Paper

# Structural changes in material flows from the mid-20th century in the Netherlands

## Material use related to climate change

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# 1. Introduction

The need for natural resources and the associated environmental impacts will intensify in the future as a result of a growing population and welfare. In order to reduce resource, use the European Commission and member countries, like the Netherlands, have set up an extensive program to make a transition towards a circular economy. To monitor this transition, Eurostat and statistical agencies are working to produce key indicators such as DMC (Domestic Material Consumption) and resource productivity. These indicators can be derived from EW-MFA (Economy Wide Material Flow Accounts) in combination with economic data from the national accounts. EW-MFA consist of the import, export and extraction of different types of materials. The main material categories are biomass, fossil energy carriers, metals and non-metal minerals. EW-MFA data is collected by Eurostat under regulation 691/2011 for the year 2000 onwards

For policy makers there is a growing need for information on structural economic changes that underlie a change in resource use and, hence, a transition towards a circular economy. A time series that goes back beyond 2000 is beneficial because structural changes are not masked by incidental occurrences like changes in weather conditions or economic crises. A long time series will therefore provide insight for policymakers into future structural changes that can contribute to a transition towards a more circular economy. The contribution of a circular economy to the reduction of climate change is paramount in order to achieve EU's climate targets. Therefore several drivers, like circular economy, economic growth and the energy transition, behind changes over time in $CO_2$ emissions are investigated with an Index Decomposition Analysis.

## 1.1 Objectives

**Data collection Compilation long time series**

The first objective of this project is to collect statistical information on resource use, for at least the main material categories (biomass, fossil energy carriers, metals and non-metal minerals), waste production and treatment, and economic variables. Data is collected from the 1950s (in 5 or 10 year intervals) onwards. Historic data is derived as much as possible from international available data sources like the International Resource Panel. This will make it easier for other EU counties to replicate the methodology used here. The data on resource use will be joined with the short (2000 onwards) EW-MFA time series[1].

Due to data gaps (especially for older years) some data need to be estimated, for example on the basis of proxies or by using interpolation. The different methods and assumption that are used to fill data gaps are described in this report.

**Estimation of policy relevant indicators and decomposition analysis**

Second objective is to derive indicators on resource consumption combined with historic economic and social data like GDP and population size in order to draw conclusion on structural economic changes related to resource use. The long times series data can also provide information on the national urban mine and the potential materials that are available for recycling in the future. The urban mine consist of capital goods with a long life span, like

[1] https://ec.europa.eu/eurostat/web/environment/data/database

buildings and infrastructure. Indicators like DMC combined with information on type of material (e.g. minerals and metals), final waste treatment or lifespan can give information on the accumulation in the urban mine over time. The size of the urban mine is relevant with regard to a circular economy because it provides information on recycling potential and dependency of materials of our national stock.

For the benefit of climate and circular economy policy, we would like to quantify relationships between climate change, circular economy and material use. A transition to a circular economy should reduce environmental pressures and be a prerequisite to the achieve the EU's 2050 climate neutrality target. We apply the technique of index decomposition analysis (IDA) in order to answer questions like to what extent do material use, energy consumption and other factors affect $CO_2$ emissions? An IDA decomposes the variable under consideration into a number of 'drivers'. The data collected for the long time series is input for the IDA.

# 2. Reader's guide

This report consists of two parts. Part one looks at developments in time in the amounts of material flows, waste flows and $CO_2$ emissions from 1950 onwards. Used methodology and data sources are discussed. Results are presented and interpreted. Part two considers the IDA. Methodology, data sources and results of the IDA are presented. This report ends with overall conclusions and recommendations.

# 3. Long time series

## 3.1 Methodology long time series

This chapter describes the methodology used to collect data and compile a long times series that is consistent over time. For the latter two challenges occur 1) data from different data sources need to be linked and 2) data gaps need to be filled. In order to compile consistent times series different methods can be used depending on what is available. In this chapter we describe the step by step approach that is generally used for the different data sets. Other case-specific methodologies are described in chapter 3.

In general terms, the challenge to be overcome is that older data does not conform to the concepts and definitions employed in the new data. The approach is therefore to take the new data as given and to extend the series by taking information on the trend from older data. In this way the concepts and definitions are (artificially) held constant throughout the time series.

To demonstrate this, let us take the example where there is an overlap over one year between the new and the old data. Let us define *t-n* as the oldest year in the old series and *t* as the oldest year in the new series. The new series runs to 2020. In total then we have data over all years from *t-n* to 2020 with data from both series for the year *t.* The approach is to use the old data to calculate an index per material type. The index is equal to 100 in year *t*. Let us define the year *y* as any year between *t* and *t-n*. The index for a given material type is calculated as

$$i_y = 100\frac{x_{L,y}}{x_{L,t}}$$

where $x_{L,y}$ gives the values per year in the older lower quality series. In this manner the old lower quality time series is converted to a representation of the trend and no longer contains any information on absolute values. This trend can then be applied to the newer higher quality series to extend the newer higher quality series backwards. We use the notation $x_{H,y}$ to refer both to the original newer high quality data as the data created by the application of the index. Thus:

$$x_{H,y} = \frac{x_{H,t}\, i_y}{100}$$

The intention with this method is that the definitions and concepts applied in the new high quality series are preserved. This is achieved by only using the old lower quality data to determine the trend.

In order to operationalize this approach, several challenges need to be overcome. There are often multiple sources of data which can be used to compile a long time series and therefore the first challenge is to decide which data to employ. Our approach is to work with data at the highest level of disaggregation and to always give priority to data which is considered of the highest quality. In general terms we used the following types data sources, according to the following priority

1) The publicly accessible online data library of Statistics Netherlands known as Statline. We consider this data to be the highest quality data available and as such priority was always given to this data source.

2) Not publicly available Statistics Netherlands data. This consists of data which is has not been published because it is either raw data due to privacy concerns.

3) Data from other institutions, scientific articles or Statistics Netherlands archive publications. Data from several other institutions have been used in this study, most prominently, FAO data and the World Resource Institute (WRI). The publically available Statistics Netherlands Historical collection contains pdfs statistical bulletins and yearbooks as far back as 1800.

Data quality is judged according to the source of the data, the method with which the data is compiled and the age of the data. The most recent versions of Statistics Netherlands data which are publicly available (Statline) or Eurostat are considered to have the highest quality possible. All other data sources are evaluated on a case by case basis. The data used is thus of varying quality. It is important to note that the quality of the data is not constant and that the quality generally speaking declines further into the past.

Once the best data has been selected, the second challenge is to establish correspondence between the two datasets. In almost all cases the categorization of material types will not be the same in the two datasets. Where possible, this correspondence is restored by aggregating the older data to the same level as the new data. Differences in definitions and concepts need to be corrected for as far as possible in order to achieve the best possible correspondence. For example, units of measurement for the import of cattle can vary and this can be corrected for. Specifically, old data may record the import of cattle in heads, whereas newer data uses tons. Conversion factors need to therefore be estimated in order to convert the old data into tons.

The correspondence between old and new data is checked by plotting both series for any years for which data is available in both series. These overlapping years can be analyzed to check for similar magnitudes and trends. By establishing the degree of correspondence in this way, it can be judged whether the old data is suitable to extend the new data series.

Effort also needs to be taken in order to understand and maximize consistency within the old time series. This is particularly the case with archive publications in the form of year books. It is therefore necessary for the user to attempt to bring data points from multiple publications and to merge them into a series. There are two principle challenges in doing so:

- Definitions of categories. In historical publications, product classifications change frequently making it difficult to compile a consistent time series. In some cases it may be possible to aggregate the categories in old data to conform to the new categories. In other cases categories may be too aggregated. In this case, data from aggregated older categories is used to provide information on disaggregated newer categories.
- Definitions of trade areas. From 1971 up to and including 1981 the Netherlands was a member of the forerunner of the EU, the B.L.E.U. (Belgium and Luxemburg Economic Union). Due to open trade agreements, imports and exports to and from Belgium and Luxembourg were no longer recorded. Unfortunately in this case, no way to reliably account for this was identified meaning that the only option was to use the data excluding international trade with Belgium and Luxembourg. This assumption is thus that the trend is the same for international trade with Belgium and Luxembourg as for the rest of the world.

In some cases an overlap year between the data sets will not exist and there may be several years between the end of the old series and the beginning on the new series. In this case it is not possible to apply the above method. It is therefore necessary to take the absolute values from the old series and attempt, if possible to adjust them to the concepts and definitions in the new series. Any gaps between the new and the (preferably adjusted) old series must be filled with interpolation.

Finally it occurs that old data which corresponds reasonably well to the new data series may simple not exist. In that case, it is necessary to find proxies or make assumptions in order to populate the series. The need to do so will increase towards the earliest years of the series. It is therefore important to be more critical of the quality of the data for these years. Such proxies and assumptions are detailed in the following chapter.

## 3.2 Data collection and processing time series

### 3.2.1 Scope of time series

The starting point for creating the time series is the current version of the MFA which run from 1996 to the present. Between 1970 and 2004 multiple data sources are required to populate the series. Especially for the years 1950, 1955, 1960 and 1965 there is limited data available meaning more use is made of assumptions and historical data which may deviate substantially from the MFA in terms of concepts and definitions. The material categories used are shown in annex 1.

### 3.2.2 Data collection extraction

*Biomass*

Harvest of grains, fruits, vegetables, potatoes, fodder crops and other crops (64 categories in total) is taken from a single Statline table[2]. Data is generally available for the entire time series. This data however is missing several necessary components of biomass.

- Data on the harvest of silage corn is only available from 1964 onwards and grass, flower bulbs, flowers, seeds and seed onions are not included at all. The Statline data on land use (hectares)[3], as opposed to harvest (tonnes) was therefore used as a proxy for the production of these crops.
- Data on residuals is not included. The extraction of residuals was therefore estimated by multiplying the harvest per crop by a factor determining the extent to which residuals are produced. These factors are available from the Eurostat MFA questionnaire (Eurostat, 2018) which is used to help countries estimate residuals flows. The factors are constant over time.
- Data on wood production is not included and was therefore taken from the FAO's forestry production and trade data[4]. This data is available from 1961 and therefore internally available data on production of the wood and furniture industry was used to extend the series to 1955. Extrapolation was used to extend the series to 1950.

[2] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/71904ned/table?dl=6C1E0
[3] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/71904ned/table?dl=6C1E4
[4] https://www.fao.org/faostat/en/#data/FO

- Data on fisheries production is not included in this table and was therefore taken from a separate Statline table[5].

*Metal*

Metals are not extracted in the Netherlands.

*Non-metal minerals*

Data is available from Statline[6] concerning sand and gravel and excavated earthen materials from 1970. Data on limestone, clay and other minerals is however not available from Statline. The closest data available on minerals for agricultural and industrial applications comes from the World Resource Institute[7]. This data disaggregates mineral use into only two categories: construction dominant and industrial or agricultural dominant. In order to use this aggregated data, it was necessary to aggregate the categories of the MFA. Accordingly, an aggregated group “limestone, clay and other minerals” was created. Additionally, data on gravel was available from Lintsen *et al.* (2018) starting in 1960. This data was used as a proxy to extend the series on sand and gravel back to 1960.

Data on salt is available on Statline[8] from 1950. However, after 1992 the data cannot be published due to privacy reasons. It was deemed inappropriate to use extrapolation in this case because salt extraction doesn’t follow an obvious trend in the years up to 1993. Therefore it is assumed that salt extraction per year in the years 1993 to 1996 is equal to the extraction in 1992.

Prior to 1970, no data is available for excavated earthen materials or for the category limestone, clay and other minerals. Further, prior to 1960, no data is available for sand and gravel extraction. Therefore, in order to complete the series, it is assume that the trend in extraction for these non-metallic minerals mirrors the trend in export of these minerals.

*Fossil Fuels*

Data for coal production is available from a dedicated Statline[9] table. Data for oil and gas production is available from the energy balance table on Statline[10]. This data is available on joules only but this is assumed to correlate sufficiently well to tonnage in order to estimate trends. Both of these tables provide sufficient coverage over time with the exception of the production of natural gas in 1950. For that year, an estimate was made based on data which is only available internally.

Research showed that peat production in the Netherlands was already negligible in 1950 and only became more negligible after 1950 (Gerding, 1995). We therefore did not attempt to populate the data for turf extraction.

### 3.2.3 Data collection trade

[5] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81029ned/table?dl=6C1E5
[6] http://opendata.cbs.nl/statline/#/CBS/nl/dataset/37759/table?dl=25518
[7] https://www.resourcepanel.org/global-material-flows-database
[8] http://opendata.cbs.nl/statline/#/CBS/nl/dataset/37759/table?dl=25518
[9] http://opendata.cbs.nl/statline/#/CBS/nl/dataset/71554ned/table?ts=1630398353167
[10] http://opendata.cbs.nl/statline/#/CBS/nl/dataset/83140NED/table?dl=65E50

Trade data in the MFA includes re-exports but excludes transit trade. This is an important condition that is preferable also met for the historic data.

