery and apparatus	79,32%	5,00%	10,53%	4,07%	0,36%	0,72%
Manufacture of radio, television & comm. equipment	82,20%	0,69%	15,34%	1,54%	0,11%	0,12%
Manufacture of medical, precision (clocks) & optical instruments	76,45%	0,97%	18,98%	3,29%	0,12%	0,18%
Manufacture of motor vehicles, trailers and semi-trailers	85,40%	2,91%	9,76%	1,27%	0,36%	0,30%
Manufacture of other transport equipment	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Manufacture of furniture; manufacturing n.e.c.	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

8.7 Percentage output of pollution for Dutch economic sectors



	Agriculture, forestry and fishing	Mining and quarrying	Manufacturing	Electricity, gas & steam	Water supply; sewerage & waste management	Construction	Wholesale and retail trade	Transporting and storage	Accommodation and food service activities	Information and communication	Financial and insurance activities	Real estate activities	Professional, scientific and technical activities	Administrative and support service activities	Public administration and defence	Education	Human health and social work activities	Arts, entertainment and recreation	Other services activities	Activities of households as employers
Ammonia (NH3)	44,81%	1,86%	14,05%	2,48%	2,08%	3,93%	2,36%	1,76%	22,55%	8,19%	6,37%	5,80%	10,99%	4,97%	7,37%	6,83%	15,97%	13,24%	10,78%	17,34%
Volatile Organic Compounds (NMVOC)	1,79%	47,59%	7,42%	5,34%	1,34%	4,20%	8,19%	6,44%	4,10%	6,91%	7,23%	5,16%	6,61%	12,39%	6,43%	6,94%	11,86%	6,96%	8,37%	6,71%
Nitrogen Oxides (NOx)	15,60%	19,35%	12,61%	25,94%	8,23%	14,18%	40,10%	43,58%	23,15%	18,72%	23,88%	17,90%	18,04%	20,65%	17,37%	16,61%	15,26%	19,26%	20,28%	17,60%
Particulate Matter (PM10)	0,53%	1,17%	2,68%	2,78%	4,66%	4,78%	2,90%	3,29%	1,65%	2,77%	2,72%	4,41%	3,19%	3,47%	3,50%	3,52%	3,22%	2,81%	3,05%	3,07%
Sulfur Dioxide (SO2)	1,82%	7,17%	9,51%	9,24%	5,02%	13,92%	9,04%	21,97%	4,68%	10,56%	9,78%	12,66%	12,03%	16,07%	13,61%	13,17%	13,95%	10,79%	12,11%	8,38%
Polycyclic aromatic compounds (PAHs)	0,01%	0,03%	0,08%	0,08%	0,16%	0,13%	0,02%	0,02%	0,03%	0,07%	0,05%	0,10%	0,08%	0,08%	0,10%	0,10%	0,07%	0,07%	0,07%	0,04%
Arsenic	0,00%	0,01%	0,01%	0,01%	0,01%	0,02%	0,04%	0,16%	0,01%	0,02%	0,02%	0,02%	0,02%	0,02%	0,02%	0,02%	0,01%	0,02%	0,02%	0,02%
Cadmium	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Carbon Monoxide	9,81%	21,51%	43,25%	52,25%	75,93%	56,49%	35,98%	21,59%	24,28%	47,95%	46,32%	50,32%	42,33%	38,86%	46,31%	48,64%	30,56%	36,88%	37,50%	31,12%
ChromiumVI	0,00%	0,02%	0,04%	0,06%	0,13%	0,07%	0,01%	0,01%	0,02%	0,04%	0,03%	0,06%	0,04%	0,04%	0,05%	0,06%	0,04%	0,04%	0,04%	0,02%
Copper	0,00%	0,01%	0,01%	0,01%	0,00%	0,01%	0,05%	0,16%	0,01%	0,02%	0,02%	0,01%	0,02%	0,02%	0,01%	0,01%	0,01%	0,01%	0,02%	0,01%
Hexachlorobenzene	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Lead	0,01%	0,03%	0,08%	0,08%	0,16%	0,14%	0,03%	0,02%	0,03%	0,07%	0,06%	0,11%	0,09%	0,08%	0,10%	0,11%	0,07%	0,07%	0,07%	0,05%
Mercury	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Nickel	0,00%	0,00%	0,01%	0,00%	0,01%	0,01%	0,01%	0,01%	0,00%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%
Polychlorinated biphenyls (PCBs)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Selenium	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Zinc	0,01%	0,02%	0,06%	0,04%	0,05%	0,10%	0,02%	0,02%	0,02%	0,05%	0,04%	0,08%	0,07%	0,06%	0,07%	0,08%	0,06%	0,05%	0,05%	0,04%
Benzo(b)fluoranthene	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Phosphorus (to Land)	7,12%	0,44%	3,27%	0,57%	0,64%	0,71%	0,54%	0,34%	8,34%	1,82%	1,24%	1,29%	1,88%	1,20%	1,54%	1,39%	3,34%	3,73%	2,90%	5,85%
Nitrogen (to Water)	18,27%	0,79%	6,81%	1,10%	1,52%	1,27%	0,67%	0,59%	10,90%	2,75%	2,19%	2,02%	4,53%	2,03%	3,42%	2,43%	5,46%	5,94%	4,64%	9,51%
Phosphorus (to Water)	0,21%	0,01%	0,09%	0,02%	0,06%	0,02%	0,02%	0,01%	0,24%	0,06%	0,04%	0,04%	0,06%	0,04%	0,07%	0,05%	0,10%	0,11%	0,09%	0,23%

