TNO's carbon footprint calculation method 2024

At TNO we aim to create impactful innovations for the sustainable wellbeing and prosperity of society. As an independent public organisation, we want to do this in a responsible and sustainable way. TNO attaches great value to ensuring its transparency and is open about its activities and work for society. We focus on the positive contribution we make, while being transparent about our negative impact: 'practise what we preach'. TNO's aims to be climate neutral ('net zero') as an organisation by 2040. In combination with our research, we pursue a net-positive contribution to climate change mitigation.

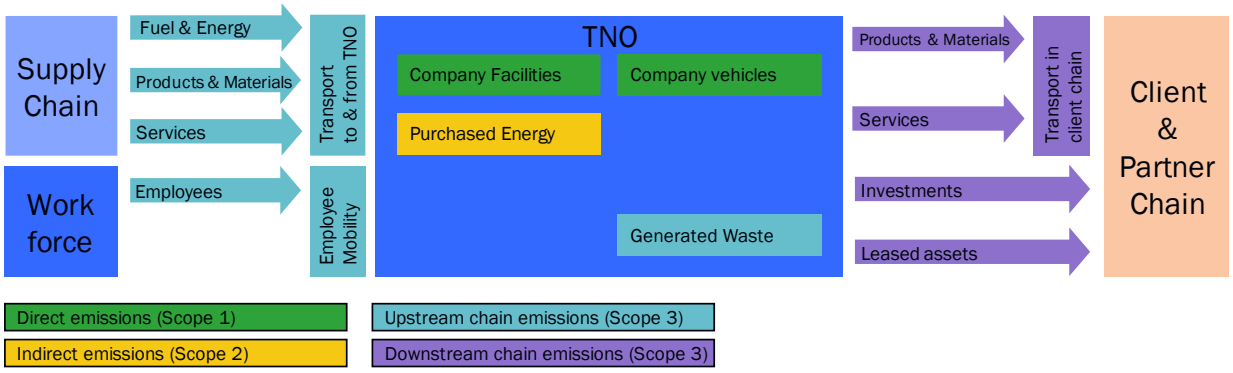
Scope

We account for 100% of Scope 1 and Scope 2 emissions from TNO's own operations. TNO does not report its participations as part of Scope 1 and 2. For TNO's Scope 3 emissions, it currently reports on ten applicable Scope 3 GHG-categories, which are discussed in chapter 3. Given TNO's core business, being research and development, the downstream emissions estimations of its products, materials and services are very complex, uncertain and with a long-term focus. Due to these uncertainties these categories are currently excluded from TNO's carbon footprint.

Each category of emissions has its own specific methodology, which is detailed in this document. The calculations adhere to the Greenhouse Gas Protocol (GHG) standards and are used for internal management purposes. All CO_2 equivalent emissions are included in the calculations, which are CH_4 , N_2O, HFCs, PFCs, SF_6, and NF_3. Everywhere in this document where CO_2 is mentioned, read CO_2 equivalent. Additionally, the external auditors of TNO provide limited assurance on provided numbers for scope 1 and 2 in the yearly report.

TNO has published its carbon footprint since 2009. For the stated ambition of climate neutrality by 2040, 2019 is used as the base year. The year 2019 was chosen because from this year forward TNO started more actively collecting data and has accelerated its effort to reduce its carbon footprint. Since, TNO's carbon emissions are compared with previous years, it is important that historical emissions are comparable with current emissions. Therefore, in line with the GHG protocol, if changes to the methodology lead to a change in emissions of >5% (cumulative) figures are retroactively adjusted back to 2019.

For internal management purposes TNO has defined its most material emission categories. The alignment between these emissions categories and the GHG Protocol categories is shown in the table at the end of this document.



1. Scope 1 Emissions

1.1. Introduction

Scope 1 greenhouse gas emissions are direct emissions emitted by the companies owned assets. For example, the burning of natural gas for heating and gasoline powered vehicles. In accordance with the GHG Protocol, stationary, mobile, fugitive and process emissions are within the reporting span.