*Biomass*

Data on international trade of detailed agricultural products is available from the FAO[11] from 1961. This data has one principle drawback, namely that flowers and flower bulbs are not included. Due to a lack of better alternatives it was decided to use the data on production as a proxy for export and to use the import of the most closely related category (other biomass products) to use as proxy for the import of flowers and flower bulbs. This solution is certainly not ideal but it is deemed acceptable because the import of flowers and bulbs is limited.

Data for 1960 and earlier is available in the Statistics Netherlands archive[12] publications. However, because of the number of categories for biomass and the need to manually extract the data from pdf scans, it was not feasible to use this data. Therefore data were used at a highly aggregated level of food, drink and tobacco from Statline[13]. This data was used as a proxy for the years 1950, 1955 and 1960.

No data was available on the international trade in crop residuals for years prior to 1970. For exports, the trend is assumed to mirror the trend of the domestic extraction of crop residuals. For imports, the trend is assumed to mirror the import of grains and derivatives, which is appropriate because the principal crop residual is straw.

Data on wood and sea food trade were principally taken from the WRP data[14]. The WRI data for sea trade between 1965 and 1970 was not used because it was judged to be of insufficient quality. For the years for which data (of sufficient quality) was not available, the CBS year books were used. This was complicated by changing product categorization over time. This meant that some guesswork was required in order to produce a consistent time series from this data source

*Metals*

Data in gross-weight from 1950 until 1985 is taken from Statistics Netherlands archive publications. From these data developments in time were derived. These indexes in combination with MFA Statline data will be used to estimate quantities from 1950 onwards. There are several problems with the archive dataset.

- It is not possible to fully exclude transit trade because of the need to include imports and exports from bonded warehouses. However, only a small proportion of bonded warehouse trade will be transit trade in the case of metals. Therefore bonded warehouse trade is included fully.
- Changes in classifications through time, such as changes to waste categories, pyrite and weaponry exist.
- Definitions of trade areas are not consistent due to the Belgium and Luxemburg Economic Union (B.L.E.U.) between 1971 and 1981. However for 1970 it can be estimated that the amount of iron ore unloaded (including transit trade) from B.L.E.U. is smaller than 1 % but the metal products unloaded from outside B.L.E.U. is 21%. We

[11] https://www.fao.org/faostat/en/#data/FO
[12] https://historisch.cbs.nl/
[13] http://opendata.cbs.nl/statline/#/CBS/nl/dataset/84407NED/table?dl=630CD
[14] https://www.resourcepanel.org/global-material-flows-database

therefore assume that metal trade with Belgium and Luxemburg is relatively small and therefore the trade figures excluding these countries are used.

*Fossil fuels*

Coal trade data was taken from the energy balance data on Statline[15]. This was sufficient for the entire time series, except for 1950. Data for this year was taken from the Statistics Netherlands archive publications.

As is the case for the production of oil and gas, the energy balance statistics on Statline are used for the import and export. However, in this case, the energy balance can only be used from 1975. The World Resource Institute data however runs from 1970 and can therefore be used to extend the series back by 5 years to 1970. In order to populate the remaining 3 years (1950, 1955 and 1960) data was taken from CBS archive publications.

*Waste and other products*

In MFA, import and export of waste residuals is reported as a separate item. Waste residuals have no economic value and are destined for final treatment (incineration, landfilling). Because waste residuals have no economic value they are not recorded in the international trade statistics. Therefore, the amount of traded waste residuals is taken from the trade of hazardous waste registration (Waste Shipment Statistics). Notice that in the MFA all non-hazardous waste is taken into account as part of the other non-waste material MFA categories. Therefore, there is some double counting between the trade of MFA materials and the trade of waste as described in chapter 3.2.4. In this report no corrections are made in order to remove this double counting.

In the MFA there is a category called ‘other products”. This is a very divers category with mainly products that consist of more than one of the main material categories (biomass, minerals, metals or fossil). Products in this category are among others, textiles, furniture and toys. We do not have data for this category earlier than 1996. In order to estimate imports and export of other products between 1950 and 1996 the development in time is estimated of the combined categories metals, fossil and products mainly of biomass. The resulting index is used to estimate the “other products” category before 1996.

### 3.2.4 Data collection waste

Data on both international trade of waste and domestic waste production are collected. Data on waste production is collected in order to make an estimate of the urban mine. The urban mine is estimated by the domestic consumption minus waste production.

In first instance data is collected for: domestic waste production, treatment method (landfilling, incineration and recycling) and international trade. The only distinction made between type of waste is: waste from industries and waste from households. For industrial waste the amount of construction waste is determined separately. Data is estimated annually from 1985 onwards. Between 1950 and 1985 estimations are made on 5 year intervals.

Data on waste is collected from several data sources. Data gaps are filled by using different estimation methods. All of these are discussed below.

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[15] http://opendata.cbs.nl/statline/#/CBS/nl/dataset/83140NED/table?dl=65E50

*International trade of waste*

Import and export data on waste is taken from the waste accounts. Data is available biannually from 1990 onwards. Intermediate years are estimated by taking the average of the adjacent years. International trade before 1990 are estimated by using a trend line derived from the available data. On the basis of the declining amount of trade between 2018 and 1990 a decreasing trend back in time is predicted by using the Excel Forecast function. As a result import and export of waste was estimated to be zero in, respectively 1965 and 1970.

*Production and treatment of waste*

Production and treatment of waste is taken from the waste accounts. Data is available biannually from 1990 onwards. Intermediate years are estimated by taking the average of the adjacent years. Between 1985 and 1990 an index is used that is derived from data of the Environmental Data Compendium [16].

In order to make a distinction between waste produced by households and waste from industries a fixed share of the total waste production was used. From available data between 2002 and 2018 a relative constant 15% share of the total waste production was household waste. This share was also used for years prior to 2002. Construction waste is determined via an index between 2018-1995, 1990 and 1985. Around 1990 and 1985 construction waste was 30% of the total industrial waste. This percentage is used to determine the amount of construction waste for years where no data was available.

Data prior to 1985 was hard to find. Therefore these figures are very uncertain. Only figures on waste production per household were available. From these figures a time series index was derived. This index was used with the 1985 data to make an estimate of household waste between 1950 and 1985. The amount of industrial waste was estimated by assuming that household waste makes up 15% of the total waste and industrial waste makes up the rest. By making this assumption the total waste supply could also be estimated. The last step was to determine the kind of waste treatment that occurred between 1950 and 1985. Because there were no figures available on this we used ratio between the different treatment methods of 1985. We are in great doubt that this provides reliable figures. The types of differentiated waste categories are presented in annex 3.

*Balancing*

Waste supply and use needs to balanced. That is: domestic waste production plus import equals domestic waste treatment plus export. Because different data sources and estimation techniques were used an additional balancing step was needed. Supply and use are balanced by changing the import and export of waste. The trade figures are considered to be least robust.

### 3.2.5 Data collection $CO_2$ emissions

Data on $CO_2$ emissions is available from the Greenhouse Gas emission accounts from 1990 onwards for 42 sectors including households and landfills. Data between 1960 and 1990 is taken from an internal CBS research project (no publication available) that took place as part of the sustainability monitor in 2013. $CO_2$ emissions were estimated based on energy use for 8 sectors including households. Development in time are derived from these data and applied to the

[16] https://www.clo.nl/indicatoren/nl0204-afvalproductie-en-wijze-van-verwerking?ond=20876

1990 data taken from the energy accounts. Developments for each of the 8 sectors are applied to the 42 sectors that came closest. Data between 1950 and 1960 was taken from the OurWorldinData website[17]. Here only totals per country are available. Totals for the years 1950, 1955 and 1960 were estimated by taking the developments in time from the OurWorldinData set and applying them to the estimated totals of 1960. Next totals are disaggregated by sector on the bases of the emission ratio per sector of 1960.

For $CO_2$ emissions from landfills a different approach is taken. No data on landfill emissions are available between 1950 and 1990. Therefore we estimated the development of emission from 1990 backwards on the basis of the amount of landfilled waste. Because landfill emissions occur over a longer period of time we estimated the developments based on the amount of accumulated landfill since 1950. The estimated development was applied to the 1990 data. The results show a similar development of methane emission between 1980 and 1990 published on the Environmental Data Compendium[18]. This supports the feasibility our used methodology because methane and $CO_2$ are both released from decomposing biotic waste in landfills.

#### 3.2.6 Data collection monetary production, intermediate use and value added

The first step in collecting the economic data was to decide on the level of sector detail. This requires considering both data availability at all points in the time series and also the kind of analyses for which the data is intended. The result is a sector categorization which includes several levels (see annex 2). For example, repair of consumer goods is interesting from a circular economy perspective but this sector can only be compiled from 1988. For all earlier years, this sector is grouped into another services category consisting of NACE J up to and including NACE U. Another example is agriculture (NACE A) which consists of three subsectors (farming, forestry and fishing). The main category of agriculture is can be compiled from 1969 but the subsectors can only be compiled from 1998.

We compile the series from 1970. Changes to the sector classification in that year make it prohibitively difficult to extend the series further. Constant prices are used at the 2015 level.

Data is available at the highest quality at all levels from 2015[19]. The first sector which becomes unavailable are the subsectors of NACE B (mining). Mining consists of three subsectors: extraction of crude petroleum and natural gas, mining and quarrying and mining support service activities. Data at 2010 prices is however available. Accordingly, the index method described in chapter 2 is used for two of the first two subsectors. The third subsector (mining services) is calculated in such a way that the sum of the subsectors equals the value of NACE B (i.e. it is used as a balancing item). Accordingly, the values for NACE B from the high quality data are preserved. Note that priority is given to the sectors involved directly in material flows (mining rather than services).

As we progress further back in time, progressively more flexibility is required to populate the dataset. For example, the production values of the oil and gas extraction industry and the other mining sector for years prior to 1994 are indexed based on the output of their respective sectors in terms of mass. This assumption is clearly somewhat weak, but the resulting data is deemed plausible. It was however not possible to use this method to index values for intermediate consumption or value added. Obviously output in tons is a better proxy for

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[17] https://ourworldindata.org/co2/country/netherlands
[18] https://www.clo.nl/
[19] http://opendata.cbs.nl/statline/#/CBS/nl/dataset/84088NED/table?dl=751F7

production than value added. Attempts to employ the proxy in this manner failed to produce plausible values for years prior to 1980.

Proxies are used in the following sectors prior to 1998:

- Construction industry. The number of buildings of different types was used to estimate NACE 41 (general construction) and NACE 43 (specialized construction) and civil construction was used as a balancing item. In this case the proxy also produced plausible results for intermediate consumption and value added.
- Water companies. Data on drinking water production from internally available data was used as a proxy for production, intermediate consumption and value added.
- Sewage treatment and waste disposal. Data on the production and intermediate consumption of public utility companies is available in the year books. To save time, this data was extracted for every fifth year and the intervening years were interpolated.

### 3.2.7 Data collection demography

All data regarding demography was taken from Statline. No processing of this data was required.

## 3.3 Results time series

This chapter presents relevant findings that can be observed from the times series data collected. Notable trends are discussed. In chapter 4 the drivers of the trends are investigated by a decomposition analysis.

### 3.3.1 Trend analysis

*Material flows*

*<u>Domestic material inputs</u>*

DMI (Domestic Material Inputs) is determined by taking extraction of resources from the domestic environment (mining, harvesting) plus imports of resources, semi-final and final products. Figure 3.3.1.1 shows the DMI for main material categories in the Netherlands. Fossil energy carriers have the largest effect on the DMI and its developments over time. The DMI for fossil energy carriers shows a large increase mainly due to increase of consumption and refinery activities in the Netherlands. There are two dips, one in 1985 and one in 2020. The first dip goes together with a decline in economic growth. The latter dip is due to the Corona crisis and a shift towards more sustainable energy use. Also, the DMI of biomass shows a steady increase .

