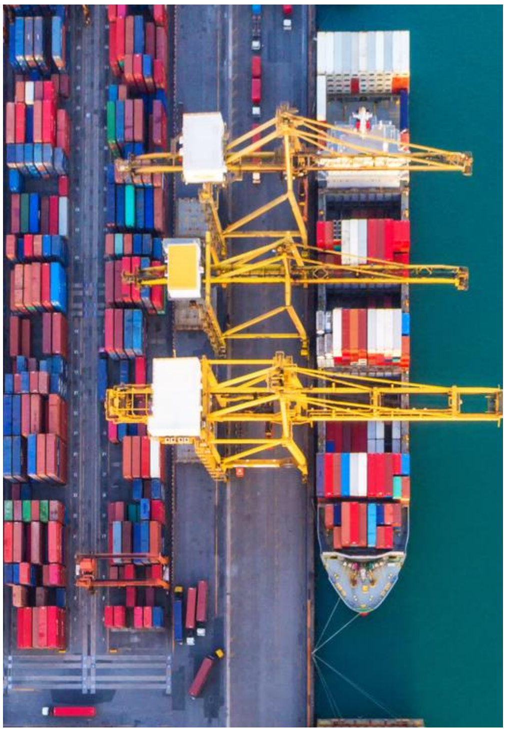
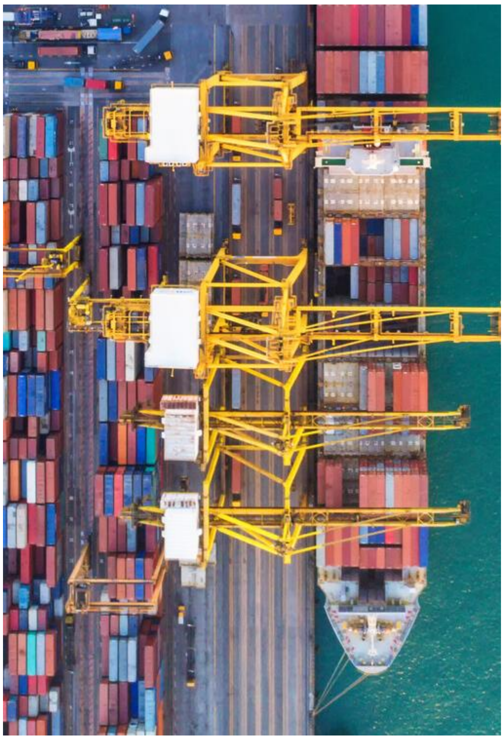


Calculating Germany's Raw Material Foot-print – Method and Results



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Abstract

We calculated central indicators for raw material use, such as Raw Material Input (RMI) and Raw Material Consumption (RMC), as well as the trade flows calculated in raw material equivalents (IMP_{RME} and EXP_{RME}) for the Resources Report of the German Environment Agency (Lutter et al. 2022). The calculation of these indicators cannot fully rely on empirical data as the international supply chains are too complex and the product diversity too high. Therefore, a model-based approach was be used. So far, Destatis calculated these indicators using a model described by Kaumanns (2014, published 2016) and Maier (2018). The calculations partly follow a different methodology than the one commonly used in other countries which means that international comparisons are possible to a limited extent only. Methodological developments take place sporadically. The publication of data is irregular, the delay in reporting is usually (at least) three years.

In order to be able to use the most up-to-date and high-quality data possible in the Resources Report, we extended the comprehensive Eurostat EU-RME (Schoer et al. 2022) Model to include German data. This makes it possible to determine raw material indicators (RMI, RMC and derived indicators such as total raw material productivity) for Germany with a methodology that is consistent with the methodology used at Eurostat. The indicators are determined for a time series covering the years 2008 - 2019. In this paper, we describe the method used and present the results for the English speaking public. The full description will be published in the report of the DeuRess Project (Dittrich et al., 2023).

In Germany, the lead indicator for monitoring the use of raw materials is total raw material productivity (BMUV, 2020; German Government, 2021). Furthermore, as part of the German sustainability strategy, the indicator "Global environmental appropriation by private households: Raw material use" is reported (German Government, 2021). The RMC per capita, which in addition to private households also includes investments, government consumption and consumption by non-governmental organisations, is particularly useful for global comparisons; however, it is not yet an official indicator in Germany.

Total raw material productivity increased by 18% between 2010 and 2019 (an average of 1.9% per year), exceeding the German government's target of achieving an increase of 1.6% per year. The RMC per capita is 15.98 tonnes in 2019 and has remained constant despite slight fluctuations of +/- 1 tonne over the past ten years. Private households are responsible for 45.2 % of the RMC. In 2019, the RMC of private households is thus 7.22 tonnes per person. Over time, there is a slight decrease of half a tonne with slight fluctuations of +/- 1 tonne.

Zusammenfassung

Für den Ressourcenbericht des Umweltbundesamtes (Lutter et al. 2022) haben wir zentrale Indikatoren für den Rohstoffeinsatz wie den Rohstoffeinsatz (RMI) und den Rohstoffverbrauch (RMC) sowie die Handelsströme in Rohstoffäquivalenten (IMP_{RME} und EXP_{RME}) berechnet. Die Berechnung dieser Indikatoren kann sich nicht vollständig auf empirische Daten stützen, da die internationalen Lieferketten zu komplex und die Produktdiversität zu hoch sind. Daher wurde ein modellbasierter Ansatz gewählt. Bisher hat Destatis diese Indikatoren anhand eines von Kaumanns (2014, veröffentlicht 2016) und Maier (2018) beschriebenen Modells berechnet. Die Berechnungen folgen teilweise einer anderen Methodik als die in anderen Ländern übliche, so dass internationale Vergleiche nur eingeschränkt möglich sind. Methodische Weiterentwicklungen finden nur sporadisch statt. Die Veröffentlichung der Daten erfolgt unregelmäßig, die Verzögerung der Berichterstattung beträgt in der Regel (mindestens) drei Jahre.

Um möglichst aktuelle und qualitativ hochwertige Daten für den Rohstoffbericht nutzen zu können, haben wir das umfassende Eurostat-Modell EU-RME (Schoer et al. 2022) um deutsche Daten erweitert. Damit ist es möglich, Rohstoffindikatoren (RMI, RMC und abgeleitete Indikatoren wie z.B. die Gesamtrohstoffproduktivität) für Deutschland mit einer Methodik zu ermitteln, die mit der Eurostat-Methode konsistent ist. Die Indikatoren werden für eine Zeitreihe ermittelt, die die Jahre 2008 - 2019 umfasst. In diesem Papier beschreiben wir die verwendete Methodik, die für ein englischsprachiges Publikum interessant ist, und stellen die Ergebnisse vor. Die ausführliche Darstellung, einschließlich Kalibrierung, ist unter Dittrich et al. (2023) im Schlussbericht des Projekts DeuRess II beschrieben.

In Deutschland ist der Leitindikator für das Monitoring des Rohstoffeinsatzes die Gesamtrohstoffproduktivität (BMUV, 2020; Bundesregierung, 2021). Darüber hinaus wird im Rahmen der deutschen Nachhaltigkeitsstrategie der Indikator "Globale Umweltinanspruchnahme durch private Haushalte: Rohstoffverbrauch" ausgewiesen (Bundesregierung, 2021). Der Pro-Kopf-Rohstoffkonsum, der neben den privaten Haushalten auch die Investitionen, den staatlichen Konsum und den Konsum von privaten Organisationen einbezieht, ist für globale Vergleiche besonders geeignet, ist aber in Deutschland noch kein offizieller Indikator.