1.2. Methodology

Scope 1 includes direct emissions from the consumption of fuels, such as (natural) gas, petrol, and diesel. Carbon emissions are calculated directly from the fuel consumption (petrol, diesel) of (lease) cars, process gases, and gas consumption in buildings, and multiplied by a carbon emission factor. At this level, we estimate that the uncertainties are relatively small.

1.2.1. Stationary emissions: Natural Gas combustion

The natural gas carbon direct emissions are calculated directly from the annual 'physical' consumption of natural gas in m3 and multiplied by the carbon emissions factor of that same year using the carbon emission factors list [13]. In accordance with the GHG protocol the carbon emissions factor of only the Tank-to-Wheel, or natural gas combustion emissions are included in this category in scope 1.

For the natural gas consumption data of TNO rented locations, consumption data (in m3) from a year earlier is used as a proxy. Given TNO's consumption profile, this can be considered a good indication but remains an assumption. This is done because the data of the reporting year is not always known and verified by the landlords in the first months of the year. This is retroactively adjusted when the annual consumption data becomes available.

1.2.2. Mobile emissions: Lease cars & Company vehicles

The carbon emissions of vehicles, lease cars and company vehicles, are calculated directly from the annual 'physical' consumption in litres (diesel and gas) for lease cars and travelled km for company vehicles. This consumption amount is multiplied by the corresponding carbon emissions factor of that same year using the carbon emission factors list [13]. In accordance with the GHG protocol the carbon emissions of only the Tank-to-Wheel, or use phase of the fuels are included in scope 1.

1.2.3. Fugitive emissions: Refrigerant leakage

The fugitive carbon emissions are calculated based on the leakage incident reports of specific refrigerants leaked annually in kg's. This 'physical' leakage is multiplied by the corresponding carbon emissions factor of the specific refrigerant using the carbon emission factors list [13]. The uncertainty of these fugitive emissions is that the calculations are based on reported incidents, but smaller incidents may not be reported. Given the quantities TNO emits this uncertainty is deemed not material.

1.2.4. Process emissions: Lab emissions

Lab carbon emissions are calculated based on the purchased gasses CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3 in kg. This 'physical' amount is multiplied by the corresponding carbon emissions factor, in accordance with the carbon emission factors list [13]. Some uncertainty remains given the offset in time between purchase and emission. Given the quantities TNO emits this uncertainty is deemed not material.

2. Scope 2 Emissions

2.1. Introduction

Scope 2 includes emissions from purchased energy, electricity and energy for heating. In accordance with the GHG protocol these emissions are considered an indirect emissions source (along with scope 3 emissions), because the emissions are a consequence of TNO activities but actually occur at sources owned or controlled by another organization (e.g. an electricity generator or utility).

2.2. Methodology

The annual amount of emissions from purchased energy (electricity and district heating), is determined on the basis of 'physical' consumption: kWh electricity for buildings and electric vehicles, and GJ for building heating.

Uncertainties in scope 2 consist of the carbon emission factor for purchased electricity for both electric vehicles and buildings. The carbon emission factor was calculated from the sustainable electricity certificates purchased by TNO and the carbon emission factor for the energy mix for grey energy in the Netherlands based on the SKAO Handbook [12] and carbon emission factors list [13]. The latter factor is not specific to TNO's supplier. Other uncertainties in the scope 2 calculations differ per calculation method applied: market based method or location based method (see further explanation in section 2.2.1 below).

As well as for natural gas consumption, for the electricity consumption data of TNO rented locations, consumption data (in kWh) from a year earlier is used as a proxy. Given TNO's consumption profile, this can be considered a good indication but remains an assumption. This is done because the data of the reporting year is not always known and verified by the landlords in the first months of the year. This is retroactively adjusted when the annual consumption data becomes available. The same estimations accounts for District heating.

