

1.4 Hybridizing and detailing of the data

As discussed in section 1.2.1, the product categories in the EIO model are generally aggregated and not very granular. Therefore, the mapping of specific products used by Novo Nordisk to aggregated product category in the model creates some uncertainties. It was therefore decided to detail one category within direct spend to illustrate that the applied approach can be refined to reflect more detailed product categories.

1.4.1 Selecting high impact spend categories:

Within Novo Nordisk's direct spend glucose was the most significant category, both in monetary terms and in weight. Glucose was thus selected to create a hybrid process that better reflects the production of glucose than the current aggregated activity, which is the Flour industry.

Within Direct spend, six other categories were identified as potential high impact areas -

Spend Category	Sourcing Country
Glucose	Primarily France
Ethanol	Primarily Germany
Glass	Switzerland, Brazil, Mexico
Nitric acid	Finland, Norway
POM	Ireland, Germany, Brazil
PP	Primarily Belgium
Aluminium foil	Portugal

TABLE 1.5 DIRECT SPEND, POTENTIAL HIGH IMPACT AREAS

With additional time and resources, it is recommended that Novo Nordisk consider looking further into the remaining top categories.

1.4.2 Improving the data granularity

The EIO sector most appropriate for glucose was identified and assessed. Where required, data from EcoInvent was merged into the EIO model to make a new and more robust profile for the glucose sector. EcoInvent is the world's leading database for traditional life cycle assessments and contains specific data for more than 4,000 processes.

The combination of EIO tables and EcoInvent

- a) Compensate for EcoInvent cut-off limitations
- b) Allow for granularity in otherwise aggregated EIO tables

1.4.2.1 Detailing of input-output data on glucose production

The starting point of the detailing was to make a copy of the original 'Flour' sector in the EIO model. If no additional information was available, this would be the best estimate of glucose production. This rule is applied for all the inputs to the activity for which we have not identified more glucose specific data. One example is the use of various services as well as production capital (machinery and buildings). For these inputs it was assumed that the use per kg glucose is the same as per kg flour.

Detailed production data on glucose were obtained from an LCA study commissioned by DuPont [10]. Within the 'Flour' industry the production of glucose involves two processes:

- Wet-milling
- Starch to syrup conversion

The wet milling process uses corn as raw material. With inputs of energy, this is converted to corn starch (this is used as raw material in the starch to syrup conversion), corn oil (by-product), and other by-products which are used as animal feed (corn gluten feed, corn gluten meal and steep liquor). The starch to syrup conversion uses corn starch as raw material. With inputs of enzymes, energy and water, this is processed into glucose and dextrose syrup greens (by-product which is used as animal feed).

All inputs to the created IO-process 'Glucose production' were modeled using the existing product flows in the IO-model:

- Electricity and heat was modeled by using the FORWAST IO-flow: Electricity, steam and hot water
- Corn was modeled using the FORWAST IO-flow: Grain crops
- Corn oil by-product was modeled using the FORWAST IO-flow: Vegetable and animal oils and fats
- Animal by-products were modeled using the FORWAST IO-flows: 'Grain crops' and 'Vegetable and animal oils and fats'

When creating the IO-process all by-products were entered as negative inputs, i.e. the so-called product technology model was used. This is consistent with the way the FORWAST IO model has been created. Further, the product technology assumption is equivalent to avoiding allocation by substitution in LCA [11]. This is in accordance with the ISO standards on LCA [12]. When by-products are used as animal feed, it is taken into account that this substitutes a combination of the marginal sources of protein animal feed (soybean meal) and energy feed (barley) [13]. The protein and energy content of the by-products are obtained from Møller et al. [14], and the calculated substituted soybean meal and barley is calculated using the methodology described in Schmidt and Weidema (2007) [15].

The modified input and output flows of the created IO-process representing glucose production are shown in the figure below. Notice that the flows in the figure are converted to 100% dry matter to fit with the units in the FORWAST hybrid IO-model. Dry matter contents are obtained from Møller et al. (2005) [14].

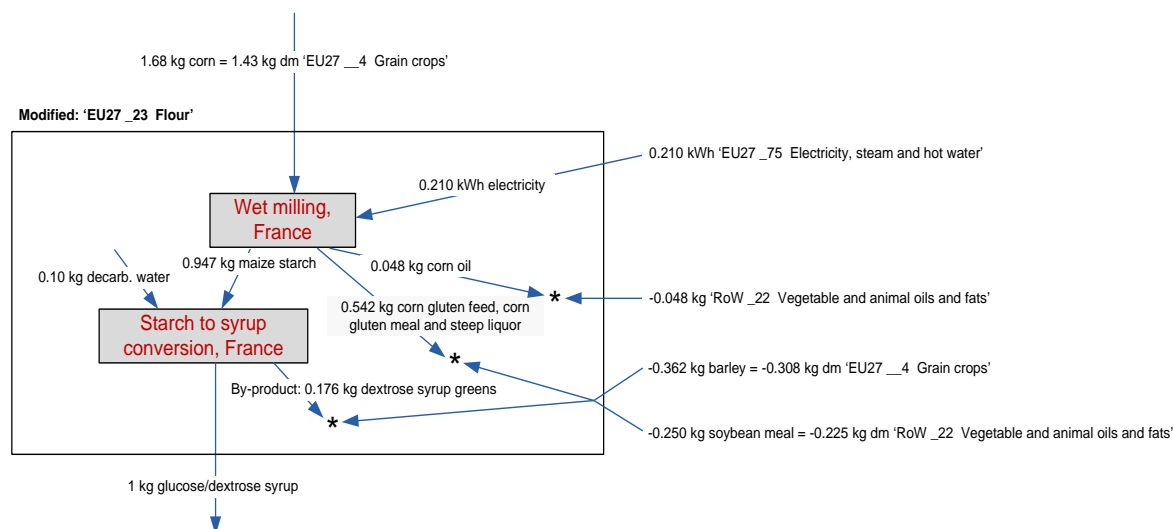


FIGURE 1.5: DETAILED LCA-DATA USED TO CREATE AN INPUT-OUTPUT PROCESS FOR GLUCOSE PRODUCTION THAT LINKS TO THE FORWAST HYBRID IO-MODEL.

The grey boxes in the figure above represent the detailed LCA data, and the large white box represents the created IO-process with its inputs and outputs. Notice that the product flows from the grey boxes are converted to IO-categories when crossing the system boundary of the large white box. The stars indicate the point of substitution where the by-product substitute animal feed.

The GHG-emissions related to the original 'EU27 _23 Flour' process and the modified one representing glucose production are shown in the figure below. The results are shown with and without the inclusion of indirect land use changes (iLUC). The iLUC model described in Schmidt et al. (2012) [16] is linked with the FORWAST database, and thereby iLUC can be switched on and off.