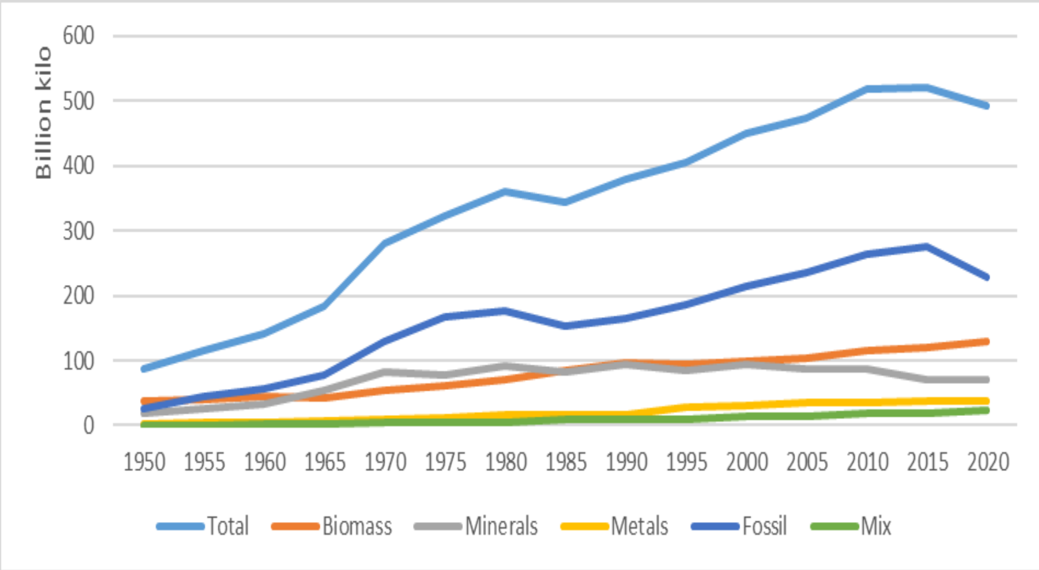


**Figure 3.3.1.1 Domestic Material Input for main material categories in the Netherlands**

In figure 3.3.1.2 a closer look at fossil energy carriers shows the developments of DMI of coal, crude oil and natural gas. Crude oil follows the developments in time close to the total DMI of fossil energy carriers. The effect of natural gas discoveries in the 1960s is clearly visible in Figure 3.3.1.2. Natural gas replaced the use of coal in the Netherlands in the 1970s. Also Dutch coal mines closed in the 1970s. The resulting decrease of coal was later reversed because of the use of coal in power plants. Between 2015 and 2020 the DMI of natural gas decreased due to reduction of Dutch extraction activities (as a result of earthquakes caused by gas extraction). The DMI of coal decreased due closure of coal fired power plants for the benefit of more sustainable energy generation. However, due to the high gas prize as a result of the war in the Ukraine the use of coal increased again in 2022.

In the 1950s the amount of extraction of fossil fuels equaled the amount of imported fossil fuels. In 2020 the amount of domestic extraction was only 9% of the total fossil DMI. Also for non-metal minerals there is a shift from domestic extraction to imports. In the 1950s domestic extraction was larger than import. In the 1970s and 1980s they were approximately equal and from the 1980s onwards imports were larger than domestic extraction of minerals. Thus, over time imports take up an ever-increasing part of the DMI, thereby increasing our resource dependency.

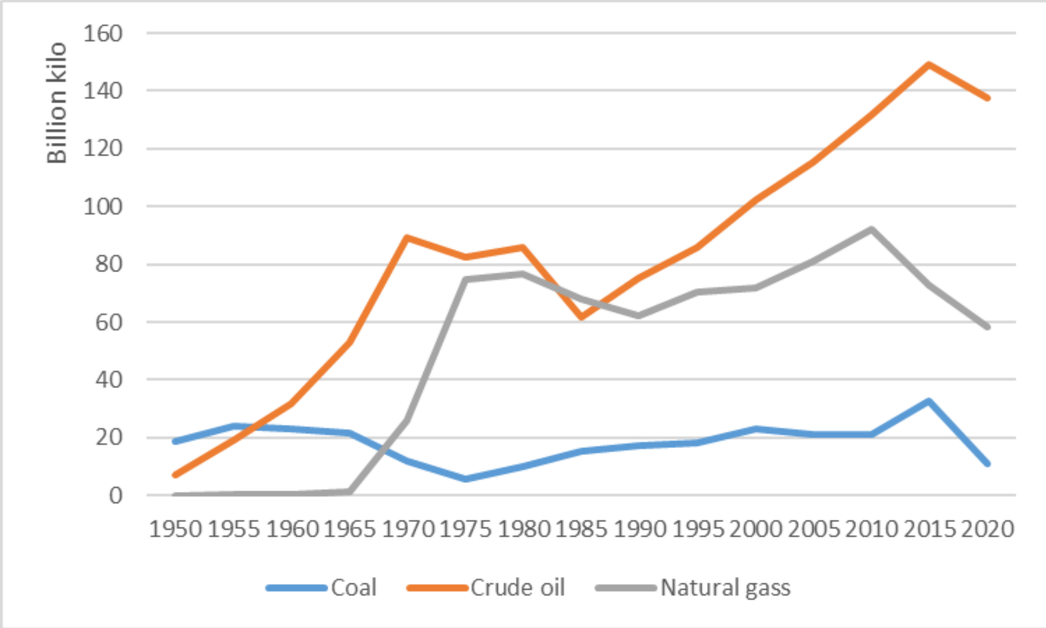


**Figure 3.3.1.2 Domestic Material Input of fossil energy carriers**

*Domestic material consumption*

DMC (Domestic Material Consumption) is determined by subtraction of exports from the DMI. DMC measures apparent consumption in the sense that all losses to environment (e.g. incineration of energy carriers, landfilled waste or excrements) are also part of the DMC. Figure 3.3.1.3 shows the DMC for the main material categories. Again fossil energy carriers determine developments in time of the total DMC to a large extent. The very low values in 1960 and 1965 cannot be explained and might be due to data uncertainties in the trade of energy carriers. The large increase after 1965 is probably due the economic growth in general and the resulting increase of the use of motor fuels and gas for domestic use. After 1980 the DMC of fossil fuels seems to stabilize until the last years in which the use of fossil fuels to generate electricity is replaced by more sustainable alternatives.

For non-metallic minerals a substantial increase is found between the 1950s until the 1970s. This is mostly due to the construction activities that were necessary after the war. From 1990 onwards a slow decline can be observed for the mineral DMC. This decline is directly linked to the decline in building activities, which may have been caused by more demanding building regulations.[20].

[20] https://www.cbs.nl/nl-nl/nieuws/2021/31/8-miljoen-woningen-in-nederland. Where the number of houses increased on average by more than 90,000 each year during the 1960s, 1970s and 1980s, this trend decreased during the 1990s. Since 2000, this number has dropped to below 60,000, with the exception of 2013. Since 2018 the building activities have increased again up to 79,250 in 2021.

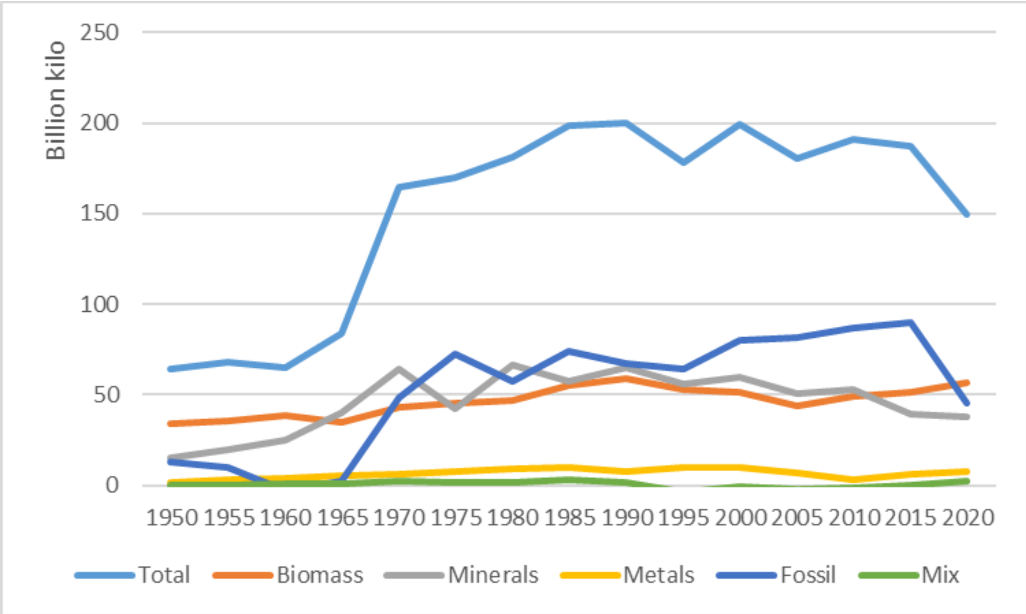


**Figure 3.3.1.3 Domestic Material Consumption for main material categories in the Netherlands**

*Waste flows*

In de 1950s most household waste consisted of ashes (from coal burning) and kitchen waste. There was hardly any waste from big appliances or packaging waste. At that time there was hardly any policy on waste treatment. Some organic waste was collected door-to-door, for animal feed or compost, and the rest was landfilled or informally incinerated. In the 1960s natural gas replaced coal (reducing the amount of ash waste), packaging materials were introduced, and more consumer appliances used, and eventually disposed of. At the start of the 1970s, when landfilled waste become problematic in some areas, waste incineration plants were build. In 1975 the first serious waste policy was developed. This cumulated in 1979 by the introduction in Dutch politics of a waste treatment hierarchy (known in Dutch as De Ladder van Lansink). The waste hierarchy, or Lansink's Ladder, distinguishes six steps of waste management to reduce and manage waste to maximize natural resources' efficient use. It ranks waste management options according to what is best for our environment.[21]

It is unfortunate that hardly any data on waste is available between 1950 and 1985 because a lot changed during that period both in waste composition as in waste treatment. In figure 3.3.2.1 we only present results from 1985.

[21] https://www.recycling.com/downloads/waste-hierarchy-lansinks-ladder/

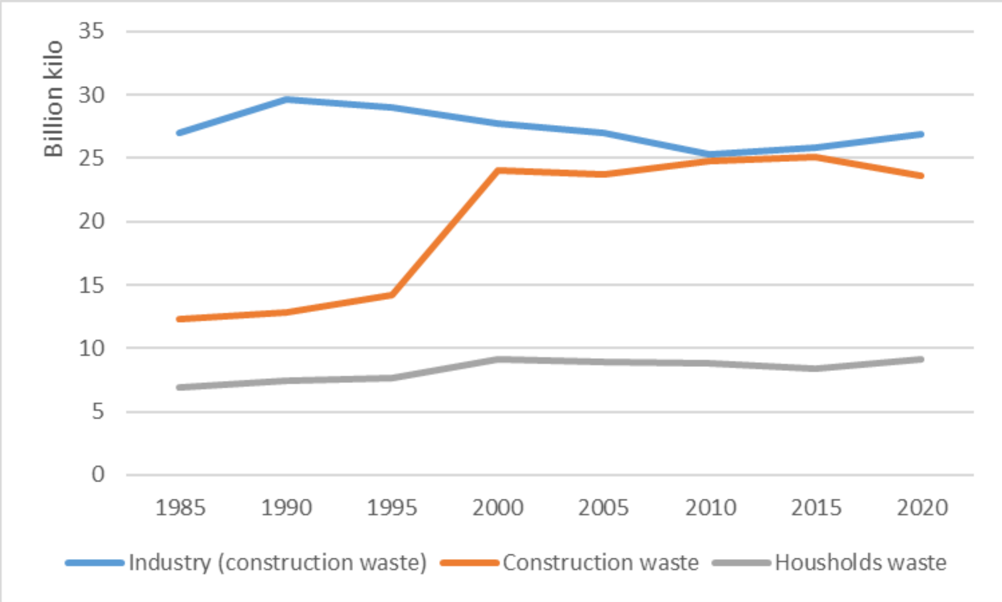


**Figure 3.3.2.1 Waste production for different types of waste in the Netherlands**

Production of construction waste shows a very large increase between 1995 and 2000. This increase determines developments over time in total waste production as households waste increase slightly and industrial waste decreases over time. Although the figures on construction waste are taken from a government website it is unclear to us what is behind this increase. We do not see a large increase in demolition activities between 1995 and 2000[22].

Most of the construction waste is being recycled from 1995 onwards. As a result the share of recycling in total waste treatment also increases. Figure 3.3.2.2 shows that the amount of recycled waste (excluding waste incineration for energy generation) stabilized around 50 billion kilo in 2000. The amount of landfill decreased significantly due to government policy. Landfilled waste was taxed and recyclables were no longer allowed to be landfilled. Waste incineration (with and without energy generation) continued to slowly grow. In fact for many years the Netherlands import waste for incineration in order to generated heat to warm houses.