8.8 Percentage output of pollution for the manufacturing sector

	Processing of Food products nec	**Manufacture of fabricated metal products, ex. machinery**	**Petroleum Refinery**	**Manufacture of machinery and equipment n.e.c.**	**Processing of dairy products**	**Re-processing of secondary aluminium**	**Chemicals nec**	**Manufacture of other transport equipment**	**Manufacture of electrical machinery and apparatus**	**Processing of meat pigs**	**Manufacture of rubber and plastic products**	**Manufacture of motor vehicles, trailers**	**Re-processing of secondary plastic**	**Plastics, basic**	**Manufacture of medical, precision & optical instrument**	**Manufacture of cement, lime and plaster**	**Casting of metals**	**Processing of meat cattle**	**Paper**	**Manufacture of furniture; manufacturing n.e.c.**	**Rest**
Ammonia (NH3)	29,71%	1,78%	2,35%	5,77%	40,23%	4,14%	4,50%	3,60%	1,88%	62,26%	8,25%	2,89%	4,25%	4,44%	6,25%	1,60%	1,03%	45,48%	3,46%	3,72%	11,93%
Volatile Organic Compounds (NMVOC)	6,28%	1,58%	33,91%	2,52%	2,08%	1,66%	19,19%	2,39%	3,65%	1,84%	14,12%	5,71%	10,97%	12,62%	2,46%	2,77%	1,38%	1,95%	3,72%	5,83%	5,90%
Nitrogen Oxides (NOx)	13,78%	6,18%	19,28%	8,70%	15,24%	4,06%	13,96%	9,32%	8,14%	22,78%	13,23%	9,10%	13,01%	14,53%	11,02%	33,35%	7,83%	17,06%	14,46%	17,26%	15,43%
Particulate Matter (PM10)	1,34%	3,46%	2,90%	3,70%	1,06%	0,99%	2,71%	4,19%	3,84%	0,60%	3,44%	3,78%	2,78%	2,88%	3,23%	9,34%	3,46%	0,61%	4,31%	3,07%	3,50%
Sulfur Dioxide (SO2)	4,76%	8,66%	19,81%	10,90%	3,04%	2,12%	12,66%	8,94%	12,96%	2,13%	14,13%	9,99%	9,77%	11,26%	10,82%	20,81%	8,54%	2,15%	18,82%	9,49%	15,02%
Polycyclic aromatic compounds (PAHs)	0,03%	0,15%	0,04%	0,15%	0,02%	0,01%	0,06%	0,16%	0,15%	0,01%	0,08%	0,16%	0,07%	0,07%	0,10%	0,06%	0,12%	0,01%	0,08%	0,09%	0,08%
Arsenic	0,01%	0,02%	0,03%	0,02%	0,00%	0,00%	0,01%	0,02%	0,02%	0,00%	0,02%	0,02%	0,01%	0,01%	0,02%	0,01%	0,01%	0,00%	0,02%	0,02%	0,01%
Cadmium	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Carbon Monoxide	15,79%	76,45%	19,25%	66,29%	12,76%	83,41%	42,04%	69,14%	67,65%	7,08%	40,99%	66,46%	54,00%	48,84%	64,26%	30,93%	76,37%	7,76%	52,78%	57,76%	36,17%
ChromiumVI	0,01%	0,09%	0,02%	0,08%	0,01%	0,01%	0,04%	0,10%	0,09%	0,01%	0,04%	0,09%	0,04%	0,04%	0,06%	0,03%	0,08%	0,01%	0,06%	0,05%	0,05%
Copper	0,01%	0,01%	0,02%	0,01%	0,00%	0,00%	0,01%	0,01%	0,01%	0,00%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%	0,00%	0,01%	0,01%	0,01%
Hexachlorobenzene	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Lead	0,03%	0,17%	0,05%	0,16%	0,02%	0,01%	0,07%	0,16%	0,16%	0,01%	0,08%	0,17%	0,07%	0,07%	0,10%	0,06%	0,13%	0,01%	0,09%	0,10%	0,09%
Mercury	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Nickel	0,00%	0,01%	0,01%	0,01%	0,00%	0,00%	0,01%	0,01%	0,01%	0,00%	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%	0,01%	0,00%	0,01%	0,01%	0,01%
Polychlorinated biphenyls (PCBs)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Selenium	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Zinc	0,02%	0,12%	0,04%	0,12%	0,01%	0,01%	0,05%	0,09%	0,11%	0,01%	0,06%	0,12%	0,05%	0,05%	0,07%	0,04%	0,09%	0,01%	0,04%	0,07%	0,06%
Benzo(b)fluoranthene	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,01%	0,00%	0,00%	0,01%	0,00%
Phosphorus (to Land)	8,58%	0,45%	0,77%	0,53%	9,33%	1,35%	1,76%	0,65%	0,44%	1,06%	2,02%	0,52%	1,57%	1,72%	0,53%	0,35%	0,29%	12,25%	0,77%	0,95%	3,00%
Nitrogen (to Water)	19,42%	0,84%	1,48%	1,01%	15,90%	2,18%	2,88%	1,20%	0,87%	2,18%	3,45%	0,95%	3,32%	3,39%	1,04%	0,61%	0,61%	12,33%	1,33%	1,53%	8,64%
Phosphorus (to Water)	0,23%	0,01%	0,02%	0,02%	0,28%	0,04%	0,05%	0,02%	0,01%	0,03%	0,06%	0,02%	0,05%	0,05%	0,02%	0,01%	0,01%	0,36%	0,03%	0,03%	0,08%