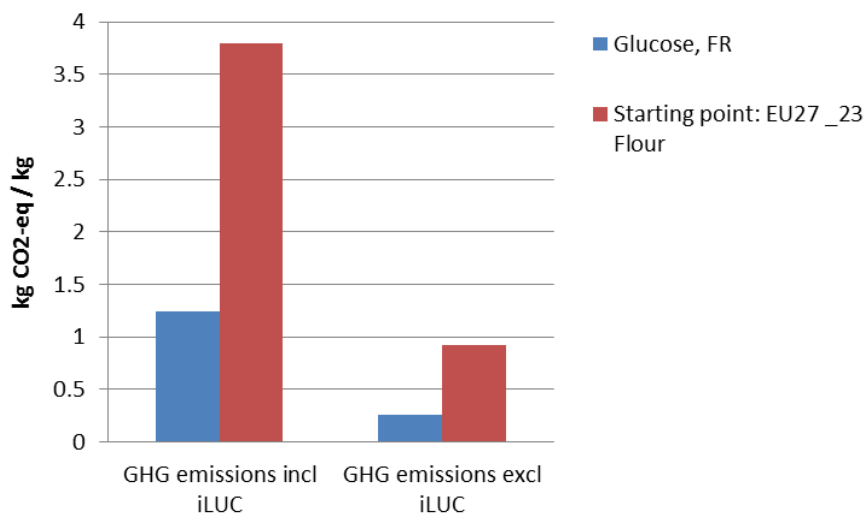


FIGURE 1.6: GHG-EMISSIONS PER KG GLUCOSE. RESULTS ARE COMPARED FOR THE ORIGINAL IO-PROCESS 'EU27 _23 FLOUR' AND THE MODIFIED ONE REPRESENTING GLUCOSE PRODUCTION. FURTHER THE RESULTS ARE SHOWN WITH AS WELL AS WITHOUT INDIRECT LAND USE CHANGES (ILUC).

In the figure below, the process contribution from the most important IO-processes are shown. The results are shown for the modified flour process representing glucose production. iLUC is included.

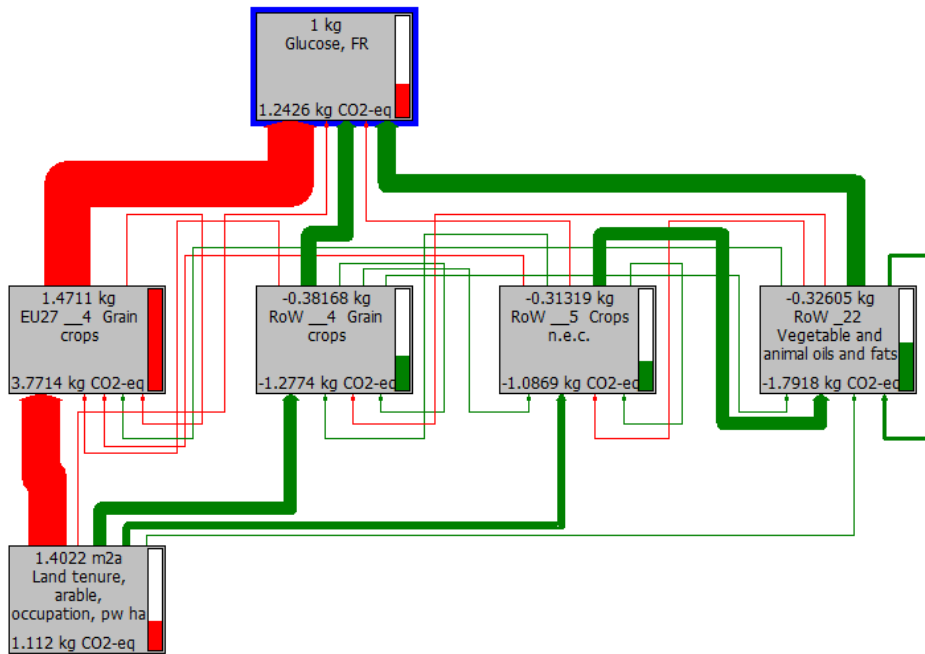


FIGURE 1.7: GHG-EMISSIONS: PROCESS CONTRIBUTION FOR THE MODIFIED FLOUR IO-PROCESS THAT REPRESENTS GLUCOSE PRODUCTION. THE RESULTS ARE SHOWN WITH ILUC. NOTICE THAT THE VIEW USES A CUT-OFF RULE SO THAT ONLY THE PROCESSES THAT TOGETHER CONTRIBUTE WITH 90% OF THE GHG-EMISSIONS ARE SHOWN. RED ARROWS REPRESENT POSITIVE FLOWS, AND GREEN ARROWS REPRESENT NEGATIVE FLOWS, I.E. SUBSTITUTIONS CAUSED BY UTILISATION OF BY-PRODUCTS.

For water, Trucost hybridised Hoekstra [17] water data for the production of maize grain in France and overwrote the existing E IO water quantities from “grain farming” with the country level water quantity based on the amount of glucose purchased in the Novo Nordisk supply chain.

2. Valuation of environmental impacts

After the quantification of each eKPI, valuations were applied. This converts all impacts into a single monetary unit (EUR). Converting environmental impacts into financial units allows for comparison between impacts and a better understanding of overall supply chain impacts relative to spend, turnover, and profit.

This document presents valuation methodologies based on the recommendations in the Danish Guidelines in socioeconomic analyses and by Trucost. The benefit of presenting both methodologies is to be able to compare their results and test sensibility of different valuation estimates. The valuation of the emissions quantified through this EP&L will be based on the approach developed by Trucost, as this is more in line with the global approach in the E P&L. The table below summarises the eKPIs concerned by these methodologies. As presented in the table below, water and land use are only valued by Trucost methodology as no “Danish” methodology has been developed.

Emission type	Presented in the methodology report		Used in the final report	
	Danish EPA	Trucost	Danish EPA	Trucost
Greenhouse Gases	yes	yes	no	yes
Other air pollutants	yes	yes	no	yes
Water	no	yes	no	yes
Land use change	no	yes	no	yes

TABLE 2.1: EKPIs AND VALUATION SOURCES

Both valuation approaches are based on welfare economic theory and attempt to quantify in monetary terms the changes in human welfare which result from environmental impacts. This reflects a ‘cost to society’ from the environmental impacts across Novo Nordisk’s supply chain.