[22] https://opendata.cbs.nl/#/CBS/nl/dataset/82235NED/table?dl=6C82F

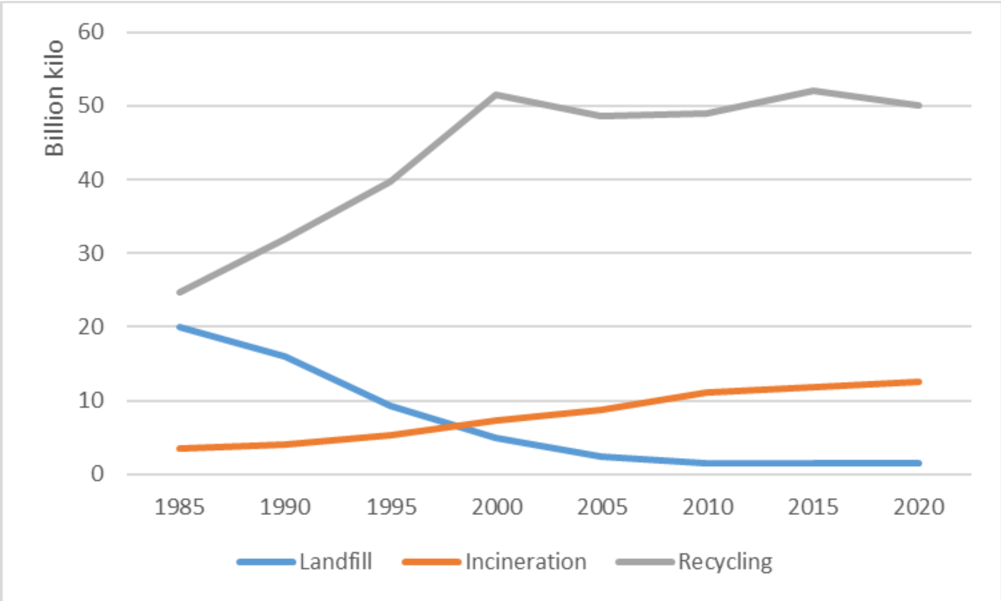


**Figure 3.3.2.2 Waste treatment by type in the Netherlands**

*Cyclical Material Use Rate*

Eurostat developed an indicator about the circularity of our economies at the macro level. This new indicator is known as the 'Circular material use rate'[23] (CMUR). The CMUR measures the share of recycled materials to overall materials use. In this report the CMUR is defined as:

$$CMUR = \frac{domestic\ recycled\ waste}{DMC\ ex\ fossil + domestic\ recycled\ waste}$$

We take DMC exclusive fossil energy carriers because most of these materials cannot be recycled as they are lost as air emissions but also because the use of secondary materials for energy generation is not included because this is not considered recycling. Unfortunately, we do not have the data available to included non-energetic use of fossil energy carriers. for example, for the production of plastics. The CMUR is also estimated by Statistics Netherlands by taking the DMI excluding re-exports. Because no information is available on re-exports in the long-time series database we decided it was better to take the DMC.

The blue line in figure 3.3.3.1 shows a CMUR with a clear increase between 1985 and 2005 after which the increase becomes less. The sharp increase of the early period is mainly due to the increase of recycling of construction waste. For the latter years the CMUR lies slightly above 30%. If construction waste is not considered the CMUR drops to around 20% in 2020. Therefore in order to derive policy relevant indicators it is important to monitor products with a high circular potential and a large socio-environmental impact. Unfortunately, detailed data on products and waste categories is not available in the long-time series database.

[23] https://ec.europa.eu/eurostat/documents/3859598/9407565/KS-FT-18-009-EN-N.pdf/b8efd42b-b1b8-41ea-aaa0-45e127ad2e3f

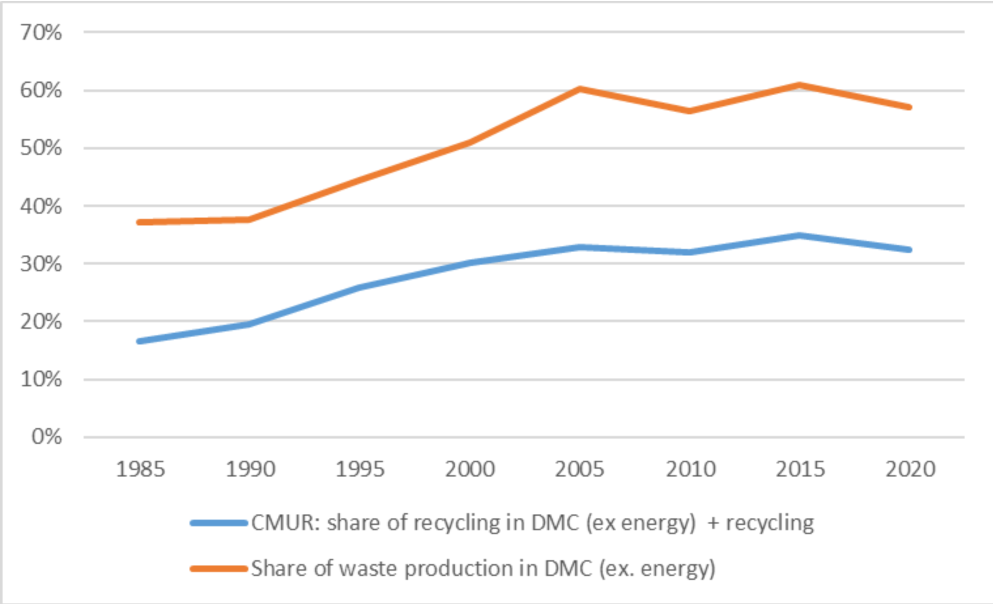


**Figure 3.3.3.1 CMUR and consumption efficiency**

In figure 3.3.3.1 the orange line shows the amount of waste produced relative to the Dutch material consumption. An increase can be observed with regard to the amount of waste produced per unit consumption (DMC). This finding does not seem to support one of the goals in a circular economy which is to reduce the amount of waste. It appears that more and more of our consumed goods ends up as waste instead of remaining functional within our economy by, for example, re-use or repair. However, more research is necessary to make sure what the drivers behind the development in time are. A disrupted factor might be that waste of durable consumer goods and buildings is produced at a much later time than the time of its consumption.

*Environmental impact ($CO_2$ emissions)*

Emission of $CO_2$ increased sharply between 1960 and 1980. From 1985 onwards $CO_2$ emissions slowly increased with a peak around 2010. After this, emissions declined sharply in 2020 due to the Covid-19 pandemic (less air and road traffic) and climate policy measures in the energy sector to meet the Dutch 2020 $CO_2$ emission target. A similar pattern can be observed when total emissions are related to the Dutch population which increased from 10 million inhabitants in 1950 to 17,5 million in 2020. Total Dutch emissions per resident almost doubled between 1950 and 2020. This doubling is mainly due to increasing emissions from mainly chemistry, energy production and transport sector. These sectors account for a little over halve of all emissions by economic activities in 2020. However, households also attribute to the increase in total emissions as emissions from households per resident rose by 25%. The share of emissions by households in total Dutch emissions decreased from 25% in 1950 to 17% in 2020.

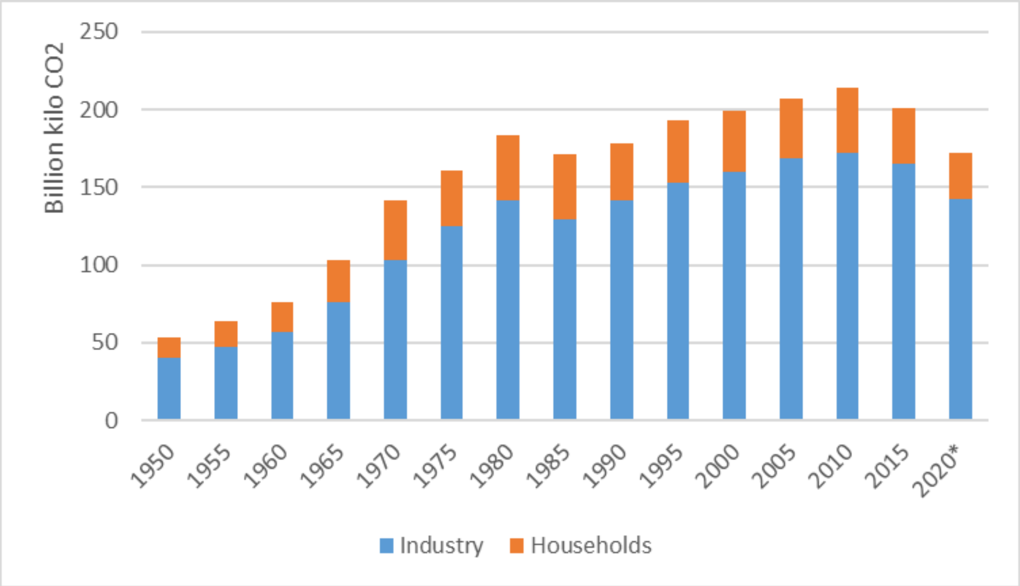


**Figure 3.3.4.1 $CO_2$ emissions by industry and households.**

Dutch $CO_2$ emissions related to material consumption show a different development over time than $CO_2$ emissions related to GDP (figure 3.3.4.2). Comparisons can only be made from 1970 onwards because data before 1970 on GDP is lacking. The slow increase of $CO_2$/DMC indicates that more $CO_2$ per kilo material consumption is emitted over time. To some extent this is due to the increased share of fossil energy carriers in the total material consumption.[24]

Relative to GDP, $CO_2$ emissions decline over time. GDP increases much faster over time than $CO_2$ emissions due to a shift towards more service (=less $CO_2$ intensive) based economy and the transition towards fossil-free energy production.

Thus our economy has become more fossil fuel intensive with regard to the type materials we use. However due to the fact that we moved to a more service type of economy, in economic terms, we became less $CO_2$ intensive. The latter is supported by the fact that GDP per unit consumption (DMC) also increases (figure 3.3.5.1).

[24] The increment between 2015 and 2020 is (partly) due to a data issue. An updated version of the MFA showed a lesser decline of the DMC than the MFA data used for the time series. Unfortunately we were nog able to update the MFA for the times series analyses. A lesser increase of the DMC would result in a lesser increase of the $CO_2$/DMC.

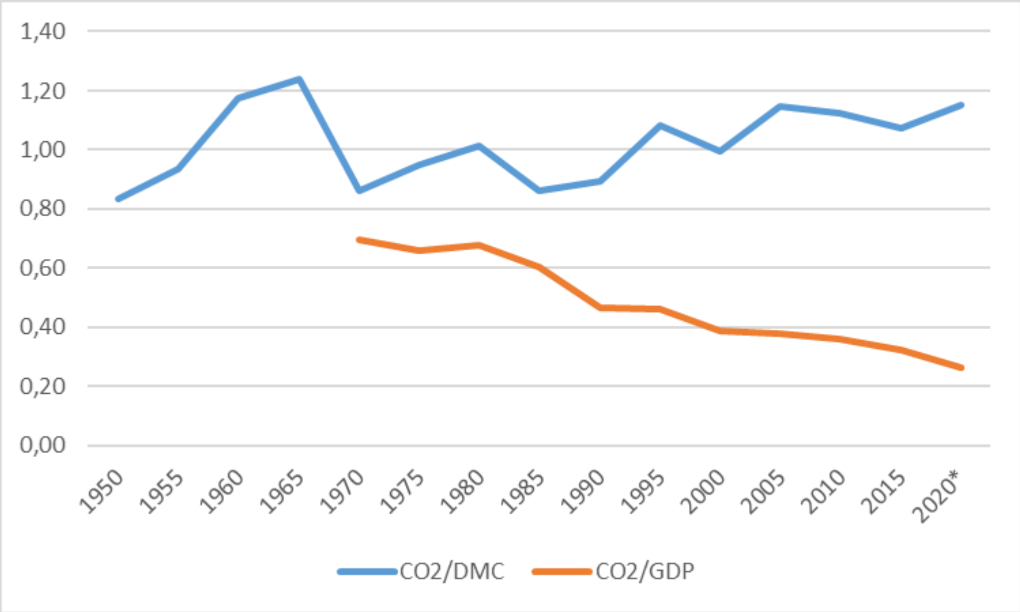


**Figure 3.3.4.2 $CO_2$ emissions with regard to domestic consumption (DMC) and GDP.**

In figure 3.3.4.2, $CO_2$/DMC is also presented for the period 1950-1970. Here a sharp increase followed by a sharp decrease between 1965 and 1970 can be observed. This finding is partly due to a change of the energy mix. As shown in figure 3.3.4.3, the period between 1965 and 1970 is the first period in which natural gas became a substantial part of household energy use as a replacement for coal. After 1990s the energy mix is relatively stable until 2020 where after it declines . This decline is partly due to the closing of coal fired power plants. Solar and wind generated energy is not included in figure 3.3.4.3.