Die Gesamtrohstoffproduktivität ist zwischen 2010 und 2019 um 18 % (durchschnittlich 1,9 % pro Jahr) gestiegen und hat damit das Ziel der Bundesregierung von 1,6 % pro Jahr übertroffen. Der RMC pro Kopf liegt im Jahr 2019 bei 15,98 Tonnen und ist trotz leichter Schwankungen von +/- 1 Tonne in den letzten zehn Jahren konstant geblieben. Die privaten Haushalte sind für 45,2 % der RMC verantwortlich. Im Jahr 2019 liegt die RMC der privaten Haushalte somit bei 7,22 Tonnen pro Person. Im Zeitverlauf ist ein leichter Rückgang um eine halbe Tonne zu verzeichnen, mit leichten Schwankungen von +/- 1 Tonne.

1 Introduction

The RME model for Germany is an environmental-economic raw material model based on an input-output approach. The aim of the model is to determine central indicators of raw material use in Germany. The raw material indicators are determined in raw material equivalents, i.e., all raw materials used along the entire supply chain of traded goods are considered. Thus, imports and exports are calculated comparably to domestically produced goods. The methodology of the model is harmonised with the Eurostat EU-RME model (Schoer et al. 2022) for the determination of raw material indicators at the EU level and the RME country tool (Schoer et al. 2023) which Eurostat provides to the countries.

Methodologically, the model follows the logic of input-output analysis (Miller / Blair 2009). This was developed by Wassily Leontief in the 1930s and used to observe the economic development of countries. Data on the flow of goods between and within economic sectors are used to draw up so-called input-output tables (IOTs). These describe which inputs are used on average for the production of goods of an economic sector and how high the final demand, i.e. consumption, investment and exports of these goods are. With the help of the Leontief method, coefficients can then be determined by matrix calculation that describe which intermediate inputs are needed to produce one unit of a good. Input-output tables can be extended to include environmental data (e.g. greenhouse gas emissions, raw material use) with the help of so-called satellite accounts.

In the RME model for Germany, the raw material input is calculated with such a satellite account. Direct and indirect raw material imports and the domestic extraction of raw materials are thereby allocated to the goods of the last use according to the IOT.

In many cases, input-output models are based on a monetary IOT. Here, however, a hybrid IOT is used, i.e. for raw material-intensive production activities (e.g. raw material extraction, first processing of raw materials) physical units are used, which better represent the raw material flows, while the remaining groups of goods are represented in monetary units.

The model is a national model, i.e. the IOT depicts the German economy including its imports and exports. In addition to national models, there are also multi-regional models that map the linkages between different economies (e.g. WIOD[1], Exiobase[2], EORA[3]). These have the advantage that the production technology can be derived directly from the IOTs of the countries of origin and imports can be traced back to the producing country via average chains. However, the data requirements are very high. If only insufficient or incorrect data are available for one country, as it is often the case, the errors and uncertainties are transferred to the calculations of all countries.

[1] URL: http://wiod.org/home
[2] URL: https://www.exiobase.eu/
[3] URL: https://worldmrio.com/

2 Method

2.1 Overview

The core of the RME model for Germany is a high-resolution input-output table (IOT) with 182 product groups, which represents the interlinkages within the economy. The subdivision of the product groups is optimized to depict raw material flows. This means that raw material-intensive product groups, such as agricultural products, ores or metal products, are disaggregated further than e.g. services. In comparison, the IOTs published by Destatis and Eurostat have a breakdown of 72 and 64 goods groups respectively.

As already mentioned, the method is closely based on the method of the Eurostat EU RME model (Schoer et al. 2022) and the Eurostat RME country tool (Schoer et al. 2023). The EU RME model was created by Karl Schoer and ifeu as part of a Eurostat project and is updated annually. The method is regularly developed further. In the EU-RME model, raw material coefficients of imports are estimated using the adapted 'Domestic Technology Assumption' (A-DTA). This means that it is assumed that, in general, imports are produced with the same technology as domestically. However, with regard to raw material-relevant production activities, such as electricity and metal production, country-specific information on production technology is used. The RME country tool is a simplified calculation tool that Eurostat provides to countries. Imports and exports in RME are derived on the basis of EU RME coefficients which are a result of the EU RME model.

For the calculation of imports in RME, the RME model for Germany directly uses the RME coefficients of the EU RME model analogously to the RME country tool. German exports in RME are calculated using the detailed, hybrid IOT analogously to the EU RME model.

The use of the EU RME coefficients for imports has the advantage that all information of the EU RME model on the production technology within the EU and the additional information from other countries on electricity mixes etc. is included. Thus, the data coverage of the EU-RME coefficients is higher compared to a direct calculation based on a German IOT. For the calculation of the raw material content of goods produced in Germany, including export goods, on the other hand, the German IOT is used so that German production technology can be mapped specifically and in detail.

2.2 Disaggregation of the monetary IOT

As a basis for the disaggregation, we use Destatis IOTs[1] with 72 sectors excluding further processing production, which are made available by Destatis on request. Since the publication of the IOT for 2019 is not planned by Destatis until 2023, the IOT for 2019 was estimated with an iterative procedure using key figures from national accounts and the IOT for 2018.

With the help of additional information, the IOTs are further disaggregated. The basis for this disaggregation is Destatis' very detailed internal product matrix (approx. 2,600 product groups), which is made available on request. This product matrix is compiled annually by Destatis. For reasons of time and effort, the current RME model for Germany is limited to the use of the product matrix for the year 2010. The basic IOT with 182 product groups derived from it for the year 2010 is updated by using numerous data sources listed below:

- imports from the EU by 182 product groups;
- imports from countries outside the EU by 182 product groups;
- exports to the EU by 182 product groups;
- exports to non-EU countries by 182 goods groups;
- production values/output of the domestic economy by 182 goods groups.

Those estimates are adjusted to fit the annually published Destatis IOTs for Germany by 72 product groups. The accuracy of the model could be improved in the future by including more recent versions of the detailed product matrix.

2.2.1 Time series of monetary imports and exports by 182 product groups

For the calculation of imports and exports, data from the Comext database on foreign trade in goods[2] are used (foreign trade in services is not covered by Comext). The data are reported in the Combined Nomenclature (CN), an EU-wide uniform classification of goods for foreign trade, which currently comprises 13,540 different tariff codes (European Commission 2020). With the help of a conversion key created by us, each tariff code is assigned to one of the 182 product groups.

For each data point on EU trade, there are two values in Comext - one reported by the exporting country and one by the importing country. These values usually do not match due to different pricing concepts and differences in reporting. Since the RME model for Germany is a national model with a focus on Germany, the data on imports and exports reported by Germany are used.

For the countries of origin and destination, EU countries and non-EU countries are distinguished and the data aggregated accordingly. The vectors generated in this way are then matched to the Eurostat IOT benchmark values, i.e. the values are scaled in such a way that the values aggregated to 64 groups of goods match the import and export vectors from the

[1] Destatis (2020): Volkswirtschaftliche Gesamtrechnungen: Input-Output-Rechnung 2018 (Revision 2019, Stand: August 2020), Fachserie 18 Reihe 2.