The Danish guidelines are mainly targeted at national studies and therefore national environmental impacts⁵, while the Trucost approach has a global perspective. When the Danish guidelines have been used in studies which include pollution outside Denmark, the Danish unit prices have been used to value the effects of the pollution in those countries. This has been done in spite of the fact that willingness-to-pay of the Danish population probably is not the same as willingness-to-pay of

⁵ And regarding air pollution the cost of Danish emissions in other countries.

populations in other countries. The Trucost approach, however, deviates from the Danish model to provide insight on how to apply valuation estimates on a global scale. Trucost's approach accounts for how WTP can vary from one country to another.

Further development is needed on the Danish Guidelines on how to integrate an approach to analyses with a global scope as an E P&L which differs from a traditional national socio economic analyses. An E P&L attempts to value effects in the entire value chain and is therefore not restricted to a national approach.

In the following section both valuation approaches will be described and in the end of the section the specific valuation estimates are presented along with a discussion of differences.

2.1.1 Greenhouse gas emissions

Greenhouse gas emissions include carbon dioxide (CO₂), nitrous oxide (N₂O) and methane (CH₃). Increased emissions from industrial processes of greenhouse gases increases the overall average temperature of the Earth, which could lead to an increase in natural disasters, droughts, rise in sea level, and more.

2.1.1.1 Trucost approach

Trucost uses a forward-looking price to calculate the global annual external costs of greenhouse gases emitted by Novo Nordisk operations and supply chain. This represents the present day value of future climate change impacts and is based on the social cost of carbon from the Stern Review on the Economics of Climate Change [18].

Stern's estimate of the social cost of carbon is based on business-as-usual (BAU) emissions with low per capita economic growth. The study estimates that GHG emissions would lead to damages equivalent to 5-20% of global GDP. Stern provides a central estimate of the cost of likely climate change impacts from emissions over 200 years (2001-2200), based on the IPCC's Third Assessment Report (2001) [48] and an average 5°C temperature rise. The resulting marginal cost of damages, discounted to 2000 prices, results in a social cost of carbon of US\$85 per tonne. The study uses a relatively low implied discount rate of 1.4% [19] derived from a per capita consumption growth rate of 1.3% and a time preference rate of 0.1% [20].

The carbon cost has been inflated from US\$85 in 2000 to US\$113 in 2011 based on the World Bank of Consumer Price Inflation[21].

2.1.1.2 Danish guidelines

In Danish analyses, the prices of CO₂ quotas in the EU ETS are used. This price reflects the marginal cost of reaching the CO₂ emission target and not the damage cost of carbon. If the majority of emissions from the Novo Nordisk supply chain are assumed to be emitted in Europe, using the quota price is more robust than using the damage cost, which has more uncertainty. The estimated average price for the next 20 years is 20 EUR/tonne based on predictions from the Danish Energy Agency (DEA). The actual quota in 2011 was approx. 18 EUR/tonne [22].

2.2 Other air pollutants

Air pollutants can cause acid rain, smog and ground-level ozone, which can damage human health and ecosystems. Health effects can include chronic bronchitis and respiratory problems, while acidification can damage plant and animal life. Ozone, a secondary pollutant can also effect crop and timber growth.

Six air pollutants are included in the valuation:

1. Particulate matter (PM₁₀)
2. Ammonia (NH₃)
3. Sulphur dioxide (SO₂)
4. Nitrogen oxides (NO_x)
5. Volatile organic compounds (VOCs)⁶
6. Ozone (O₃)

Each pollutant is associated with different but overlapping types of external costs. Some effects are caused directly by the primary pollutant emitted (e.g. health impacts of particulates) and some are caused by secondary pollutants formed in the atmosphere from pollutants that act as precursors (e.g. sulphur dioxide forming sulphuric acid as well as sulphate compounds which contribute to smog). As each pollutant has a unique set of effects, each pollutant is valued using an individual methodology (although there is overlap between methodologies).

Air pollutants undergo chemical transformations in the atmosphere and the secondary pollutants formed can be the main driver of negative impacts. For example, after transport and chemical transformation, SO₂ and NO_x form secondary particulates that can cause lung and heart damage. The primary emissions of NO_x and SO₂ have relatively few individual effects [23]. Below is a brief overview of each pollutant.

2.2.1 Particulate Matter (PM₁₀)

Particulate matter, also known as particle pollution or PM, is a complex mixture of extremely small particles and liquid droplets from sources including fuel combustion in power plants, industry, road transport and construction sites. Particulates can cause cardiac problems, respiratory disease and premature death. Particle pollution is made up of a number of components, including acids (such as nitrates and sulphates), organic chemicals, metals, and soil or dust particles. The size of particles is directly linked to their potential to cause health problems. Governments are generally concerned about particles that are 10 micrometres (µm) in diameter or smaller because these can pass through the throat and nose and enter lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects [24]. Particles smaller than 10µm in diameter are generally referred to as PM₁₀⁷.

2.2.2 Sulphur dioxide (SO₂)

Sulphur dioxide (SO₂) can form sulphuric acid deposition (acid rain) and sulphate particulates (which form part of PM). Almost 90% of SO₂ in the atmosphere stems from fossil fuel combustion at power plants and industrial facilities [25].

2.2.3 Ammonia (NH₃)

Agriculture is the main source of anthropogenic emissions of ammonia (NH₃), which can react with nitric and sulphuric acids in the atmosphere to form fine particulate matter. Ammonia can also contribute significantly to acid rain and acidification of ecosystems [26].

2.2.4 Nitrogen oxides (NO_x)

Nitrogen oxides (NO_x) refer primarily to nitric oxide (NO) and nitrogen dioxide (NO₂) [27]. NO_x is emitted largely from road transport, power plants and off-road equipment. It can react with volatile

⁶ Only outdoor air pollution effects are included in this valuation methodology. VOCs can also have indoor effects on health which would require a separate valuation methodology.

⁷ Evidence is emerging that suggests PM_{2.5} could be a better predictor for PM-driven acute and chronic health effects. However, most studies still focus on PM₁₀ due to availability of data⁷. This valuation therefore focuses on PM₁₀ (encompassing all particles smaller than 10µm in diameter – including particles less than 2.5µm).

organic compounds (VOCs), sunlight and heat in the atmosphere to form tropospheric (ground-level) ozone (see below). NO_x can also react with ammonia to form particulates.

2.2.5 Volatile Organic Compounds (VOCs)

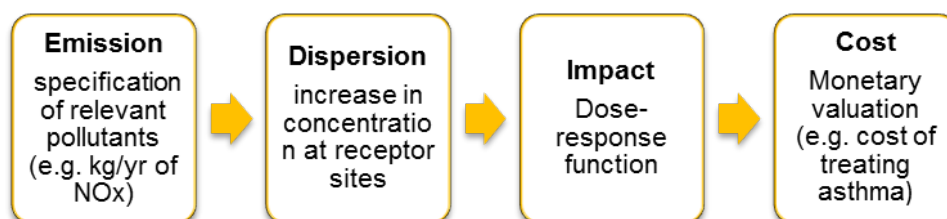
Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short and long-term adverse health effects[28]. VOCs also play a role in ozone formation (see below).