2.2.1. Purchased Energy: Electricity

For electricity use in buildings, both the market based method as well as the location based method are reported. TNO uses the market based method as the basis. This market based method takes the sustainable electricity (certificates) purchased by TNO, or TNO's lessors, into account. The generated electricity technology type of the certificates is a mix of electricity generated by the Sun, Wind and Biomass.

For the ***market based method***, the CO_2-emissions factor for purchased electricity is applied to both electricity use in buildings as well as for electric vehicles. The CO_2-emissions factor calculated, is based on the sustainable electricity certificates (EACs) that TNO purchases (mix of electricity generated by Wind, Sun, and Biomass), the electricity generated by TNO's own solar panels and the CO_2-emissions factor for the electricity grid mix (residual mix) in the Netherlands of the corresponding year from the CO_2-emissions factor list [13]. The latter is not specific to TNO electricity suppliers. In accordance with the GHG protocol the carbon emissions factor of only the Tank-to-Wheel, or use phase of the purchased electricity are included in this category in scope 2.

For the ***location based method***, only the CO_2-emissions factor for the electricity grid mix (residual mix) in the Netherlands from the CO_2-emissions factor list [13] is applied. This is not specific to TNO electricity suppliers produced electricity mix and thus will differ.

The purchased electricity used for electric lease cars also fall under this category. The carbon emissions of electric lease cars are calculated directly from the annual 'physical' consumption in kwh. This

consumption amount is multiplied by the corresponding carbon emissions factor of that same year using the carbon emission factors list [13]. In accordance with the GHG protocol the carbon emissions factor of only the Tank-to-Wheel, or use phase of the electricity for lease cars, are included in this category in scope 2.

2.2.2. Purchased Energy: District heating

The carbon emissions purchased district heating for buildings are calculated directly from the annual 'physical' consumption in GJ. This consumption amount is multiplied by the corresponding carbon emissions factor of district heating in the Netherlands that same year using the carbon emission factors list [13]. In accordance with the GHG protocol the carbon emissions factor of only the Tank-to-Wheel, or use phase of heating are included in this category in scope 2.

3. Scope 3 Emissions

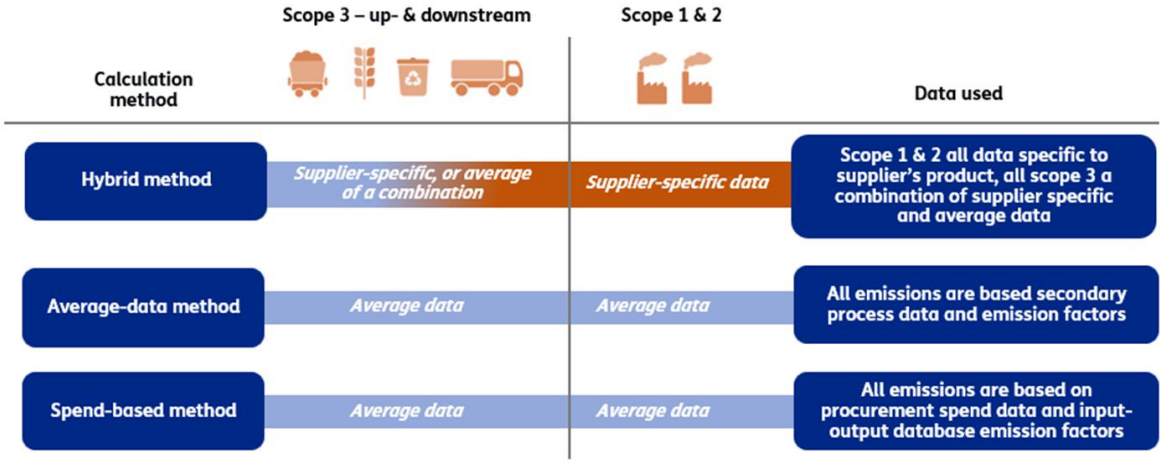
3.1. Introduction

Scope 3 includes all other indirect emissions that occur in TNO's value chain, including for instance purchased services and materials, commuting, business travel and investments. The GHG protocol distinguishes 15 categories in scope 3 and TNO reports on all relevant categories.