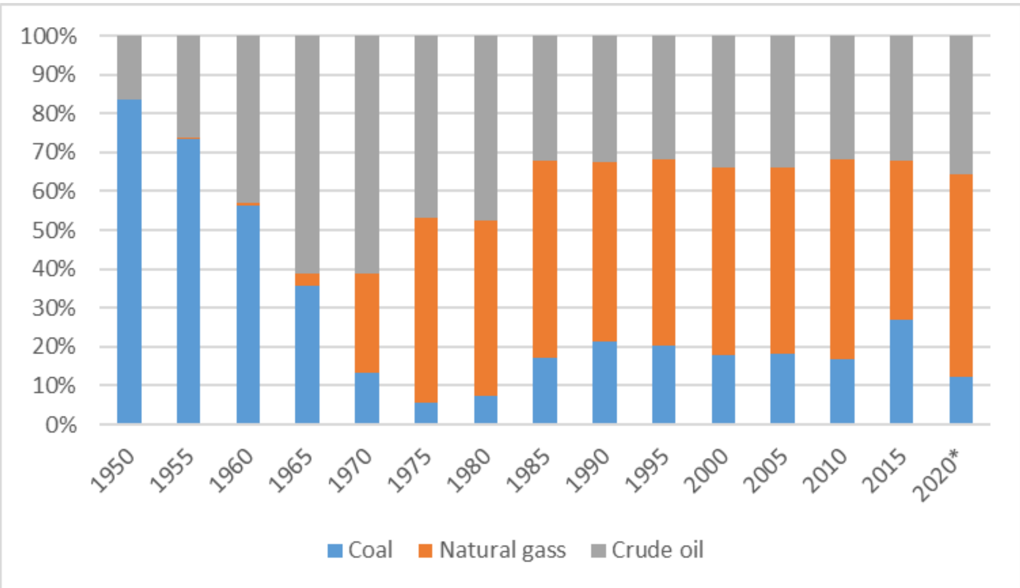


**Figure 3.3.4.3 Energy mix of total energy used.**

*Productivity*

Resource productivity is a measure of the total amount of materials directly used by an economy (measured as domestic material consumption) in relation to GDP. It provides insights into whether decoupling between the use of natural resources and economic growth is taking place. Figure 3.3.5.1 shows that from 1985 onwards there is steep increase in resource productivity. More value added can be generated by using less resources. Between 2015 and 2020 DMC decreases while value added increases. The reason behind this decoupling may be a more efficient use of resources or a shift towards less resource intensive economic activities. The decomposition analysis in chapter 4 will shed more light on this.

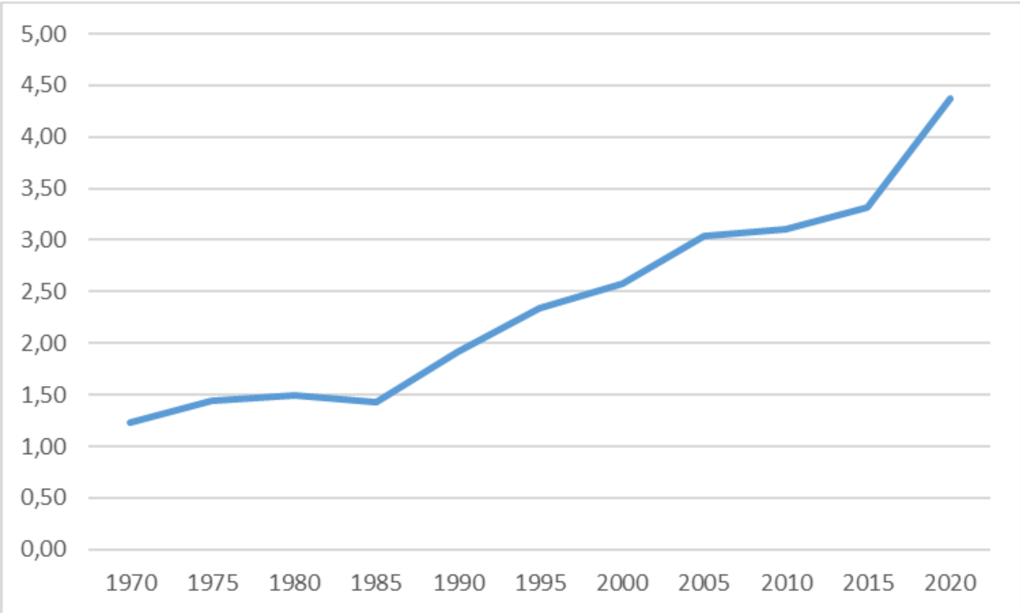


**Figure 3.3.5.1 Productivity as output (GDP) per unit consumption (DMC).**

*Urban mine*

The urban mine consists of all man made capital that is part of our economy. This capital stock can consist of buildings, durable consumption goods or even landfills. Research by CML and CBS (not yet published) estimated that the total Dutch urban mine consist of 7,8 trillion (12 zero's) kilo of materials. Some of this capital can be in use but some of it might lie dormant, for example obsolete mobile phones in a drawer. Material stock that is no longer used but is not yet recovered, is defined as hibernating stock. Materials in the urban mine are, or will be at some point, available for re-use and recycling. In a circular economy you would expect a shift from geological mines to urban mines. In Figure 3.3.6.1 a crude estimate is made of materials that are added to the Dutch urban mine. Additions to the urban are estimated by taking the material consumption (DMC) and subtracting the amount of waste that is not recycled. The latter is done to avoid losses of materials being included as additions to the urban mine.

Because we lack detailed data we have to make some crude assumptions. 1) We take the DMC excluding fossil energy carriers because most of them are burnt and, therefore, do not become part of the urban mine. However, this means that plastics are not taken into account. 2) We assume that all consumed biomass becomes part of the urban mine. 3) With regard to waste, we assume that landfilled waste is not part of the urban mine. 4) Finally we do not take trade of waste into account because we cannot determine how traded waste is treated.

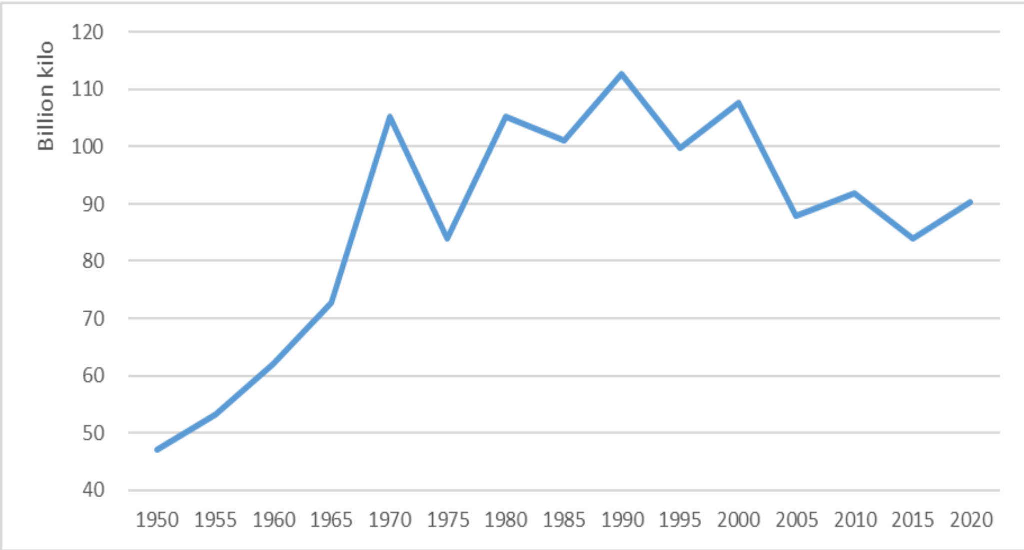


**Figure 3.3.6.1 Additions to the urban mine as consumption (DMC ex fossil) minus recycled waste.**

Figure 3.3.6.1 shows a steep increase in the additions to the urban mine between 1950 and 1970. This was a period in which post war construction took place and consumerism increased. After 1970 the addition to the urban mine remained high until 2000 after which a small decrease can be observed. It is hard to draw conclusion from figure 3.3.6.1 because the assumptions we had to make due to data constraints. However, it seem that our urban mine is still growing and that we are still a long way from a fully circular economy.

# 4. Decomposition analysis

## 4.1 Methodology IDA

Climate change, circular economy and material use are strongly linked with each other. A transition to a circular economy should reduce environmental pressures and be a prerequisite to achieve the EU's 2050 climate neutrality target.[25] For the benefit of climate and circular economy policy, we would like to quantify relationships between these variables. To what extent do material use, energy consumption and other factors affect GHG emissions? In this section we apply the technique of index decomposition analysis (IDA). An IDA decomposes the variable under consideration into a number of 'drivers'.

In an IDA you apply a multiplicative equation for a variable $Y$ with $n$ driving factors $X(i)$:

$$Y = X(1) \cdot X(2) \cdot \ldots \cdot X(n).$$

This is converted into an additive equation for the change in $Y$ decomposed into the contributions of changes in factors $X(i)$:

$$\Delta Y = \Delta X(1) + \Delta X(2) + \ldots + \Delta X(n),$$

In our decomposition analysis below, $\Delta Y$ represents the change in emissions.

In our search for a sensible and neat decomposition of the change in emissions, we applied an IDA model from Eurostat (2022). With data for EU countries, Eurostat (2022) estimated the contributions of various drivers $X(i)$ to emissions in the EU. We implemented our IDA with data for the Netherlands.

A disadvantage of the Eurostat approach is that it applies natural log to calculate growth rates, which sometimes give problems if numbers are negative or changes are very large. An IDA model from Delahaye and Couzy (2020) of Statistics Netherlands is technically neater, as it calculates an average of the contribution of a driver in a year from a system of equations comprising variants which resemble each other very closely.[26] The main disadvantage is that the number of equations increases sharply with the number of drivers in the IDA. We refer to Delahaye and Couzy (2020) for more detail on their method. We also applied this model and it was found that the results are similar for both methods. This gives a validation of the Eurostat approach. In the analysis below, the Eurostat method is applied, because it is intuitive and easily explained, and can be implemented straightforwardly in a spreadsheet.

The Eurostat method states that the contribution of a driver $X(i)$ to the change in $Y$ (here: emissions) in period $[t-1, t]$ (here: two consecutive years) is calculated as the ratio between the growth rates of $X(i)$ and $Y$, multiplied by the change in $Y$:

[25] Zie Circular economy action plan (europa.eu), en https://www.pbl.nl/publicaties/hoe-kan-circulaire-economiebeleid-bijdragen-aan-de-klimaatdoelstelling

[26] In turn, their mathematical system is derived from Dietzenbacher and Los (1998).

$$\Delta X(i)_t = \frac{\ln(X(i)_t) - \ln(X(i)_{t-1})}{\ln(Y_t) - \ln(Y_{t-1})} \cdot \Delta Y_t$$

## 4.2 Drivers of emissions

We chose to measure *Y* with $CO_2$ emissions instead of total GHG emissions. $CO_2$ is the main greenhouse gas emerging from materials and energy consumption. Methane gas (another important greenhouse gas), for example, is mainly sourced in livestock farming. In the implementation of the IDA, we adjusted and expanded the Eurostat model with alternative drivers and measurements, in order to investigate the robustness of the resulting contributions of drivers to changes in $CO_2$ emissions. Here we only present our final result.[27]
We aimed to highlight the contribution of changes in economic activity, materials use and energy consumption. This is not only about factors that lead to increased emissions, such as economic growth, primary material use and fossil fuel consumption. But it is also about changes or solutions that reduce emissions, such as a shift from a goods to services sector, recycling and renewable energy sources. These are also policy issues in economic policy, materials transition and circular economy, and climate policy and energy transition. With these factors, we may observe shifts due to technological changes and innovations, and changes in consumption behavior. Below we present our final model, where the changes in $CO_2$ emissions in the Netherlands are decomposed into the contribution by seven relevant drivers:

$$CO_2 = VA \times \frac{VA_G}{VA} \times \frac{(DMCexFossil + U)}{VA_G} \times \frac{DMCexFossil}{(DMCexFossil + U)} \times \frac{Pop}{DMCexFossil} \times \frac{E}{Pop} \times \frac{CO_2}{E}$$

where we distinguish the drivers into three issues, namely economy, materials and energy:

### 4.2.1 Economy

- $VA$ = gross value added. It is generally expected that growth of value added or economic growth leads to an upward pressure on $CO_2$ emissions. Climate and circular economy policy should aim for decoupling between emissions and economic activity.
- $VA_G/VA$ = share of the goods sector in total value added. Goods sectors are usually industries that produce, extract or use raw materials in production. These activities are generally energy intensive and produce relative more $CO_2$ emissions than the service sector. Here we measure the goods sector as the sum of value added of agriculture, mining and manufacturing (NACE A, B and C). We leave aside sectors such as energy utilities (NACE D) and the construction sector (NACE F), because production chains run from the primary and secondary sectors into these (and other) sectors. This might obscure the quantification of the impact of goods production on emissions. Over a longer run, a shift from goods sectors to a services economy lead to less (direct) emissions, because the production structure of the total economy changes towards less material and energy intensive production.