2.2.6 Ozone (O₃)

Tropospheric (ground-level) ozone is the primary constituent of smog. It is not usually emitted directly into the air, but can be created by a chemical reaction between NO_x and VOCs [29]. Tropospheric ozone is a complex pollutant and consequently difficult to control. Often the "precursor" gases are emitted in one area, but the actual chemical reactions, stimulated by sunlight and temperature, take place in another. Combined emissions from motor vehicles and stationary sources can be carried hundreds of miles, forming high ozone concentrations over large regions[30]. Ozone can cause respiratory problems and reduce crop production.

2.3 Impact Pathway Approach

Studies into the damage costs of air pollution use Impact Pathway Analysis (IPA) to follow the analysis from identification of burdens (e.g. emissions) through to impact assessment and then apply valuations in monetary terms[31]. These studies translate exposures into physical effects using dose–response functions (DRFs). The relationships embodied in the DRFs are established in peer-reviewed studies. The IPA measures the relationship between a unit concentration of a pollutant (dose) and its impact on an affected receptor (population, crops, buildings, water, etc.) based on scientific data, and then assigns a financial value to those impacts.



Source: Adapted from EXIOPOL (2009) [49]

FIGURE 2.1: IMPACT PATHWAY ANALYSIS

2.4 Trucost approach

Literature reviews were carried out for each air pollutant. The bottom-up, IPA approach was used to assess air pollution impacts. Data on the number of effected end points per tonne were compiled to derive an average number of each type of effect per tonne (for example the number of cases of chronic bronchitis per tonne of particulate emissions). The general approach taken when performing function transfer for air pollution is to scale the number of effect end points from the literature based on the receptor density. Therefore the number of effect end points per tonne is adjusted based on relevant factors (e.g. population density for health impacts, crop ratios for crop effects). Due to the function transfer approach, Trucost's air pollution methodology is global and country specific.

Disaggregating data from studies enables more effects than might have been included in each particular study. It also enables a disaggregation of the costs of the effects (e.g. health costs) from

the number of effects and applies its own costs, based on further detailed reviews of valuation literature. Isolating individual effects, and then adjusting each effect based on relevant factors, provides a more robust estimate of the total environmental damage cost than, for example simply adjusting a total damage cost for Purchasing Power Parity (PPP), as is carried out in some studies. Taking this approach of disaggregation derives the most indicative costs for the effects of air pollution emissions of a company's operations and supply chain and enables each effect to be adjusted and valued appropriately.

Valuations of externalities account for both market and non-market costs. Market values are applied to impacts on marketed goods such as crops, materials and timber, for which valuation data are relatively easy to obtain. For non-market elements such as impacts on health and ecosystems, values are based on averages from the literature, where valuation techniques are used to infer the value of non-market goods. Alternative techniques such as stated preference and revealed preference techniques are used. Stated preference methods include contingent valuation surveys, which can determine people's Willingness To Pay (WTP)⁸ to reduce their mortality risk. For health effects, studies from the literature were used to create health costs curves which linked health to GDP per capita.

The figure below describes how Trucost adjusted each of the impacts included in its air pollutants valuation. For example, the magnitude of air pollution impacts on crops will differ from one country to another. Not all cultivated plants have the same resistance to air pollution. Some plants, such as oat, are very resistant, whereas others, such as wheat, can be highly impacted in terms of yield. Considering that countries have different crop mix, air pollution impacts on crops will vary between countries. Hence, Trucost integrated the crop mix of each country into its air pollution impacts on crops in order to capture the agriculture variation between countries.

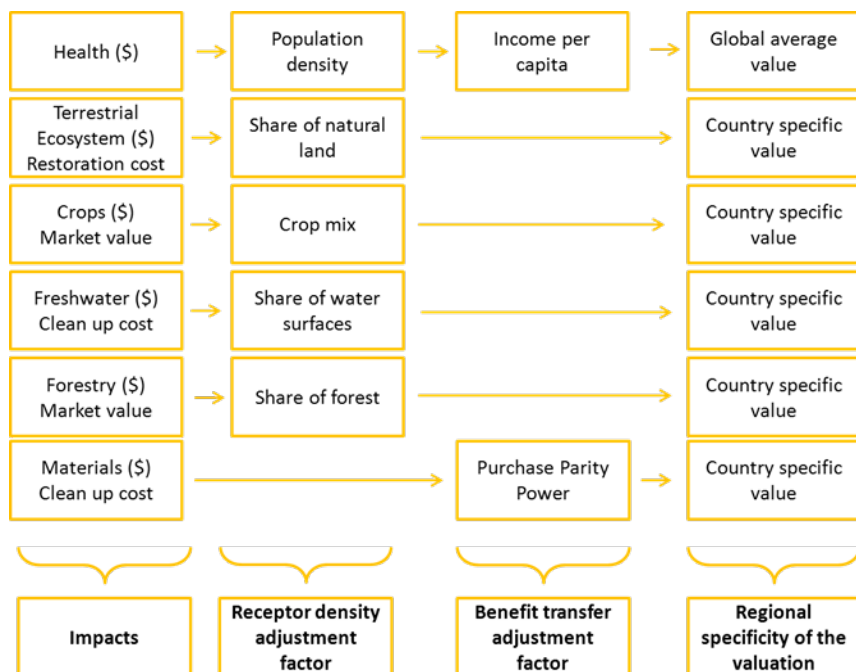


FIGURE 2.2: DAMAGE COSTS ADJUSTMENT

⁸ Willingness To Pay (WTP) is defined as the amount of money which, if taken away from income, would make an individual exactly indifferent between experiencing an environmental improvement and not experiencing either the improvement or any change in income (an analogous measure can also be constructed for "not experiencing degradation" rather than "experiencing an improvement").

The impacts present in this figure are not included in each air pollutant valuation scope. The figure 2.3 describes the damage cost integrated in the scope of each air pollutant.