Given TNO's business of research and development the application of our products and services is often a long time from scaled application. Additionally, there often is a large time lag between TNO's activities and emissions resulting of the use of products and their end-of-life. Given the uncertainty and complexity of estimating this downstream emission contribution of TNO greenhouse gas protocol categories 9 (Downstream transportation & distribution), 10 (Processing of sold products), 11 (Use of sold products) and 12 (End-of-life treatment of sold products) are currently deemed not material and are not included in TNO's footprint. Category 14 Franchises is not applicable to TNO. An explanation of how the applicable categories are reported is provided below.

3.2. Methodology

The scope 3 calculations of TNO are based on two overall calculation methods, determined by the type of data available per category or sub-category. These are the average-data method and the spend-based method. The figure on the following page, adapted from the GHG protocol, shows the difference between the methods applied. As you move up in the figure in calculation method, the accuracy of data input improves due to more specificity from (first tier) suppliers. Also the data output in CO_2-emissions and degree of control increases. TNO has the ambition to apply the hybrid calculation method for all material emission categories.



For the ***average-data method***, physical (non-euro) input data per (sub)category is collected via various TNO administration systems. The majority of the emission factors come from the carbon emission factors list [13]. Where specific emission factors were not available from this secondary source, e.g. specific waste type treatment, the Ecoinvent's LCA database was used, which contains data on emissions and raw material consumption in the production of products, processes, and services. In Ecoinvent, emissions and resource consumption are modelled from 'cradle to gate': from raw material extraction and transport to energy use, emissions, and waste disposal in production processes.

For the ***spend-based method***, data is collected in euros from the TNO procurement database per catogory and sub-category. The USA input-output database [2] was used for the environmental profiles per euro. An input-output database is a database that combines a sector's emissions (known from the emissions register) and the sector's total turnover with the deliveries made between sectors (economic databases and models). The USA input-output database was chosen because it is the most detailed (five hundred sectors). Danish research [3] has shown that a high level of detail is more important in reducing the uncertainty margin than the geographical origin of the figures. This is partly because the diversity between sectors is relatively high and this is lost at a high level of aggregation. Also, as the world's economy is global, many products in Europe are similar to products in America because they are produced in Asia for both continents.

The uncertainties in emission factors for purchased services and products based on this spend-based method are high. For example, if suppliers increase their prices, the calculated carbon emission factor also increases while inflation does not directly affect carbon emissions.

3.3. Products & Materials

The purchased products and materials (category 1: purchased goods and services of the GHG protocol) at TNO can be for various applications, including for instance furniture for office but also lab specific products and materials. Almost all purchased products and materials are calculated using the spend-based method, where data from the TNO procurement system on euro's spent annually per specific category are multiplied by a specific carbon footprint emissions factor for the specific category or sector from the USA input-output database [2].

Currently only the sub-category datacenters and contracting external employees are based on actual consumption data and multiplied by a emissions factor from secondary sources.

The TNO capital goods category (category 2 of the GHG protocol) includes real estate, ICT materials and lab & research equipment. These categories were calculated using the spend-based method, where

data from the TNO procurement system on euro's spent annually per specific category are multiplied by a specific carbon footprint emissions factor for the specific category or sector from the USA input-output database [2].

3.4. Services

For services (category 1: purchased goods and services of the GHG protocol), including for instance cleaning, catering, security, software, all sub-categories were calculated using the spend-based method, where data from the TNO procurement system on euro's spent annually per specific category are multiplied by a specific carbon footprint emissions factor for the specific category or sector from the USA input-output database [2].

3.5. Employees

The TNO scope 3 category employees (category 1: purchased goods and services of the GHG protocol), is based on both the spend-based calculation method as well as the average-based calculation method. The category on contracting external employees are based on actual consumption data (e.g., km for commuting, working from home and emissions for recruitment company overhead) and multiplied by a emissions factor from secondary sources, mainly the carbon emission factors list [13]. The training and education services purchased for employees are based on the euro's spent annually captured in the TNO procurement system and multiplied by the specific category or sector from the USA input-output database [2].