### 4.2.2 Materials

[27] Our estimation results are available on request.

- $(DMCexFossil + U)/VA_G$ = material intensity, a proxy for material efficiency. Here, domestic material consumption $DMCexFossil$ comprises primary material flows of biomass, metals and minerals. The circular economy is aimed at reduction of the use of these materials. Energy is measured in a separate driver (see below).[28] The term $U$ denotes secondary material flows of recycling from waste. In principle, secondary materials should replace primary materials. The material intensity will decrease if there is more recycling and less primary materials consumption.[29] Hence, if the intensity decreases, material flows become more circular. In the longer run, this should contribute to reduction of carbon emissions. Note that the denominator $VA_G$ refers to the value added of the goods sector, that produces most of the primary raw materials.
- $DMCexFossil/(DMCexFossil + U)$ = material flow linearity. This indicator is the share of primary material flows in total material flows (excluding fossil fuels). It is the counterpart of $U/(DMCexFossil + U)$, the material flow circularity indicator. The linearity ratio decreases if there is more recycling, replacing primary materials.
- $Pop/DMCexFossil$ = population – material consumption ratio. This is the inverse of DMC (excluding fossil fuels) per capita, a standard measure of the level of material consumption. The higher the level of $Pop/DMCexFossil$, the lower the primary resource use per capita. Over the longer run, this may indicate a transition to a circular economy, and thereby should contribute to a reduction of carbon emissions.

### 4.2.3 Energy

- $E/Pop$ = energy use per capita. We measured energy separately, in order to highlight the role of the energy transition. A higher level of fossil energy consumption leads directly to emissions. In fact, fossil energy combustion is responsible for the largest part (around 90 percent) of carbon emissions. Energy saving and a shift to renewable energy sources may prevent further emissions or even reduce them. We briefly discuss how to measure $E$ in Box 1 below. Here we chose to measure it as total final energy consumption (in TeraJoule), including energy from both fossil resources and renewables.
- $CO_2/E$ = carbon intensity of the energy mix, with $E$ measured as above.[30] The ratio decreases if the energy mix becomes 'cleaner' because of shifts from fossil fuel combustion to consumption from renewable energy sources.

Note that there are mutual and hidden effects between drivers. For example, economic growth and consumption of energy and materials are correlated. However, insight in dependencies between economic policy, climate policy and circular economy policy benefits from linking monetary and physical drivers on emissions and material consumption, here within one model.

**Box1**

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**Measuring energy $E$**

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[28] Here, we ignore the potential overlap between energy and the other materials. At the macro-level, incineration is only a small source of carbon emissions.

[29] If the volume of secondary materials would be the same as the volume of primary input it is replacing, the ratio would not change. Therefore it is assumed that, in a circular economy, less secondary materials are needed than the quantity of avoided primary input.

[30] If $E$ is measured alternatively (see Box 1 on measuring the energy indicator), the driver $CO_2/E$ will have to be renamed. E.g. with $E$ measured by only fossil fuels, it is not about the energy mix any more.

We tested the model with a number of alternative measures for the energy indicator ($E$). One may include only fossil energy sources, or also renewable sources. Further, there are various possible measures. These alternatives were tested:

- Material fossil fuel flows (kg), from our database on material flows. However, this does not comprise renewable energy sources.
- Final fossil energy consumption (TJ), excluding electricity from renewables and other non-fossil use. In this measure, renewables are also not accounted for.
- Gross inland energy consumption (TJ).[31] This measure accounts for both fossil fuels and renewable energy sources. However, as the measure is a gross quantity, it includes energy conversion as well as final consumption. This might comprise double counting in energy use leading to emissions.
- Final energy consumption (TJ), our choice. Including renewable energy consumption, but avoiding the double counting problem as in the total gross energy consumption measure.

## 4.3 Data and measurement

Table 4.3.1describes the variables, their measurement and data sources. Most of the data are derived from the long time series presented in chapter 3. Some additional data are taken from the National Accounts and the energy balance of Statistics Netherlands.

**Table 4.3.1. Variables for the IDA**

| Variabels | Measurement | Data source |
|---|---|---|
| $CO_2$ | Emissions to air by the Dutch economy (mln kg) | Emission accounts |
| $VA$ | Gross value added (Output basic prices -/- intermediate consumption) from the output, all economic activities A-U (mln euro, prices 2015) | National accounts |
| $VA_G$ | Gross value added (Output basic prices -/- intermediate consumption) from the output, sectors A agriculture, B mining and C manufacture (mln euro, prices 2015) | National accounts |
| $DMCexFossil$ | Primary material flows of biomass, metals and non-metallic minerals (mln kg). Calculated as extraction + import – export. | Material flow accounts |
| $U$ | Secondary material flows via recycling (mln kg). Recycling of materials is one of the processing methods of waste. | Waste accounts |
| $E$ | Total final energy consumption, the amount of energy used by companies, households and transport in the Netherlands. | Energy balance sheet |

[31] Eurostat (2022) applied this measure as EU country time series were more complete than the EU data for material fossil fuel flows.

A time series with consecutive annual data is only available for 1995 to 2020. For the period before 1995, there are only five-year data points for some of our variables. In a preliminary experiment for our IDA, we filled data gaps in the period 1970-1995, by linearly interpolating the data points. We do not officially publish these interpolated data, but use them for the benefit of the IDA on the period 1970-1995. In Table 4.3.2 we show which time series had 5 year intervals (and therefore are interpolated for our IDA). Time series for all other variables are complete from 1970 onwards. In this way, we can apply IDA on a long time period of 50 years.

**Table 4.3.2. Interpolation of data**

| Variable | 5 year data points | Annually from | Method to fill data gaps |
|---|---|---|---|
| $CO_2$ emissions | 1970, 1975, 1980, 1985 | 1990 | Interpolation between 5-year data points |
| Imports and exports of metals, 'other products' and waste residues | 1970, 1975, 1980, 1985, 1990 | 1995 | Interpolation between 5-year data points |
| Recycling from waste ($U$) | 1970, 1975, 1980 | 1985 | Interpolation between 5-year data points |
| Final energy consumption ($E$) | 1970-1974 missing | 1975 | The 1970-1975 development in total energy consumption is applied for backward extrapolation |

## 4.4 Results Index Decomposition Analysis

### 4.4.1 Emissions

In the IDA, the time period 1970-2020 was divided into four subperiods of 10 or 15 years: 1970-1980, 1981-1995, 1996-2010 and 2011-2020. The division was based on main changes in carbon emissions, see Figure 4.4.1.1. The 1970s were a decennium of strong growth in economy and population, and accompanied by strong increasing emissions. In the early 1980s, emissions were decreasing, only to increase again up to the mid-1990s. The period 1980-1995 was a period of deindustrialisation, restructuring of agriculture and industry, and lower economic growth. Thereafter, in the period 1996-2010, the service economy experienced high economic growth due to the input of ICT and higher female labour participation. This period shows a relatively slow increase in emissions. After 2010, emissions were decreasing partly due to the start of a transition towards climate friendly energy provision.

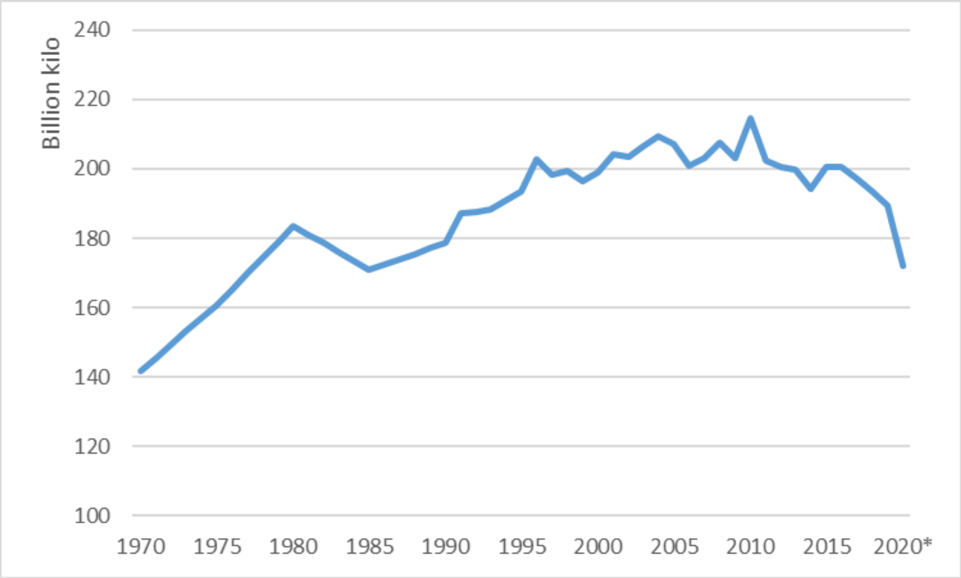


**Figure 4.4.1.1. $CO_2$ emissions in the Netherlands, 1970-2020. With interpolations between 5-year data points in the period 1970-1990. An asterix * denotes provisional data**

### 4.4.2 Drivers

Table 4.4.2.1 presents the values of all seven drivers for each time intervals we conducted a decomposition analyses in the period 1970-2020.[32] This shows some of the dynamics in the data.

**Table 4.4.2.1. Values of the seven drivers at main time points, 1970-2020**

| | | 1971 | 1981 | 1996 | 2011 | 2020 |
|---|---|---|---|---|---|---|
| $VA$ | bln eur | 212,5 | 267,7 | 417,1 | 604,5 | 656,1 |
| $\frac{VA_G}{VA}$ | share | 0,22 | 0,23 | 0,20 | 0,17 | 0,15 |
| $\frac{(DMCexFossil + U)}{VA_G}$ | kg/eur | 2,61 | 2,22 | 1,87 | 1,58 | 1,54 |
| $\frac{DMCexFossil}{(DMCexFossil + U)}$ | ratio | 0,90 | 0,85 | 0,74 | 0,68 | 0,68 |
| $\frac{Pop}{DMCexFossil}$ | capita/kg | 119,05 | 122,15 | 134,85 | 153,26 | 166,55 |
| $\frac{E}{Pop}$ | GJ/capita | 116,7 | 129,9 | 126,4 | 116,6 | 100,5 |

[32] Note that these data show the levels of the drivers, not their (annual) change.

| $\frac{CO_2}{E}$ | kg/MJ | 0,095 | 0,098 | 0,099 | 0,104 | 0,098 |
|---|---|---|---|---|---|---|

In Figure 4.4.2.1, we show the IDA result for the total period 1971-2020, and in Figures 4.4.2.2 to 4.4.2.5 we split this period into the four abovementioned subperiods. Note that one should read the years as the change between the year t-1 and the current year t. E.g. 1971 represents the change between 1970 and 1971, and so forth. The red bar on the left in the charts shows the total change in $CO_2$ emissions in the (sub)period under consideration. We can see that in all subperiods up to 2010, emissions increased, and only after 2010 did emissions decrease. To the right of the red bar, we see the contributions of the seven drivers to the changes in emissions.