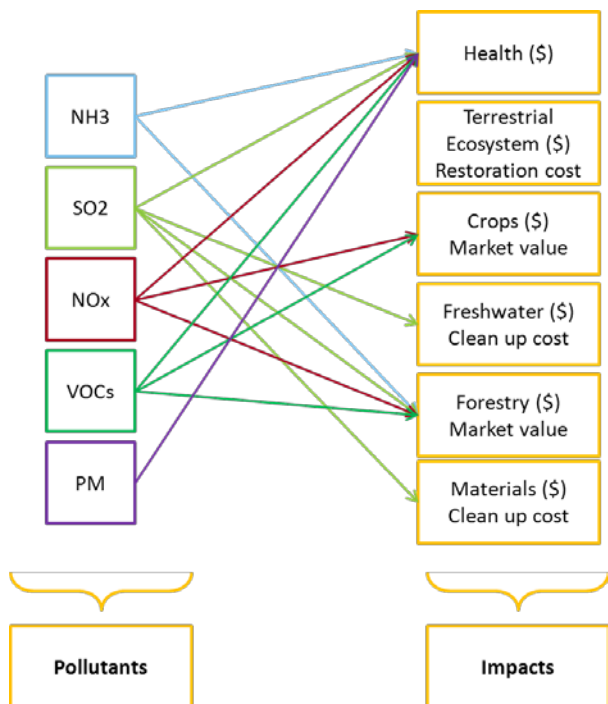


FIGURE 2.3: DAMAGE COSTS VALUED FOR EACH AIR POLLUTANT

2.5 Danish guidelines

For some air pollutants; NO_x, SO₂ and PM_{2.5} unit prices are provided by the DEA. These are based on reports from NERI (now University of Aarhus/DCE).

The pricing study from NERI (2010) assessed unit costs for both point sources and transport of SO₂, NO_x and PM_{2.5} emissions[32]. In the Novo Nordisk E P&L unit prices for point sources are used, as the majority of emissions are expected to come from point sources. Unit prices distinguish between whether the emissions are in urban areas where many people would be affected, or whether the emissions are in rural areas where fewer people will be affected. Since no information exists on where the emissions arise, an average is used.

Valuation of NMVOCs (non-methane volatile organic compounds) is based on unit prices from the European Environment Agency (EEA) (33). These unit prices do not distinguish between whether the emission is derived from transportation, heating/power plants, waste management, etc. Unit prices differs from whether it is based upon the value of lost life years (VOLY) or the value of a statistical life (VSL). According to the OECD, it is recommended that valuations are to be based on VOLY if there is a longer-lasting effect that will have a negative impact on life span. However, the valuations should be based on VSL, provided the exposure will cause acute death. The Novo Nordisk E P&L applies base unit prices based on VOLY.

The unit price for CO is based on NERI unit prices from 2003 (34), while the unit price of ammonia (NH₃) is taken from a comprehensive analyses of the evaluation of the overall Danish ammonia targets³⁵.

2.6 Water footprint; Trucost approach

2.6.1 Blue Water Valuation

System of Environmental-Economic Accounting for Water (SEEAW)^[36] defines three categories of water services:

Included in Trucost's water valuation	}	<ul style="list-style-type: none"> ▪ Environmental services of water. The environmental services can be assimilated to the instream services of water, which are the services provided by the water in its natural environmental.
Not included in Trucost's water valuation	}	<ul style="list-style-type: none"> ▪ Water as an intermediate input to production in agriculture and manufacturing; ▪ Water as a final consumer good;

The Trucost water valuation only includes the value of the environmental services of water. The table lists the environmental services included in Trucost methodology:

Environmental service	Definition	Reference
Wildlife habitat and recreational activities	Recreation benefits provided by water included activities such as fishing, boating, rafting and swimming as well as activities such as picnicking and hiking that are enhanced by their proximity to water resources.	[52] [53] [54]
Waste assimilation	Merrit and Mar ^[37] define the marginal value of dilution water as equivalent to the marginal cost of treatment. According to Gray and Young ^[38] this marginal cost of treatment increases in region where low flow of water and high level of discharge are combined.	[55] [56]
Groundwater services	Groundwater generates several environmental services such as water purification or wetland maintenance.	[57] [58] [59]
Other	Other instream services (example: salt dilution)	[60]

TABLE 2.2: ENVIRONMENTAL SERVICES INCLUDED IN WATER METHODOLOGY

2.6.2 Description of the methodology

Trucost has developed a methodology linking the environmental services of water to its scarcity in the considered region. As defined by the Food and Agriculture Organisation (FAO), water scarcity is the freshwater withdrawal as a percentage of total renewable resources^[39]. The methodology employed by Trucost to calculate the environmental services value of water follows two steps. The first step involved proving the statistical relationship between the environmental services (or instream) value of water and water scarcity. The second step consists of building a mathematical relationship between the values of each environmental service and water scarcity.

2.6.2.1 Step 1

Trucost reviewed academic literature that applied a homogenous framework to valuing instream water use in different locations across the US (New England, Mid-Atlantic, South Atalantic – Gulf, Great Lakes, Ohio, Tennessee, Upper MI, Lower MI, AK-White-Red, Missouri, Texas-Gulf, Rio Grande, Uppert CO, Lower CO, Great Basin, Pacific NW, California, Souris-Red-Rainy) ^[40]. The instream value calculated in this study includes waste assimilation, wildlife habitat and recreation values. Trucost has plotted the different instream values according to the water scarcity of the considered US regions cited previously. Water scarcity data was provided by the US Geological Survey. Trucost has then modelled the relationship between the instream values and water scarcity thanks to the software R^[41]. This relationship is a quadratic function of water scarcity.

2.6.2.2 Step 2

The value curve obtained in the first step has been adjusted in order to build the mathematical relationship between water scarcity and each of the water environmental services. Trucost conducted a literature review in order to calculate weighted average values for each of these services. All valuation estimates were standardised to year 2012 in U.S. dollar equivalents per m³ per year to provide a consistent basis for comparison. Then, Trucost calculated the weighted average water scarcity of the study sites. The results are illustrated in the figure below:

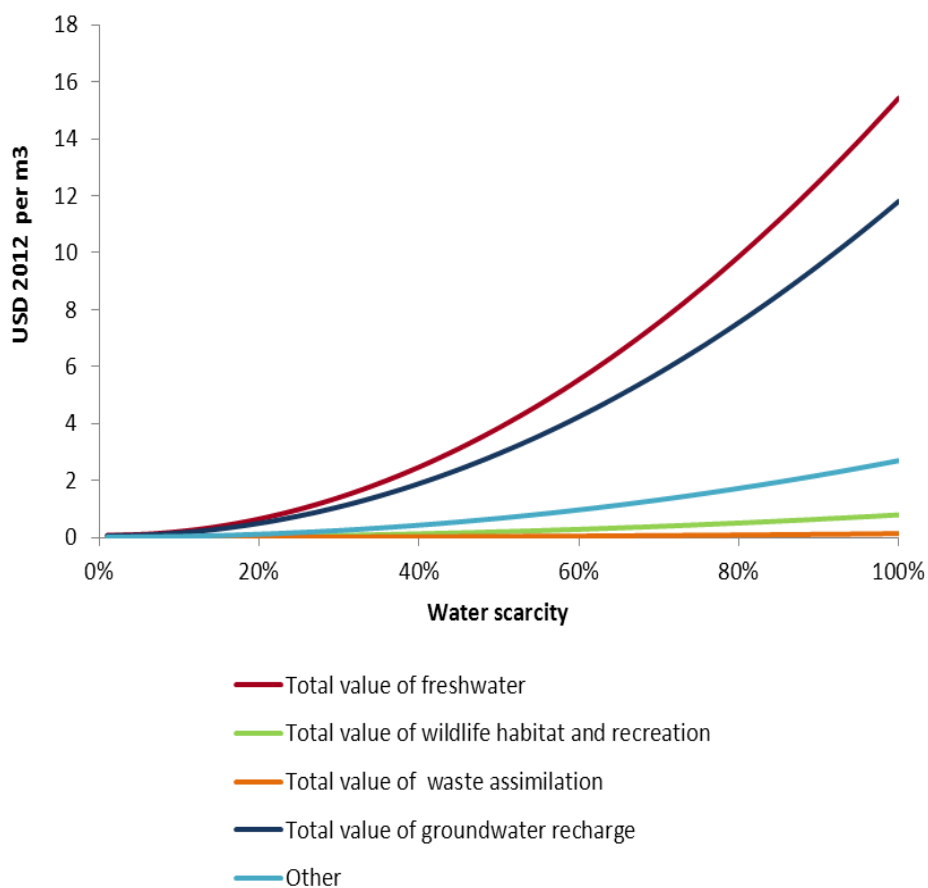


FIGURE 2.4: VALUE OF WATER AND WATER SCARCITY (DOLLARS₂₀₁₂/M₃)

As a result, the model built by Trucost is driven by the water scarcity of a particular region. In the context of this project, water scarcity has been calculated at a country level using the Aquastat database.

To calculate the value of one cubic meter of water in one specific region, the Trucost follows the following steps:

- Calculation of the country's water scarcity;
- Calculation of the four dimensions of the environmental value of water:
 - Wildlife habitat and recreation;
 - Waste assimilation;
 - Groundwater recharge;
 - Other;
- Purchase Parity Power adjustment of the dimensions based on willingness studies (wildlife habitat and recreation and groundwater recharge);
- Sum of the four dimensions: the result is the environmental services value of one cubic meter of water in the considered country.

2.6.3 Green water valuation

According to the 'Total Economic Value' (TEV) framework [42], the value of water can be broken down into 'use' values and 'non-use' values.

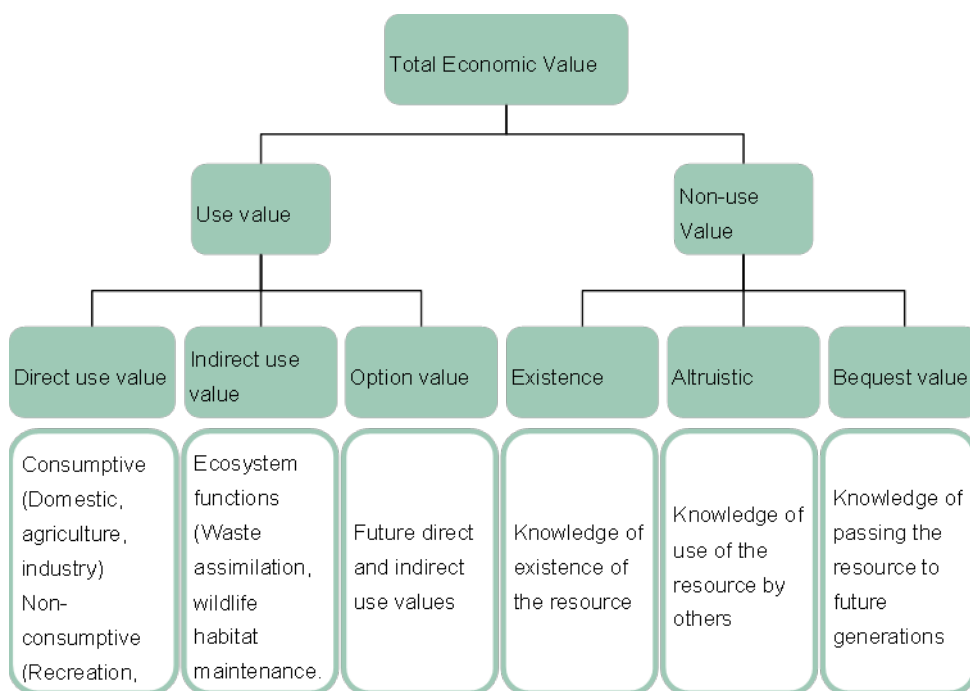


FIGURE 2.5: TOTAL ECONOMIC VALUE

The Global Footprint Network defines green water as the “precipitation on land that does not run off or recharge the groundwater but is **stored in the soil** or **temporarily stays on top of the soil or vegetation**. Eventually, this part of precipitation evaporates or transpires through plants. Green water can be made productive for crop growth (although not all green water can be taken up by crops, because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth)” [43].

To understand the value of green water, the question that needs to be answered is:

What are the ecosystem services lost through green water consumption?

According to this definition, the value of green water is generated when it is stored in the soil or situated on top of the soil or vegetation. In this state, the ecosystem services generated by water are very low compared to the other water related ecosystem services (example: waste assimilation, wildlife habitat, recreation activities...).

Furthermore, the quantity of green water in Novo Nordisk’s EP&L is immaterial compared to the quantity of blue water.

Since both the value of one cubic meter of green water is smaller than the value of one cubic meter of blue water and the quantity of green water calculated in this EP&L is very small compared to the quantity of blue water consumed, we can assume that the total value of green water will be immaterial compared to the total value of blue water. Hence, Trucost suggests applying a **value of zero** to the quantity of green water consumed through Novo Nordisk’s operations and supply chain.

2.7 Land use change (iLUC)

Land generates value through ecosystem services, defined as the benefit people obtain from the ecosystems. According to the type of land or ecosystems, the ecosystem services generated and the value of these ecosystems are different.

2.7.1 Ecosystem services generated by the environment

The framework used in this methodology is the Millennium Ecosystem Assessment [44]. This is an international program of evaluation under the United Nations Environment Program (UNEP), active from 2001 to 2005. The aim is to demonstrate the importance of conservation of biodiversity for stakeholders, by showing them how ecosystem services affect human well-being and economic expansion. The MEA suggests the following classification of ecosystem services:

- *Cultural services* providing recreational, aesthetic, and psychological benefits;
- *Regulating services* affecting climate, flooding, disease, wastes, and water quality, obtained through regulation of ecosystem processes;
- *Provisioning services* such as food, water, timber, and fibre, obtained from direct exploitation of resources by humans;
- *Supporting services* such as soil formation, photosynthesis, and nutrient cycling, which correspond to basic ecological functions at the root of biotic processes;

This paper does not address supporting services: quantifying such processes, which we know and understand insufficiently, seems to be impossible and attempting to evaluate them seems undesirable and likely to raise ethical questions [45].