3.6. Fuel & Energy

As mentioned in chapter 1: scope 1 and chapter 2: scope 2 emissions, the emissions related to the extraction, production and transport of fuels and energy, Well-to-Tank emissions are captured in this scope 3 category: fuel and energy. This category is category 3 in scope 3 of in the GHG Protocol Guidelines. Furthermore, for the sustainably purchased electricity and self-generated electricity, TNO uses emission factors including end-of-life emissions. These emissions are captured under scope 3 category fuel & energy. TNO takes responsibility for this part of emissions given its focus on circularity. The annual direct amount of kwh, km, litres or GJ of consumption of the fuel or energy sources are multiplied directly by the Well-to-Tank emissions factor in the Netherlands that same year using the carbon emission factors list [13].

The same uncertainties related to the annual figures as mentioned in the chapters 1 and 2 on scope 1 and 2 emissions apply here as the same amounts of consumption data is used.

3.7. Transport to & from TNO

Transport to and from TNO (category 4 of the GHG protocol) is calculated using the spend-based method, where data from the TNO procurement system on euro's spent annually for transport are multiplied by a specific carbon footprint emissions factor for the specific category from the USA input-output database [2].

The reported data focusses on the transport to and from TNO that is procured by TNO. Emissions of deliveries where suppliers are responsible for transportation are included as part of the emission of the categories of the specific procured product or service.

3.8. Employee Mobility

Employee mobility category includes both business travel (category 6 of the GHG protocol) and employee commuting (category 7 of the GHG protocol). Both categories are calculated using the average-based calculation method. For employee commuting exact annual travel data on mode and

km travelled per mode are extracted from TNO's service provider 'Reisbalans' and multiplied by the specific carbon emissions factor of the travel mode used form the carbon emission factors list [13]. This data is used since 2023 onwards, before 2023 data was based on commute and business travel declarations and estimations of the km travelled per mode (using CBS travel data).

Since the COVID-19 lockdown period, TNO employees have continued working from home on a regular basis. The carbon footprint of working from home is calculated using exact data from 'Reisbalans' which records the amount of days each employee works from home annually. This data has only been available from 2023 onwards, before 2023 working from home emissions are deemed not material and are not included in the calculations. The emissions factor for working from home is determined using the CBS NIBUD report on working from home and the associated costs for electricity, heating, water use, coffee/thee and toilet paper and using the carbon emission factors list [13] and Ecoinvent database for the respective categories.

For business travel by air, TNO collects data on air travel to a number of different regions of the world. For each region, an assumption was made of the average flight distance from the Netherlands to that region. The calculated flight distance per region is multiplied by average carbon emission factors for short-, medium-, and long-haul aircraft. These carbon emission factors are not specific to the type of aircraft actually flown and the exact distance of the flights. Because TNO employees travel with different airlines, the uncertainty by using the average carbon emission factor of the aviation sector is relatively small, provided the figures used are updated sufficiently with developments in the sector.

3.9. Generated Waste

The annual amounts of waste generated from TNO locations (offices and labs) (category 5 of the GHG protocol) are based on the average-based method. Specific kg of waste types are used to calculated the carbon emissions and multiplied by specific emission factors related the main treatment source (mostly incineration with energy recovery) of the specific waste type, extracted from the Ecoinvent database.

3.10. Leased Assets

The TNO leased assets (category 13 – downstream leased assets of the GHG protocol) is currently calculated by including only the energy use of lessees and multiplying this energy use by the CO_2-emissions factor of the average TNO facility (also applied for scope 2 electricity use), using the carbon emission factors list [13].