[2] Eurostat: Comext International Trade Statistics. URL: https://ec.europa.eu/eurostat/web/international-trade-in-goods/data/focus-on-comext (07.02.2023).

Eurostat IOT. The result is time series for exports and imports to the EU, as well as for exports and imports to countries outside the EU according to 182 goods groups.

2.2.2 Time series of monetary output by 182 product groups

We use various data sets to disaggregate the output vectors:

1. Use and supply tables by 85 product groups; [1]
2. Agricultural accounts for agricultural production; [2]
3. Structural Business Statistics (SBS) by approx. 500 economic sectors;[3]
4. Statistics on the production of goods (Prodcom) by 4450 product groups for metal products.[4]

For all these data sets, we created conversion keys for conversion into the RME classification with 182 product groups. In case of conflicting data, the data sets are prioritized according to the order of the list above. In some cases, values from several datasets have to be used to disaggregate a single product group and the differentiation of one data source is not sufficient to achieve the full level of disaggregation. When scaling, the values are first scaled to the next higher aggregated value if necessary.

Despite the variety of data sources, data gaps have to be filled in some places due to confidentiality or other reasons. This is done either with values from previous or consequent years or by using another known relation and extrapolating it, e.g. if the trend of a value at aggregate level is known, this is used to fill a data gap. In this way, a time series of output by 182 product groups is created that matches the aggregated output vector from the Destatis IOT.

2.2.3 Trend update of the 2010 vectors

The product matrix for 2010 from Destatis is the most precise data source among the data sets used, as it is a very detailed, consistent data set. With the other data sources, several sources have to be combined that use different system boundaries and price concepts.

To benefit from the high quality of the product matrix also for the other years, the vectors of the product matrix from 2010 are updated with the help of the time series determined above. Extreme jumps from one year to the next which arise, for example, due to the start of production in a product group or due to a very strong reduction with simultaneously very small values, are corrected to plausible values.

[1] Destatis (2020): Volkswirtschaftliche Gesamtrechnungen: Input-Output-Rechnung 2018 (Revision 2019, Stand: August 2020), Fachserie 18 Reihe 2.
[2] Eurostat: Economic Accounts for Agriculture - values at current prices (aact_eaa01). URL: https://ec.europa.eu/eurostat/web/products-datasets/-/aact_eaa01 (07.02.2023).
[3] Eurostat: Structural Business Statistics (SBS). URL: https://ec.europa.eu/eurostat/web/structural-business-statistics (07.02.2023).
[4] Eurostat: Production of Manufactured Goods (Prodcom) URL: https://ec.europa.eu/eurostat/web/prodcom/overview (07.02.2023).

The results are vectors for imports and exports to EU countries and to non-EU countries and domestic production by 182 product groups. The Total Domestic Use (TDU) vector is derived as the sum of imports and domestic production minus exports.

2.2.4 Estimation of the detailed monetary IOTs

The vectors determined with the trend update are used to estimate the detailed monetary IOTs for the individual years in a next step. First, raw values for intermediate consumption and final use of the IOT are estimated based on the structure of the German IOT of 2010, i.e. the values of the detailed IOT of 2010 are scaled to the aggregate values of the Eurostat IOT for the respective year. Afterwards, the raw values are adjusted with an iterative RAS-type scaling algorithm to both total domestic use (row sum of intermediate consumption and domestic final use) as the first constraint and to the Eurostat IOT benchmark values as the second constraint. 300 iterations are performed, which is sufficient to produce a convergent result. It is not possible to completely fulfil the constraints -- minimal deviations to the aggregate Eurostat IOT can occur for individual product groups.

The result is a time series of monetary IOTs with 182 sectors fully consistent with the total domestic use vectors derived before with minimal deviations of the totals to the aggregated Eurostat IOT.

2.2.5 Hybridisation of the IOTs

Product groups for which physical data are available and which are of high importance for raw material accounting are converted into physical units. These include crop products, forestry products, fishery products, non-metallic minerals (all in kt) and energy sources such as coal, oil, natural gas and nuclear fuel, electricity and heat (all in ktoe) and uranium (in kt RME). For the conversion, output, imports and exports are first determined in physical units based on the following data sources:

- Energy balance data for energy carriers, electricity and heat:[1] Energy balance data are converted to the RME182 classification and supplemented with data on bunkers from material flow data. The breakdown of imports and exports into intra-EU and extra-EU is carried out based on the physical (and if no physical data is available, on the monetary) Comext relations.
- Material flow accounts[2] for output (domestic production) of the remaining product groups: The material flow data are converted to the RME182 classification.
- Comext trade data[3] for imports and exports of the remaining product groups: The physical Comext data in tonnes are also converted to the RME classification.

Based on these benchmark values, the remaining values of the rows of the IOT are estimated using the monetary relations. The result is a time series of hybrid IOTs in mixed physical and monetary units.

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[1] Eurostat: Complete energy balances (nrg_bal_c), URL: https://ec.europa.eu/eurostat/web/products-datasets/-/nrg_bal_c (07.02.2023).
[2] Eurostat: Material Flow Accounts (env_ac_mfa), URL: https://ec.europa.eu/eurostat/databrowser/product/view/env_ac_mfa (07.02.2023).
[3] Eurostat: Comext International Trade Statistics. URL: https://ec.europa.eu/eurostat/web/international-trade-in-goods/data/focus-on-comext (07.02.2023).

2.2.6 Calculation of imports in RME with EU RME coefficients

Imports are calculated analogously to the RME country tool with the EU RME coefficients. The RME coefficients are a result of the EU RME model and indicate the raw material demand in kt RME per unit of imported average product.

To calculate imports in RME, we multiply the two hybrid import vectors (intra-EU and extra-EU imports) by the EU RME coefficients. Since a common classification is used with the RME182 classification, no further conversion steps are necessary. For intra-EU imports, we apply the EU RME coefficients for exports while we use the EU RME coefficients for imports for extra-EU imports.

The EU RME coefficients for exports are average values for the entire EU. However, the energy carriers used to generate electricity in some cases differ greatly from country to country. To account for this fact, an adjustment is made to the initially calculated direct and indirect electricity imports from the EU. From the data on imports by EU country of origin and the electricity mix of the EU countries, correction factors are calculated and applied to the electricity imports.

The results of this calculation are imports in RME broken down into 182 product groups and 52 materials.

2.2.7 Calculation of exports in RME with the Leontief method

Exports in RME are calculated analogously to the EU RME model with the Leontief method based on the hybrid IOT. For this purpose, the IOT is first extended to include the raw material flows into the economy.

2.2.8 Raw material extension

Raw materials are either extracted domestically or enter the country through imports. The data on domestic extraction are taken from the material flow data (Eurostat 2021f). With the help of a conversion table, the material flows are allocated to the sectors in which the raw materials first enter the economy before they are further processed in other sectors and consumed or invested as final demand goods. The result is domestic extraction in the form of a matrix (52 materials x 182 product groups). Imports in RME (52 materials x 182 product groups) are added to domestic extraction.

2.2.9 Leontief procedure

In the next step, we use the Leontief method to calculate exports in RME. First, we calculate the direct input coefficients and the direct raw material coefficients. For this, intermediate consumption and the raw material extension are multiplied by the reciprocal of output. Then the Leontief inverse is calculated using the direct input coefficients. The Leontief inverse maps the input required to produce one unit of output for final demand.