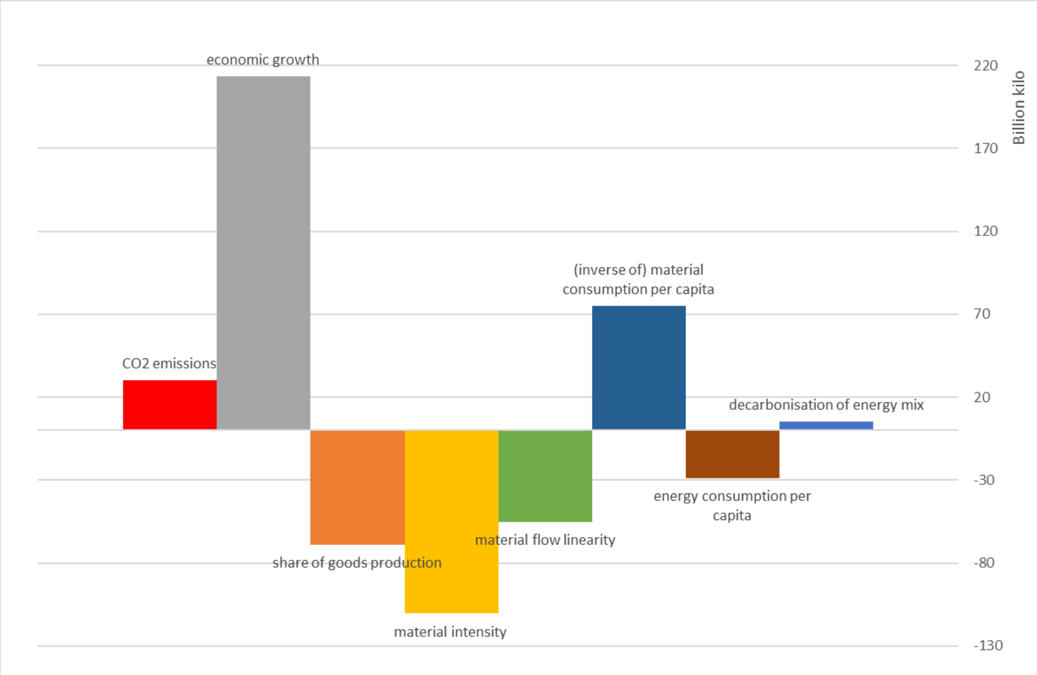


**Figure 4.4.2.1. Decomposition of change in CO2 emissions in the Netherlands, 1971-2020**

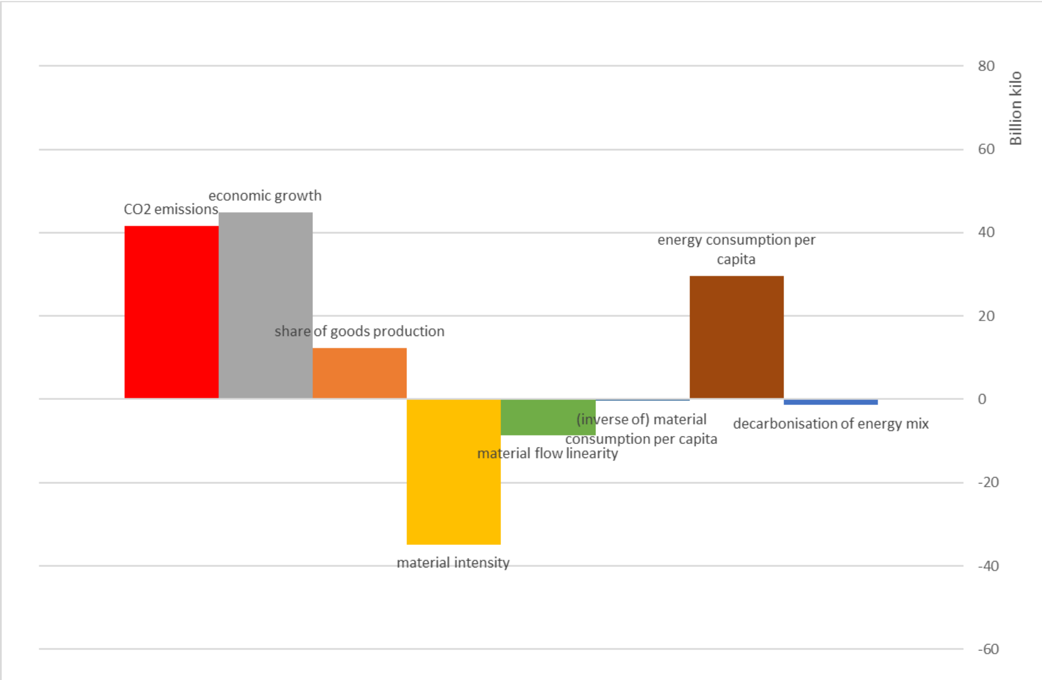


**Figure 4.4.2.2. Decomposition of change in CO2 emissions in the Netherlands, 1971-1980**

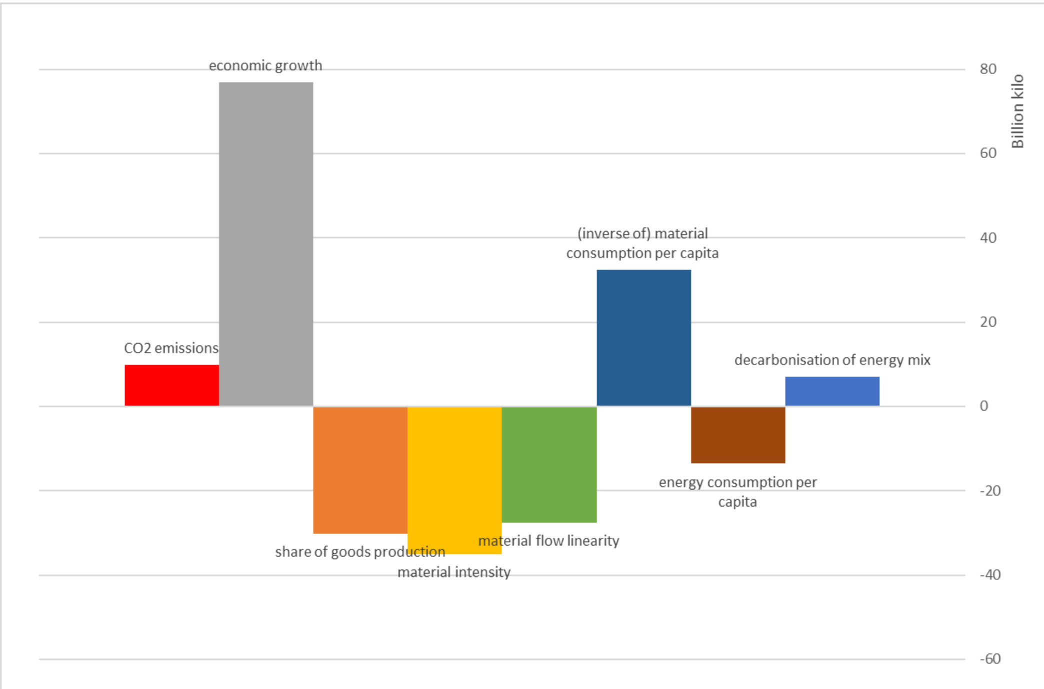


**Figure 4.4.2.3. Decomposition of change in CO2 emissions in the Netherlands, 1981-1995**

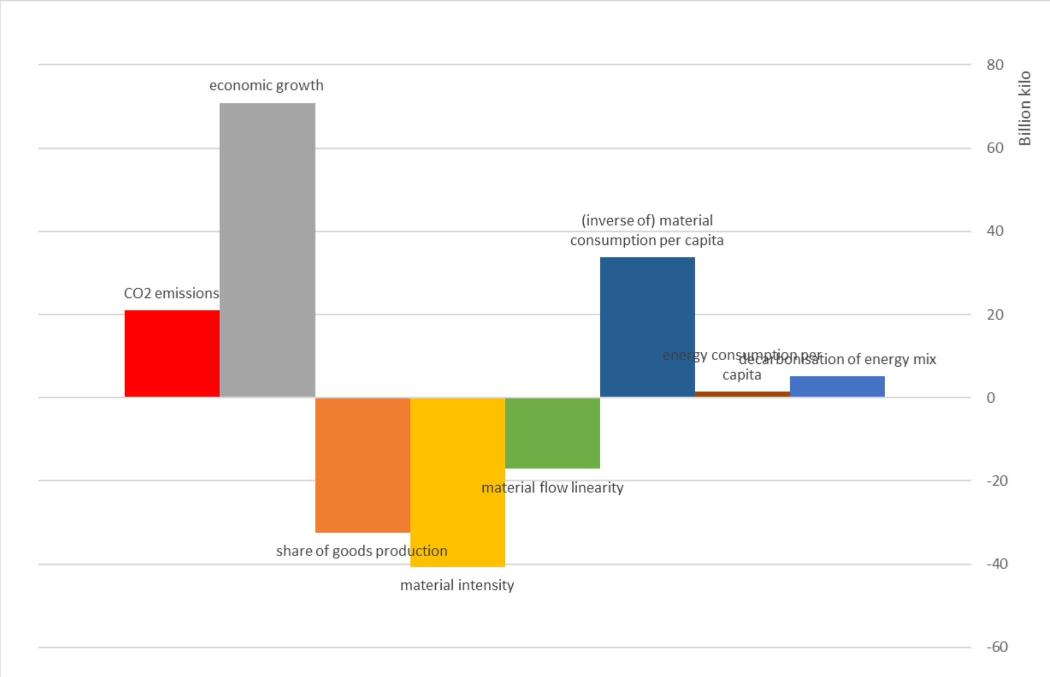


**Figure 4.4.2.4. Decomposition of change in CO2 emissions in the Netherlands, 1996-2010**

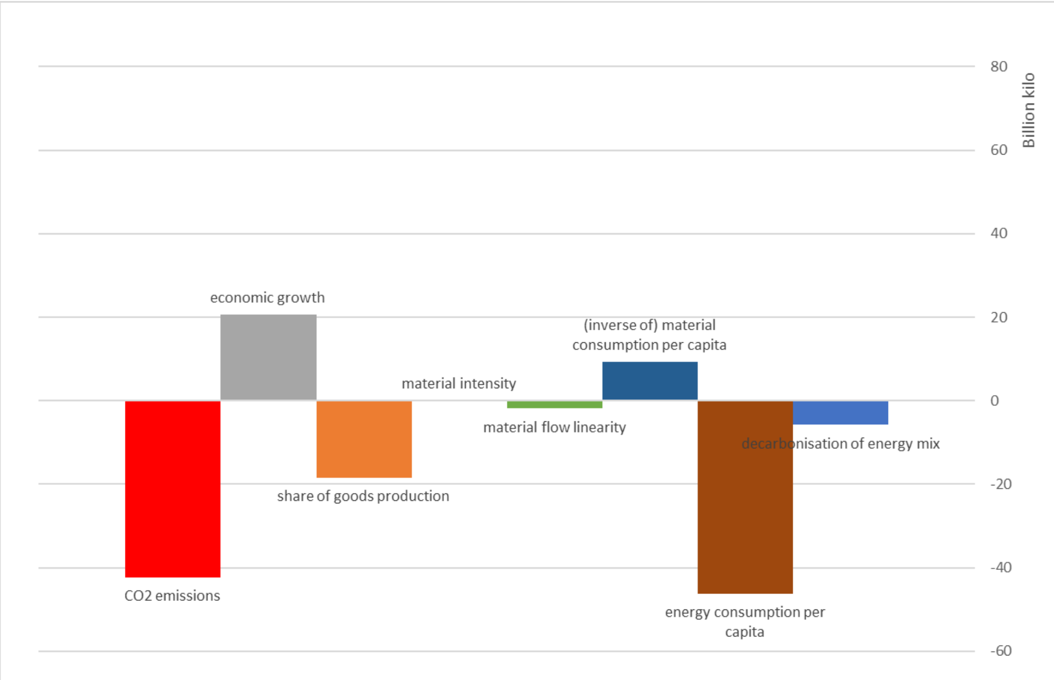


**Figure 4.4.2.5. Decomposition of change in CO2 emissions in the Netherlands, 2011-2020**

*Economy*

In the transition toward a low carbon and a circular economy, it is necessary to decouple economic activity and emissions, mainly of the goods sector. However, we observe first and foremost that economic growth is the dominant factor, with a large upward effect on $CO_2$

emissions. Only after 2010, its contribution decreased significantly, and at that time, emissions also decreased. The explanation is most likely in the decline in economic growth after the 2008 crisis. But it still has an upward effect after 2010, as there is still no absolute decoupling between economic activity and emissions. Further, the share of the goods sector (measured as NACE A, B, and C) was still high in the 1970s, contributing to an increase in emissions. However, after 1980 the shift away from 'heavy' industries to services accelerated. The contribution of the NACE A, B and C sectors to the emissions consequently declined. After 2010, the shift slowed somewhat.

*Materials*

The transition to a circular economy is enhanced by reduction of primary material use and increase of secondary materials from recycling. Up to 2010, the contribution of the (inverse of) primary materials $DMCexFossil$ per capita increased. However, this changed from 2011 onwards. The level of $DMCexFossil$ per capita increased again (i.e. the level of the inverse decreased). This causes an upward pressure on emissions, which was only compensated by the decrease in energy consumption per capita and a lower economic growth. The contributions of material efficiency or intensity $(DMCexFossil + U)/VA_G$ and circular material flows, or more precisely, the material flow linearity $DMCexFossil/(DMCexFossil + U)$ seem to have disappeared in this recent period. Before 2011, they had a 'negative' effect on emissions. That is, the lower these ratios (or the less $DMCexFossil$ or primary materials, and the more recycling replacing primary materials) lead to lower emissions. Both drivers apparently go hand in hand. Particularly material efficiency has a larger contribution in the period before 1980, and in the period 1996-2010. The contribution of the circularity driver is lower than might be expected. However, this can be explained by the limited volume of recycling compared to the volume of primary materials. If recycling increases in the nearby future, the contribution of circularity also increases. However, in the Netherlands the recycling percentage is already relative high, around 80 percent. Therefore, other CE strategies or high grade recycling might be more viable to reduce environmental impact than trying to increase the recycling percentage.