3.11. Investments

The TNO category investments (category 15 of GHG protocol) includes TNO investments and participations in tech transfers and spin-offs and pension fund investments. TNO tech transfers & spin-offs, and participations are calculation based on the % of shares or investments of the total amount and multiplied by a CO_2-emissions factor from the input-output database EXIOBASE [15]. EXIOBASE is a global, detailed Multi-Regional Environmentally Extended Supply-Use Table (MR-SUT) and Input-Output Table (MR-IOT). It was developed by harmonizing and detailing supply-use tables for a large number of countries, estimating emissions and resource extractions by industry.

The CO_2-emissions of the pension fund, a separate TNO entity, are calculated by the company Cardano. The overall carbon footprint for the pension fund emissions are thus determined based on the quarterly ESG reporting documentation of the pension fund[1].

[1] Documenten - PensioenFonds TNO

4. Appendix Relation TNO categories & GHG protocol categories

Scope	GHG Protocol Categories	TNO (sub-) Categories
1	1.1 Stationary Combustion	Natural Gas combustion
1	1.2 Mobile Combustion	Company vehicles
1	1.2 Mobile Combustion	Lease cars
1	1.3 Fugitive emissions	Refrigerant leakage
1	1.4 Process emissions	Lab emissions
2	2 Purchased Energy	Electricity use (location-based approach)
2	2 Purchased Energy	Electricity use (market-based approach)
2	2 Purchased Energy	District heating use
3	3.1 Purchased Goods and Services	Products & Materials | Lab & Research consumables
3	3.1 Purchased Goods and Services	Products & Materials | Real Estate Materials
3	3.1 Purchased Goods and Services	Products & Materials | Maintenance Materials
3	3.1 Purchased Goods and Services	Products & Materials | Facilities Materials
3	3.1 Purchased Goods and Services	Products & Materials | Water
3	3.1 Purchased Goods and Services	Products & Materials | ICT Materials
3	3.1 Purchased Goods and Services	Products & Materials | Marketing & Events Materials
3	3.1 Purchased Goods and Services	Services | Lab & Research Services
3	3.1 Purchased Goods and Services	Services | Consultancy Services
3	3.1 Purchased Goods and Services	Services | Maintenance Services
3	3.1 Purchased Goods and Services	Services | Facilities Services
3	3.1 Purchased Goods and Services	Services | ICT Services
3	3.1 Purchased Goods and Services	Services | Marketing & Events Services
3	3.1 Purchased Goods and Services	Employees | Hiring Temporary Employees
3	3.1 Purchased Goods and Services	Employees | Training & Education
3	3.2 Capital Goods	Products & Materials | Lab & Research equipment
3	3.2 Capital Goods	Products & Materials | Real Estate Materials
3	3.2 Capital Goods	Products & Materials | ICT Materials
3	3.3 Fuel & energy related activities	Fuel & Energy | Natural Gas
3	3.3 Fuel & energy related activities	Fuel & Energy | Electricity
3	3.3 Fuel & energy related activities	Fuel & Energy | District Heating
3	3.3 Fuel & energy related activities	Fuel & Energy | Fuel
3	3.4 Upstream Transportation & distribution	Transport to & from TNO | Customer transport
3	3.5 Waste generated in operations	Generated Waste | Waste treatment
3	3.6 Business Travel	Employee Mobility | Business travel
3	3.7 Employee commuting	Employee Mobility | Employee commuting

3	3.7 Employee commuting	Employee | Working from Home
	3.9 Downstream Transportation & distribution	Currently not estimated; not material for TNO
3	3.10 Processing of sold products	Currently not estimated; not material for TNO
3	3.11 Use of sold products	Currently not estimated; not material for TNO
3	3.12 End-of-life treatment of sold products	Currently not estimated; not material for TNO
3	3.13 Downstream Leased assets	Leased Assets | Real Estate services
3	3.13 Downstream Leased assets	Leased Assets | Energy use Lessee
3	3.14 Franchises	Not applicable to TNO
3	3.15 Investments	Investments | Participations
3	3.15 Investments	Investments | Pension Fund

5. Appendix: References

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