Now the direct raw material coefficients are multiplied by the Leontief inverse. As a result, we get the (cumulative) RME coefficients. By multiplying these with the hybrid export vectors, we get exports in RME (52 materials x 182 raw material groups). Raw material input

(RMI) is the sum of domestic extraction and imports in RME. To determine raw material consumption (RMC), the RME coefficients are multiplied by final domestic use. Alternatively, RMC can also be calculated as RMI minus exports in RME.

2.3 Implementation in Python

The model was implemented in the open-source programming language Python[1]. Python is often used in the field of data analysis and provides specialised libraries for data manipulation and analysis. For the model, mainly the packages 'Pandas'[2] and 'Numpy'[3] were used. Compared to Excel, Python offers some advantages in data processing. For example, data can be loaded directly its most current version via an API[4] interface provided by Eurostat (Destatis unfortunately only provides bulk access for selected data sets). In addition, very large amounts of data, such as foreign trade data, can be processed simultaneously and in a structured manner. Algorithms, such as iterative scaling, can be implemented efficiently. Linking and formula errors can be avoided through a uniform data structure. Frequent routine tasks, such as conversions between classifications, can be automated with functions.

The model itself consists of about 30 Python scripts. A Python script usually loads one or more data sets, processes them with the package 'Pandas' and saves the results in a new file. Cross-model functions are stored in a separate Python script. The model's data folder contains raw data (Excel, CSV) loaded for the model calculation and processed data as HDF files. Excel files store additional information such as conversion keys, classifications, labels for the individual codes and sort orders. Model results are reported in Excel files and in plots.

[1] URL: https://www.python.org/about/
[2] URL: https://pandas.pydata.org/about/index.html
[3] URL: https://numpy.org/doc/stable/
[4] Application Programming Interface

3 Results

The results calculated with the RME model for Germany are available according to 182 product groups, 52 raw materials and 5 categories of final domestic use (household consumption, government consumption, consumption of private organisations, investment and change in inventories). Imports and exports can be differentiated by EU and non-EU countries. By using additional data, evaluations can be made according to areas of need (consumption categories). The results presented below are exemplary and show a selection of possible evaluations.

The results presented are based on the updated EU RME coefficients from the Eurostat model calculation of summer 2021. Since the publication of the IOT for 2019 is not planned by Destatis until 2023, the IOT for 2019 was estimated using benchmarks from national accounts and the IOT of 2018. This means that a time series from 2008 to 2019 is available. Table 1 provides an overview of the results for the main indicators of the RME model according to the four material groups biomass, metal ores, non-metallic minerals and fossil fuels.

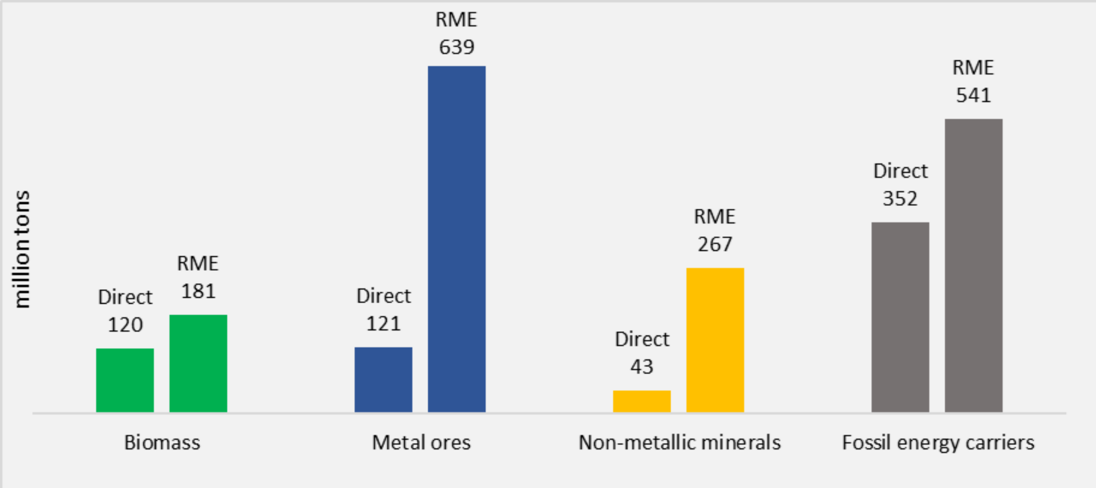
Table 1: Results of the RME model for Germany

Raw materials	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Domestic Extraction												
Total	1.041	995	971	1.046	1.019	1.005	1.021	941	948	1.015	954	908
Biomass	213	215	198	212	214	205	234	210	209	214	190	205
Metal ores	0	0	0	0	0	0	0	0	1	1	1	1
Non-metallic minerals	615	577	573	628	592	593	588	533	550	614	584	561
Fossil energy carriers	212	203	200	206	212	206	199	197	188	187	180	142
Exports in RME												
Total	1.301	1.064	1.122	1.165	1.095	1.152	1.192	1.194	1.206	1.307	1.274	1.209
Biomass	121	121	125	128	128	133	139	141	142	140	140	146
Metal ores	511	373	427	437	385	422	455	437	455	486	496	472
Non-metallic minerals	254	223	216	236	215	217	212	216	212	262	242	238
Fossil energy carriers	415	347	354	363	367	381	385	400	397	420	396	353

Imports in RME												
Total	1.635	1.374	1.457	1.492	1.360	1.456	1.497	1.523	1.537	1.689	1.681	1.628
Biomass	163	155	161	165	159	172	172	173	178	182	183	181
Metal ores	660	480	574	581	502	547	589	590	591	654	678	639
Non-metallic minerals	226	225	197	215	187	190	199	206	205	270	258	267
Fossil energy carriers	586	514	525	531	512	547	537	554	562	583	562	541
Raw material input (RMI)												
Total	2.676	2.369	2.428	2.538	2.379	2.461	2.518	2.463	2.485	2.704	2.635	2.536
Biomass	376	370	359	376	373	377	406	383	387	396	373	386
Metal ores	661	480	574	582	503	548	590	590	592	654	678	640
Non-metallic minerals	841	801	770	843	779	783	787	739	755	884	842	828
Fossil energy carriers	798	717	725	737	724	753	736	751	751	770	742	683
Raw material consumption (RMC)												
Total	1.375	1.304	1.307	1.374	1.284	1.309	1.327	1.269	1.278	1.397	1.361	1.328
Biomass	255	249	235	248	245	245	267	242	245	256	233	240
Metal ores	150	107	147	145	118	126	135	153	137	169	182	168
Non-metallic minerals	587	578	554	607	564	566	575	523	542	622	600	590
Fossil energy carriers	383	370	371	374	357	373	351	351	354	350	346	330