*Energy*

Energy saving (of fossil fuels) and the transition to clean energy sources is an essential part of climate and circular economy policy. Before 1980, final energy consumption per capita had an upward effect on emissions. The contribution of the driver was very small or nearly zero between 1996 and 2010, only to suddenly show a large downwards effect on emissions after 2010. The emergence of sustainable energy, cleaner technologies and energy saving measures lead to lower energy consumption per capita. In all subperiods, the contribution of the decarbonization of the energy mix remains relatively small. The indicator on energy comprises fossil resources and renewables. At first, the share of fossil energy consumption in the energy mix is very high, leading to more emissions (before 1980). Slowly, the mix changes in favor of renewables, but in the Netherlands, natural gas from Groningen remained an important source of energy. As a result, the Netherlands lagged behind in the shift to renewable energy sources until more recently (since 2010).

*Corona*

Finally, there is the issue of the impact of corona in 2020. As the economy went into a lockdown, economic activity decreased, and particularly the consumption of fossil fuels went down. To show the difference, Figure 4.4.2.6 excludes the year 2020 from the IDA in the last subperiod. Comparing this to Figure 4.4.2.5, this shows that the decrease in energy consumption per capita in 2020 is linked to a strong decrease in the carbon emissions in that year. As the decarbonisation of the energy mix also comprises fossil fuels, we see also a, though small, difference here. Without corona, the energy mix was less decarbonized. The impact of the other drivers also differs somewhat, mainly that of economic growth and material intensity (see Figures 4.4.2.5 and 4.4.2.6).

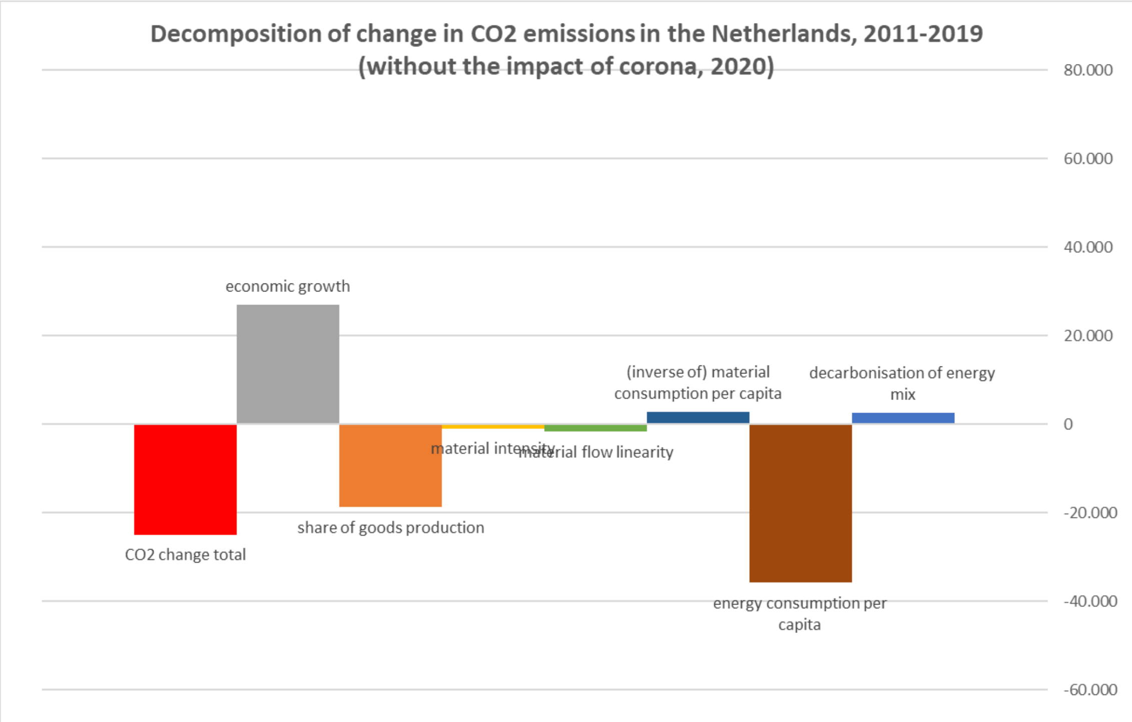


**Figure 4.4.2.6. Decomposition of change in CO2 emissions in the Netherlands, 2011-2019 (without the impact of corona, 2020)**

# 5. Conclusions

**Trends in time**

This first part of this report presents data from 1970 onwards on resource use, economy, waste and CO2 emissions for the Netherlands. From the long time series dataset we estimated policy-relevant indicators related to the circular economy. The following conclusions were drawn.

Changes in domestic material inputs (DMI) over time are determined by fossil fuels. The use of different kinds of fossil fuels depends both on autonomous events (e.g. exploitation of new gas discoveries, world crises and earthquakes in Groningen as a result of gas extraction) and policy (e.g. more sustainable energy use). In time, imports became a larger part of DMI at the expense of domestic extraction. In this respect, the dependency of the Netherlands on other countries increased.

Hardly any data is available regarding waste production and treatment before 1985. This is a pity because between 1950 and 1985 the types of waste and kind of waste treatment changed a lot during. Construction waste and the treatment thereof determines to a large extent macro indicators on waste. The policy to recycle more construction waste causes a large relative increase in the use of secondary materials with respect to the use of primary materials (Cyclical Material Use Rate - CMUR). More detail in the data is necessary in order to derive indicators that are more related to socio-environmental impacts related to the use of secondary resources.

Industry emissions account for an increasing share in total Dutch emissions despite the fact that household emissions per capita also increase. Dutch industry remains CO2-intensive due to the increasing share of energy carriers in the total materials used. However, a shift towards the service sector has resulted in the generation of more value added per unit CO2. A similar result relates to productivity increase: in time more value added is generated by using less resources.

After a steep increase in the additions to the urban mine between 1950 and 1970, additions to the urban mine remained high until 2000 after which a small decrease can be observed. It appears that we are still a long way from a fully circular economy. However, it is hard to draw a strong conclusion because of the assumptions we had to make due to data constraints.

**Decomposition analysis**

Data collected and presented in the part of this report was used as input for an index decomposition analyses (IDA) on the development of CO2 emissions over time. The following conclusions can be drawn.

The level of economic production and energy consumption have large effects on the amount of CO2 emissions. Economic growth was a dominant driver, and less economic growth also helped to decrease emissions after 2010. The lower level of energy consumption per capita also contributes significantly to the decrease of emissions after 2010. More ‘innovative’ changes such as recycling, circularity and a shift to renewable energy sources have up to now contributed less to reduction in emissions.

We emphasize that our results have to be interpreted carefully. Nonetheless, the results shows the potential of long time series data for an integrated analysis of climate change, circular economy, energy transition and sustainable production and consumption. We would suggest the following lines for future research:

- Testing the robustness of the model presented. For instance, an extended analysis that shows how the model was built by stepwise addition of drivers, starting from e.g. economic drivers (value added), then adding energy drivers which have a direct relationship with emissions, and finally adding materials as indicator for the circularity of the economy.
- Alternative models. For example, implement a separate IDA for material consumption, and compare this to an IDA of $CO_2$ emissions.
- Alternative data or measurements, and/or filling the data gaps with real data. For example, we might add the construction sector and utilities to the 'goods sector'. Also we can look into considering alternative time periods or subperiods.

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# Annex

## Annex 1, Material categories

| Material categories | | |
|---|---|---|
| MF.1 | **Biomass (total)** | |
| MF.1.1 | | Crops (excluding fodder crops) |
| MF.1.1.1 | | Cereals |
| MF.1.1.2 | | Roots, tubers etc. |
| MF.1.1.3 | | Sugar crops |
| MF.1.1.4 | | Pulses |
| MF.1.1.5 | | Nuts |
| MF.1.1.6 | | Oil-bearing crops |
| MF.1.1.7 | | Vegetables |
| MF.1.1.8 | | Fruits |
| MF.1.1.9 | | Fibre crops |
| MF.1.1.A | | Other crops (excluding fodder crops) n.e.c. |
| MF.1.2 | | Crop residues (used) and fodder crops |
| MF.1.2.1 | | Crop residues (used) |
| MF.1.2.2 | | Fodder crops and grazed biomass |
| MF.1.3 | | Wood |
| MF.1.4 | | Wild fish catch, aquatic plants and animals, hunting and gathering |
| MF.1.5 | | Live animals and animal products (excluding wild fish, aquatic plants and animals, hunted and gathered animals) |
| MF.1.5.1 | | Live animals (excluding wild fish, aquatic plants and animals, hunted and gathered animals |
| MF.1.5.2 | | Meat and meat preparations |
| MF.1.5.3 | | Dairy products, bird eggs, and honey |

| | | |
|---|---|---|
| MF.1.5.4 | | Other products from animals (animal fibres, skins, furs, leather etc.) |
| MF.1.6 | | Products mainly from biomass |
| MF.2 | **Metal ores (gross ores)** | |
| MF.2.1 | | Iron |
| MF.2.2 | | Non-ferrous metal |
| MF.2.3 | | Products mainly from metals |
| MF.3 | **Non-metallic minerals** | |
| MF.3.A | | Predominantly for construction |
| MF.3.B | | Predominantly for industry/agriculture |
| MF.4 | **Fossil energy materials/carriers** | |
| MF.4.1 | | Coal and other solid energy materials/carriers |
| MF.4.1.2 | | Hard coal |
| MF.4.1.4 | | Peat |
| MF.4.2 | | Liquid and gaseous energy materials/carriers |
| MF.4.2.1 | | Crude oi, condensate and natural gas liquids (NGL) |
| MF.4.2.2 | | Natural gas |
| MF.4.3 | | Products mainly from fossil energy products |
| MF.5 | **Other products** | |
| MF.6 | **Waste for final treatment and disposal** | |

## Annex 2, classification of economic sectors

| Classification of economic sectors | |
|---|---|
| Total Netherlands' economy | |
| Total private households | |
| Private transportation private households | |
| Other private households | |
| A-U All economic activities | |
| | A Agriculture, forestry and fishing |
| B-E Industry (no construction), energy | |
| | B Mining and quarrying |
| | C Manufacturing |
| | 10-12 Manufacture of food and beverages |
| | 13-15 Man. of textile-, leather products |
| | 16-18 Man. wood and paper prod., printing |
| | 16 Manufacture of wood products |
| | 17 Manufacture of paper |
| | 18 Printing and reproduction |
| | 19 Manufacture of coke and petroleum |
| | 20-21 Chemistry and pharmaceuticals |
| | 20 Manufacture of chemicals |
| | 21 Manufacture of pharmaceuticals |
| | 22-23 Man. plastics and construction prod |
| | 22 Manufacture rubber, plastic products |
| | 23 Manufacture of building materials |
| | 24-25 Man. of basic metals and -products |
| | 24 Manufacture of basic metals |
| | 25 Manufacture of metal products |
| | 26-27 Electrical and electron. Industry |
| | 26 Manufacture of electronic products |
| | 27 Manufacture of electric equipment |
| | 28 Manufacture of machinery n.e.c. |
| | 29-30 Transport equipment |
| | 31-33 Other manufacturing and repair |
| | D Energy supply |

| | |
|---|---|
| | E Water supply and waste management |
| | F Construction |
| G-I Trade, transport, hotels, catering | |
| | G Wholesale and retail trade |
| | H Transportation and storage |
| | 49 Land transport |
| | 50 Water transport |
| | 51 Air transport |
| | 52 Warehousing, services for transport |
| | 53 Postal and courier activities |
| | I Accommodation and food serving |
| | J Information and communication |
| | K Financial institutions |
| | L Renting, buying, selling real estate |
| M-N Business services | |
| | M Other specialised business services |
| | N Renting and other business support |
| O-Q Government and care | |
| | O Public administration and services |
| | P Education |
| | Q Health and social work activities |
| R-U Culture, recreation, other services | |
| | R Culture, sports and recreation |

| | |
|---|---|
| | S Other service activities |
| | T Activities of households |
| | U Extraterritorial organisations |
| | Landfill sites |

## Annex 3, waste categories

| **Waste categories** | |
|---|---|
| Waste production | Total |
| | Manufacturing |
| | Of which construction and demolition |
| | Households |
| Waste processing | Total |
| | Landfill |
| | Incineration |
| | Recycling |
| Trade | Import |
| | Export |

## Explanation of symbols

| | |
|---|---|
| Empty cell | Figure not applicable |
| . | Figure is unknown, insufficiently reliable or confidential |
| * | Provisional figure |
| ** | Revised provisional figure |
| – | (between two numbers) inclusive |
| 0 (0.0) | Less than half of unit concerned |
| 2022–2023 | 2022 to 2023 inclusive |
| 2022/2023 | Average for 2022 up to and including 2023 |
| 2022/'23 | Crop year, financial year, school year, etc., beginning in 2022 and ending in 2023 |
| 2020/'21–2022/'23 | Crop year, etc., 2020/'21 to 2022/'23 inclusive |

Because of rounding, some totals may not correspond to the sum of the separate cells.
Revised figures are not marked as such.

## Colophon

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