In the context of this EP&L which is focused on environmental externalities, Trucost will not take into account the ecosystem services which are part of the market (example: provisioning of maize or timber).

2.7.2 Land use change general approach

To calculate the value gained or lost through land use change, Trucost recommends comparing the value generated by the current ecosystem to the value generated by the natural ecosystem (the most probable ecosystem before the land use change). Trucost recognizes that there are various land use change valuation methodologies. Figure 2. describes the general approach.

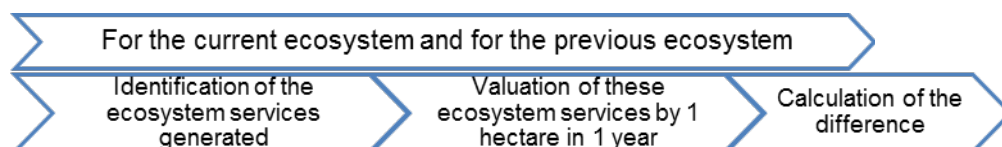


Figure 2.6: Land use change general approach

2.7.3 Application of Trucost methodology to the cultivation of corn in France

As the methodology is under development the objective is to value land change of the cultivation of corn in France as a case study. According to a 2009 report[46], the main non-urban or non-cultivated ecosystem in France is temperate forest. Hence, Trucost will compare the value of one hectare of corn cultivated in France to the value of one hectare of French forest. In order to have a consistent comparison, the scope of the ecosystem services valued must be the same for the two ecosystems considered. The most material ecosystem services valued in the literature for these two ecosystems are described below:

		Forest	Cultivated corn
Direct, use value	Provisioning services	Wood forest product (Timber, firewood)* Non wood forest product (honey,	Corn*

		berries, mushrooms...)	
Direct, non-use value	Recreational activities	Hunting, promenades, collecting...	Promenades
Indirect value	Carbon sequestration	Soil Vegetation and leafs Trunks and roots	Corn
Indirect value	Pollination	Process by which pollen is transferred in the reproduction of plants, thereby enabling fertilization	

*Ecosystem services included in market (hence, excluded from the scope)

TABLE 2.3: ECOSYSTEM SERVICES GENERATED BY FOREST AND CULTIVATED CORN

Valuation of 1 hectare of French forest

- Provisioning services

The provisioning services included in the scope only concern externalities, which means that the provisioning services such as timber which are part of an existing market are not included.

According to Montagne et al. [47], the “non market” provisioning services generated by French forests equal 33.2 million Euros 2001. Trucost divided this number by number of hectares of French forest (FAO STAT) and inflated this number to 2011.

- Recreational activities

Based on six studies from European countries, Trucost calculated the median European recreational value by forests adjusted to French PPP.

- Carbon sequestration

The data used to calculate the quantity of carbon sequestered in 1 hectare of forest come from Montagne et al (2001) [43]:

- Soil: 70 tC
- Vegetation and leafs: 4.4 tC
- Wood and roots: 0.7 tC.

The cost applied follows the carbon cost methodology developed by Trucost (86 Euros 2011 per tonne).

- Pollination

According to Brenner-Guillermo [48], the pollination value generated by 1 hectare of forest equals 400 USD 2004 per year. This number has been inflated to 2011 and converted into euros.

Valuation of 1 hectare of cultivated corn

- Recreational activities

According to Brenner-Guillermo (2007) [44], the recreational value generated in Spain by 1 hectare of forest equals 37 USD 2004 per year. This number has been adjusted according to French PP, inflated to 2011 and converted into euros.

- Carbon sequestration

1 kg of corn contains around 367g of carbon^[49]. According to the French corn yield (FAO STAT, 2011) [51]; this implies that 1 ha of cultivated corn contains 3.7 tonnes of carbon.

The table below summarizes the results of the land use change of 1 hectare of forest into corn.

		Temperate French forest	Corn cultivated in France
		Euros 2011 per ha	Euros 2011 per ha
Direct, use value	Provisioning services	2.56	
Direct, non-use value	Recreational activities	2,940.18	22.87
Indirect	Carbon sequestration	6,457.50	321.62
Indirect	Pollination	304.74	15.24
Total		9,702.42	359.72
Net loss		(9,342.70)	

TABLE 2.4: LAND USE CHANGE VALUE OF CORN IN FRANCE

The table below summarizes the land use change value for Novo Nordisk glucose sector:

Novo Nordisk glucose land use (ha)	Land use change value (Euros 2011)
3,940	(36,810,229)

TABLE 2.5: GLUCOSE LAND USE CHANGE RESULTS

2.8 Comparison of valuation estimates

The table below compares the scope between the methodologies recommended in the Danish guidelines and by Trucost.

Emission type	Damage scope		Geographical scope	
	Danish guidelines	Trucost	Danish guidelines	Trucost
Greenhouse Gas emissions	Marginal abatement cost	Social and environmental costs	Denmark	World, country specific
SO ₂	Health	Health, timber, material, water acidification	Total cost of Danish emissions	World, country specific

NOx	Health	Health, timber, crops	Total cost of Danish emissions	World, country specific
Particulate matter*	Health	Health	Total cost of Danish emissions	World, country specific
CO	Health	-	Denmark	-
VOC	Health, crops ecosystem risks	Health, timber, crops	Total cost of Danish emissions	World, country specific
NH3	Health	Health, timber	Denmark	World, country specific
Water	-	Wildlife and recreation, waste assimilation, groundwater recharge and other	-	World, country specific
Land use change	-	yes	&	France

TABLE 2.6: COMPARING OF SCOPES BETWEEN VALUATION METHODS *THE DANISH ESTIMATES COVER PM_{2.5} WHEREAS TRUCOST ESTIMATES COVER PM₁₀

As shown in this table, the results of the methodologies recommended in the Danish guidelines and by Trucost cannot be directly compared, as the scope of their environmental impacts is different. However, even if Trucost air pollutant methodologies are less focused on health impacts compared to Danish Guidelines, this dimension still remains the highest contributor in terms of value.

In the table below, Danish and Trucost estimates for GHG emissions and other air pollutants are shown. Using the Trucost methodology, it is possible to calculate country specific estimates on air pollutants. Global averages as well as estimates for Denmark are shown.