Source: own results ifeu/SSG

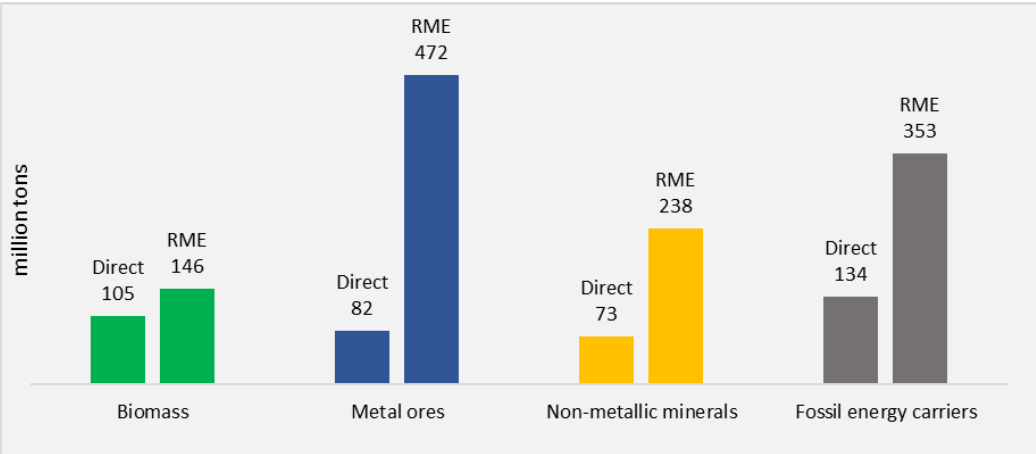
Figure 1: Imports of Germany 2019, mass according to EW-MFA versus raw material equivalents



Source: own results ifeu/SSG

In Figure 1 and Figure 2, imports and exports in RME are compared with imports and exports from material flow statistics. It is important to note at this point that the results are not directly comparable, as in the material flow statistics imports and exports are allocated to the material groups according to their mass-determining component (Eurostat 2013b). A car, for example, is assigned to the material group metals.

Figure 2: Germany's exports 2019, weight according to EW-MFA versus raw material equivalents



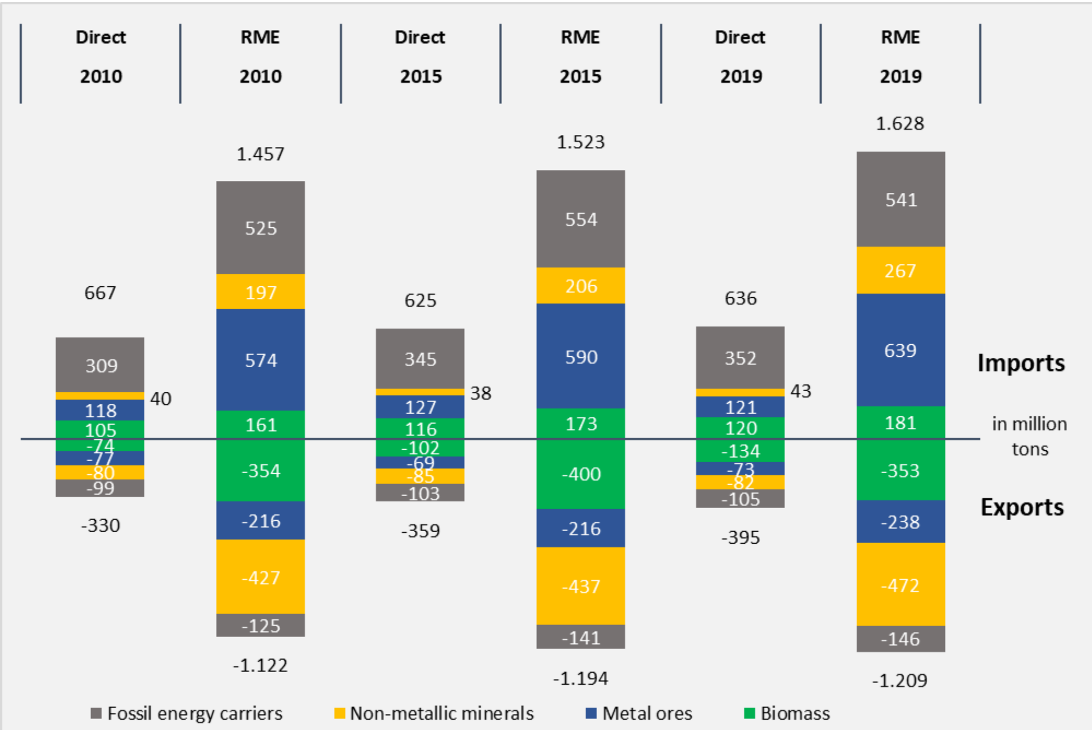
Source: own results ifeu/SSG

Nevertheless, trends can be identified: In the case of metal ores, the difference between 'direct' values and the values in RME is the highest. The values in RME are 5.3 times higher for imports and 5.7 times higher for exports than the values from the material flow statistics. This is mainly because large quantities of ore with low metal contents have to be extracted to produce metal. In addition, the production of metals is associated with energy-intensive and thus raw material-intensive processes.

It is also interesting to observe that the ratio between the values in RME and the direct values for fossil energy sources is significantly higher for exports at 2.6 than for imports at 1.5. This can be explained by the fact that we import a large amount of low processed crude oil and natural gas, while we export fossil energy sources mainly in indirect form as energy input to produce highly processed export goods.

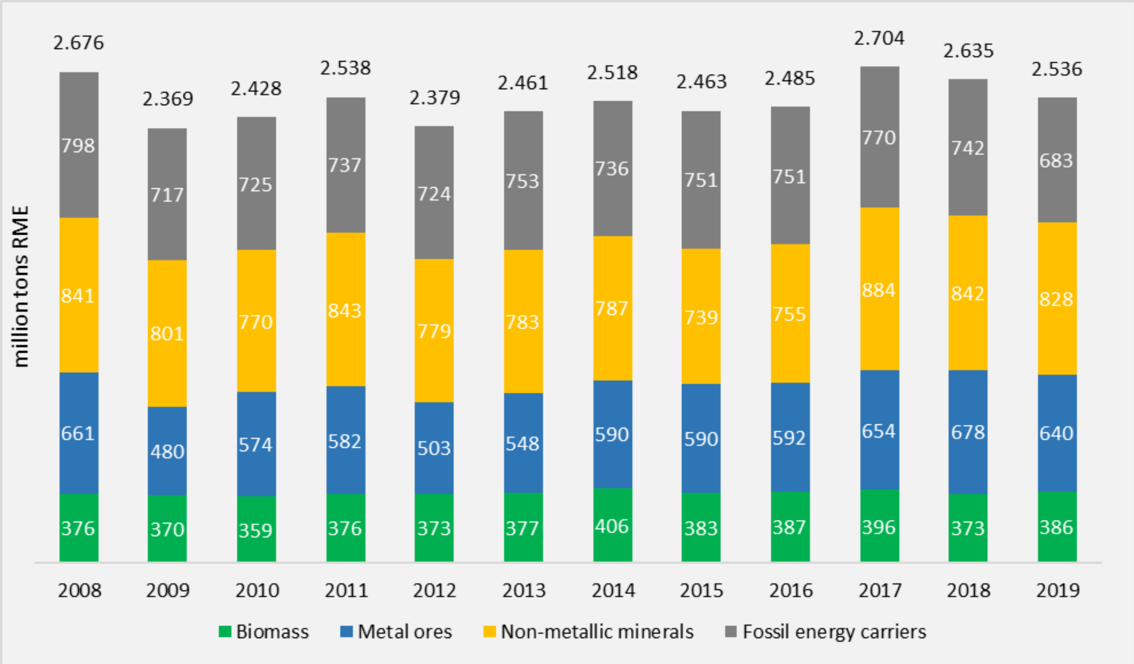
Figure 3 provides an overview of the development of imports and exports. Both imports in RME and exports in RME have increased by 11.73 % and 7.75 % respectively in the period from 2010 to 2019. Imports and exports according to the material flow statistics have remained relatively constant in relation to this.

Figure 3: Development of raw material imports and exports in Germany, direct and in RME



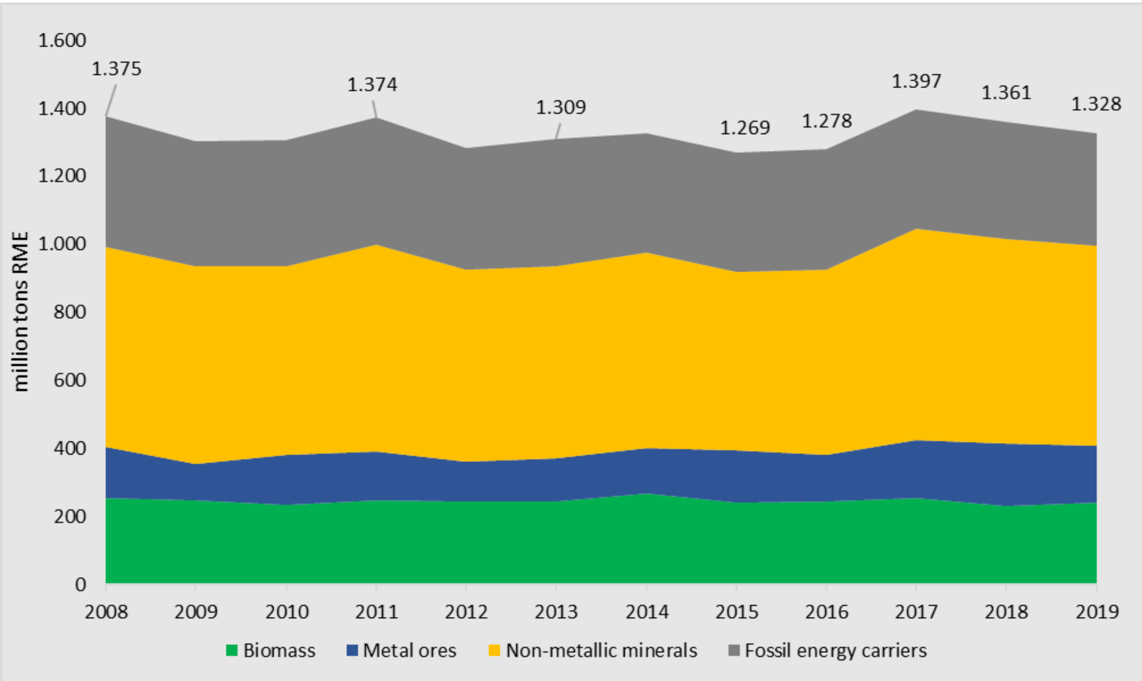
Source: own results ifeu/SSG

Figure 4: Raw material use (RMI) in Germany by raw material groups, 2008-2019



Source: own results ifeu/SSG

Figure 5: Development of raw material consumption (RMC) in Germany by raw material groups

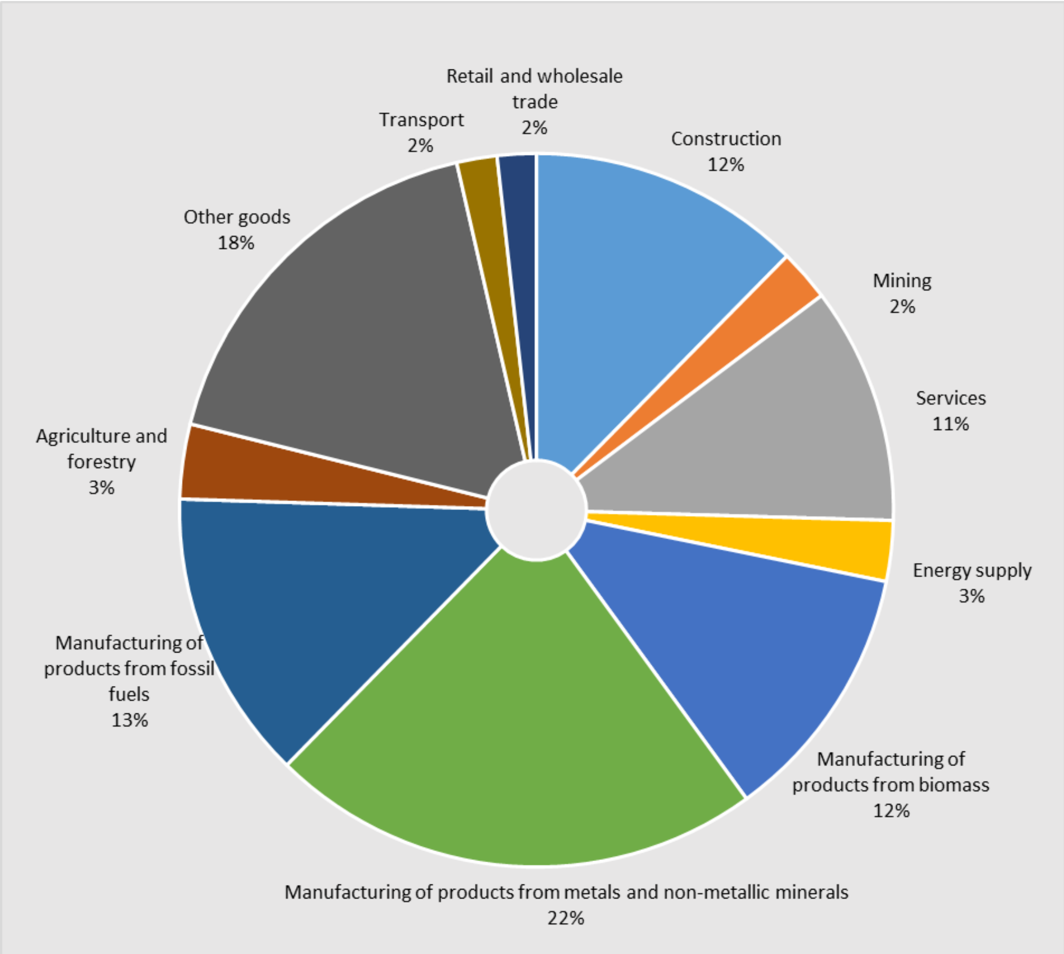


Source: own results ifeu/SSG

In Figure 4 and Figure 5, the development of raw material input (RMI) and raw material consumption (RMC) are shown. The development is relatively constant over the years, but in 2011 and 2017 there is a significant increase in both RMI and RMC. In 2011, this is mainly due to catch-up effects after the economic crisis in the construction sector. The increase is clearly dominated by non-metallic minerals. In 2017, there was a significant increase, which can mainly be attributed to an increased domestic extraction of sand and gravel.

In 2019, non-metallic minerals account for the largest share of the RMC with 44.4 %, followed by fossil fuels with 24.9 % and biomass with 18.1 %. Metal ores account for the smallest share with 12.6 %.