Trucost's valuations are country specific. The global average has been weighted by population

Emission type	Danish Guidelines	Trucost global average	Trucost Estimates for Denmark	Ratio Danish guidelines/TR UCOST global	Ratio Danish guidelines/TR UCOST Denmark
	€/t	€/t	€/t		
SO ₂	9,891	972	1,530	1017%	647%
NOx	6,330	1,300	577	487%	1098%
PM*	11,869	12,539	7,754	95%	153%
NMVOc	8,440	875	374	964%	2256%

CO	1				
GHGs	21	86	86	24%	24%
NH ₃	14,507	632	400	2296%	3624%

TABLE 2.7: ESTIMATES FOR GHGS AND OTHER AIR POLLUTANTS (IN EUROS 2011 PER TONNE)

Estimates from Danish Guidelines are in general significantly higher than Trucost estimates except for those relating to GHGs. That is mostly likely due to difference in cost of the value of life which is an important dimension of air pollution. The Statistical Value of Life varies from one country to another and is positively linked to GDP. Hence, the value of life in Denmark is higher compared to poorer countries or to a global average. Trucost decided to have a value of life constant among countries and decided to apply a global average statistical value of life for each country. This average global value weighted by population is approximately 420,000 euros 2011. The studies recommended in the Danish Guidelines use a value of statistical life at app. 2,300,000 euros 2011(50) Hence, the value included in Danish valuation is much higher compared to the value of life included in Trucost valuation.

Regarding GHG emissions however, using a damage cost as proposed by Trucost implies a significantly higher value of GHGs than using a marginal abatement cost as proposed in the Danish Guidelines.

2.9 Sensitivity analysis

To examine the differences between the two valuation methods, a sensitivity analysis was conducted. The sensitivity analysis only includes the two eKPIs GHG emissions and air pollution. However, they include all the different emission types from Table 2.7.

Methodology	eKPI	Indirect spend	Direct spend	Total (EUR million)
Trucost	GHG	130.840.364	40.404.764	171
Trucost	Air pollution	15.842.834	3.195.126	19
				190
Danish EPA	GHG	31.949.391	9.866.280	42
Danish EPA	Air pollution	75.322.168	18.879.019	94
				136

TABLE 2.8: SENSITIVITY ANALYSIS

The Trucost valuation method yields results that are 40% higher than the Danish method. However, based on the differences in the approaches taken and the assumptions made, this variation is to be expected. While valuations may vary from one method to another, it is important

to maintain transparency on the assumptions used to determine the scope and boundary of each method.

Assumptions in the E P&L Model

Using EIO tables, and other E P&L approaches implies a number of assumptions and limitations. The assumptions and their influence on the E P&L are summarised below.

Assumptions are divided into three areas:

1. Assumptions with regards to the general modelling of the EIO model
2. Assumptions regarding the detailed hybridisation processes
3. Assumptions regarding the valuation

2.9.1 Modelling assumptions

Assumption	Influence on results
DATA	
Average data from EIO tables are applied for purchased products and services.	The level of aggregation in the EIO tables are not 100% aligned with the aggregation level in the financial accounts. That entails a level of uncertainty in emission calculations.
Purchased products and services are divided into three geographical regions, Denmark, Europe and Rest of the World (ROW), depending on the geographical origin of the supplier. The supplier is assumed to follow the general transaction pattern of the respective sector and region.	Location of suppliers is for first tier indirect impacts only – location of suppliers' supply chains are unknown and results could improve if countries along each tier were disclosed.
For Trucost EIO – converted Direct Spend (kg) into USD using wet to dry weight conversions.	Could potentially over or under estimate results since price per kg was unknown and estimations of total spend were made

TABLE 2.9: ASSUMPTIONS REGARDING THE GENERAL MODELLING

2.9.2 Hybridisation assumptions

Assumption	Influence on results
DATA	

Assumed all glucose was sourced from France	Impact on energy mix, water footprint, and overall environmental impact
Assumed glucose undergoes 2 processes: <ul style="list-style-type: none"> ○ Wet-milling ○ Starch to syrup conversion 	

TABLE 2.10: ASSUMPTIONS REGARDING HYBRIDISATION

2.9.3 Valuation assumptions

Assumption	Influence on results
DATA	
Greenhouse Gas emissions	The social cost of carbon reflects the costs of the environmental damages generated by the increase of carbon in the atmosphere which assumptions are an average 5 degrees and a discount rate of 1.4% Trucost used Stern's estimation of social cost of carbon and adjusted it to 2011.
Other air pollutants	Health cost: use of a global average Terrestrial ecosystem costs: adjustment based on share of natural land Crop costs: adjustment based on crop mix Freshwater acidification cost: adjustment based on share of water surfaces Forestry: adjustment based on share of forest Material costs: adjustment based on purchase parity power
Blue water	The main ecosystem services impacted by the abstraction of water are recreation activities and wildlife habitat, waste assimilation and groundwater recharge.

Green water	The value of green water is zero
Land use change	The land use change value of glucose equals to the difference between the ecosystem services value generated by cultivated corn and temperate forest in France.

TABLE 2.11: ASSUMPTIONS REGARDING VALUATION

3. Scenario analysis of water footprint for glucose

For the scenario analysis of water use in the production of glucose, water data from Mekonnen and Hoekstra [51] was used to derive various water intensities per tonne of corn starch produced in various countries. The data set comes from the Water Footprint Network, which has data on water consumption per country per crop for 1999-2005.

The data quantifies water intensities for the farming of corn starch inputs for both green and blue water quantities. Within the scope of this project, green water is given a value of EURO and blue water is valued on a country level as described in section 2.4.3.3

A comparison was then made between water intensities in France (the country of origin for the glucose used in the Novo Nordisk supply chain), the USA, and China, both of which produce most of the world's corn. The various water intensities and costs are shown in the table below.

Crop Type	Country	Water Type	Country Average Water Footprint (m ³ /tonne of crop)	Cost/tonne (EUR)
Maize (corn) starch	France	Green water	528	-
		Blue water	114	29
		Total water	643	29
	USA	Green water	648	-
		Blue water	78	19
		Total water	726	19
	China	Green water	981	-
		Blue water	91	21
		Total water	1,073	21

TABLE 3.1: COMPARISON OF WATER INTENSITIES

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Methodology report for Novo Nordisk's environmental profit and loss account

The Novo Nordisk Environmental Profit and Loss Account (E P&L) is a response to PUMA's call for contributions to the E P&L methodology and the expert review of PUMA's E P&L.

The Novo Nordisk E P&L is reported in two parts; the main report, which focuses on the results and the application of these in a Novo Nordisk context, and the methodology report which focuses on the methodology applied for establishing the E P&L results.

This methodology report 1) summarises the methodological contributions and deviations from PUMA's original E P&L methodology, and 2) provides a detailed explanation of the data sets, quantification methods, and valuation methodologies used to complete the E P&L.



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