Figure 6: Raw material input (RMI) by raw material group, 2019

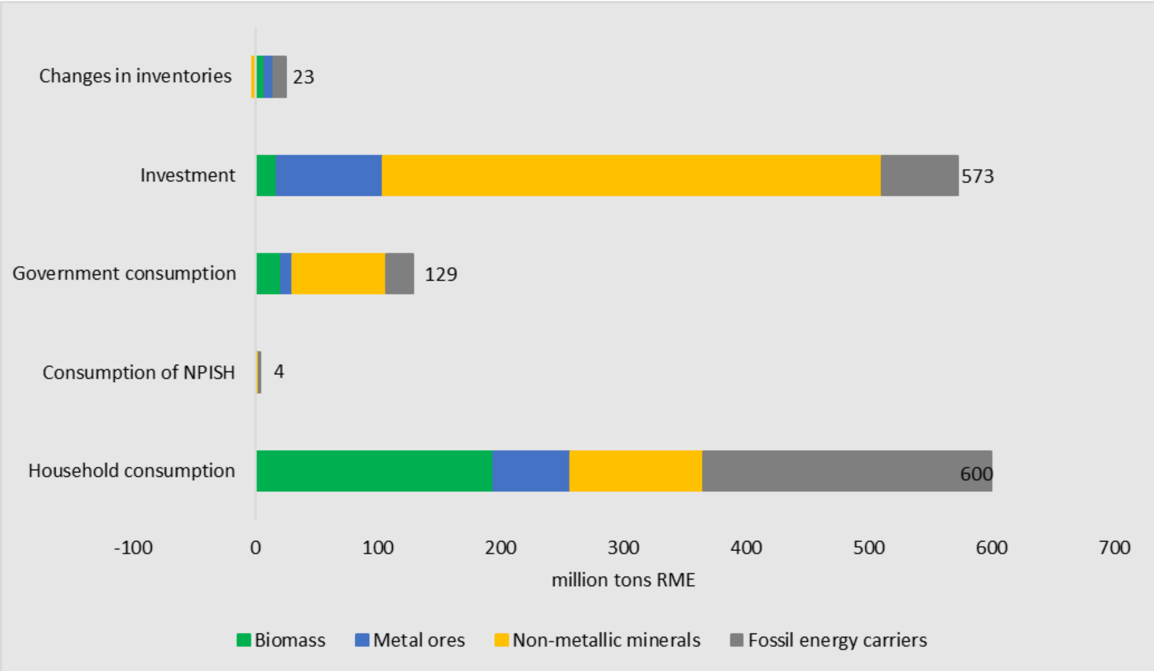


Source: own results ifeu/SSG

In Figure 6, the use of raw materials is differentiated by sector. The manufacture of products from metals and minerals consumes just under a quarter of the raw material input. Products made from fossil raw materials require a further 13 %.

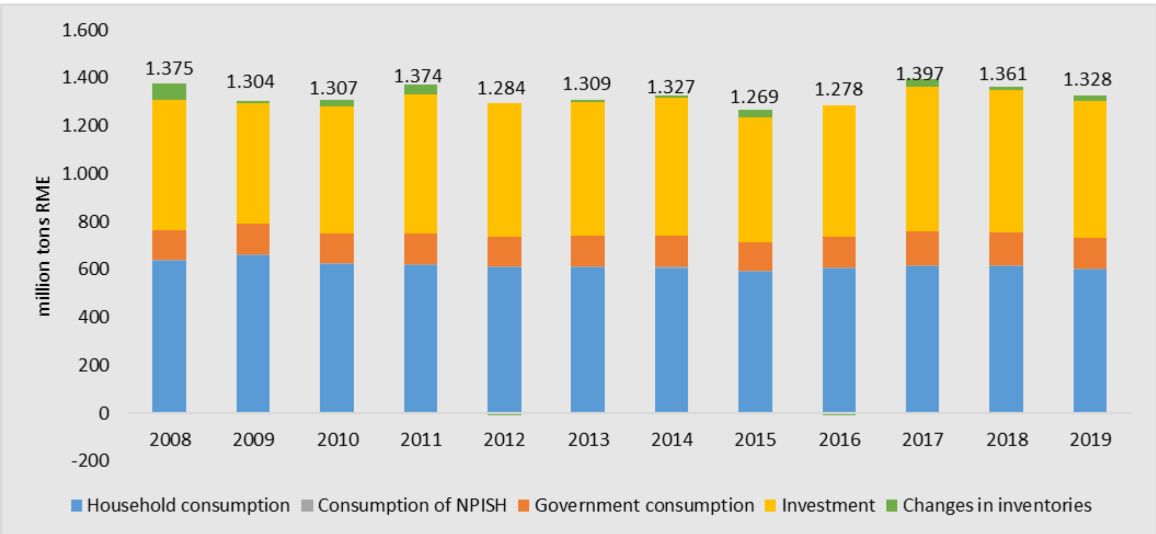
Figure 7 and Figure 8 show the composition of raw material consumption by final use categories. In 2019, households are responsible for 45.1 % and gross fixed capital formation (investment) for 43.1 % of RMC. Government consumption accounts for a much smaller share of 9.7 %. Changes in inventories and consumption by private organisations (NPISH) play a negligible role.

Figure 7: Raw material consumption (RMC) by type of final use, 2019



Source: own results ifeu/SSG

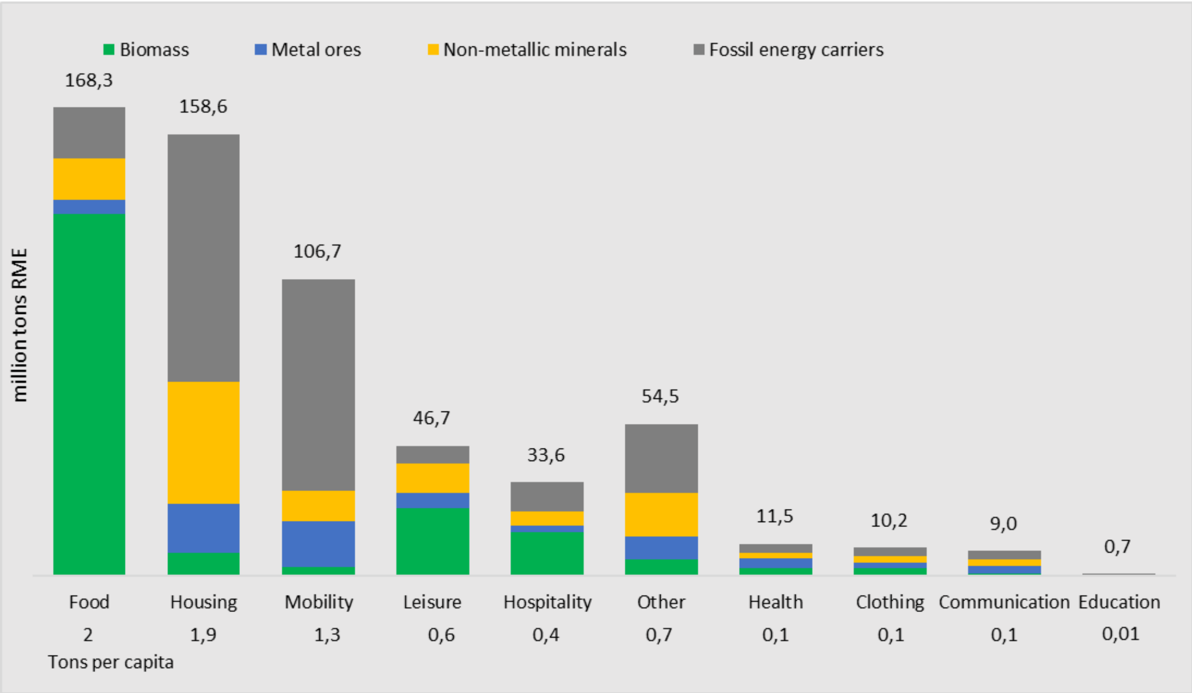
Figure 8: Development of raw material consumption (RMC) by type of final use



Source: own results ifeu/SSG

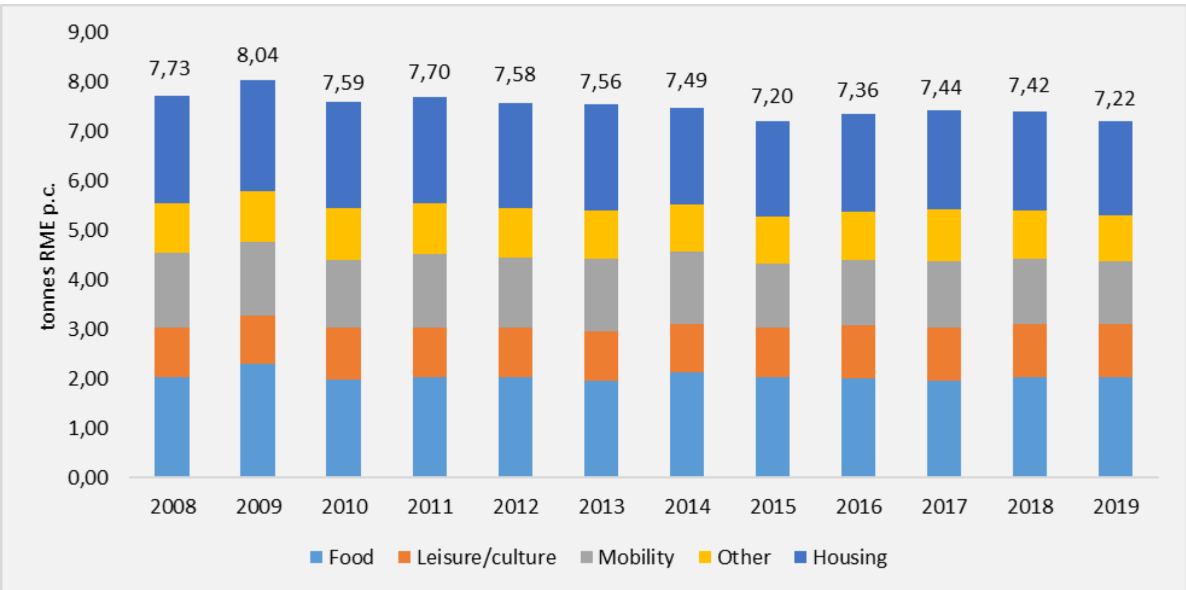
In Figure 9 and Figure 10, the consumption of raw materials by private households is broken down by areas of need. Food and housing are responsible for most raw material consumption with 168.3 million tonnes of RME (2 tonnes per capita) and 158.6 million tonnes of RME (1.9 tonnes per capita), respectively. Mobility follows in third place with 111.3 million t RME (1.3 tonnes per capita). Not surprisingly, biomass dominates in food, and fossil raw materials in housing and mobility. Per capita, the consumption of raw materials by private households amounts to a total of 7.22 tonnes in 2019. In 2008, the value was at 7.73 tonnes implying a slight decrease of about half a tonne.

Figure 9: Raw material consumption of private households by areas of need in million tons of RME (top) and in tons per capita (bottom), 2019



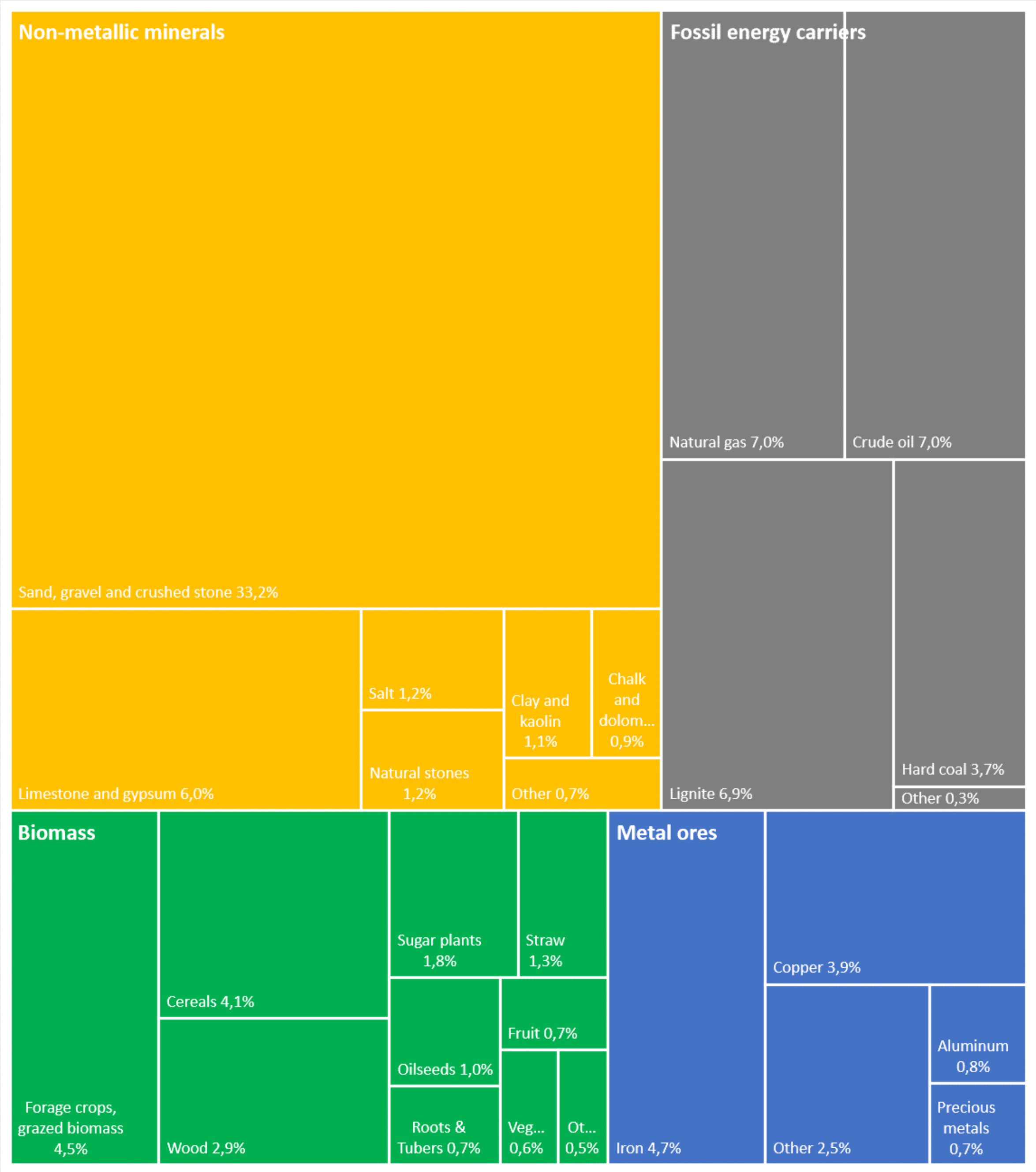
Source: own results (ifeu/SSG)

Figure 10: Development of raw material consumption (RMC) by private households



Source: own results (ifeu/SSG)

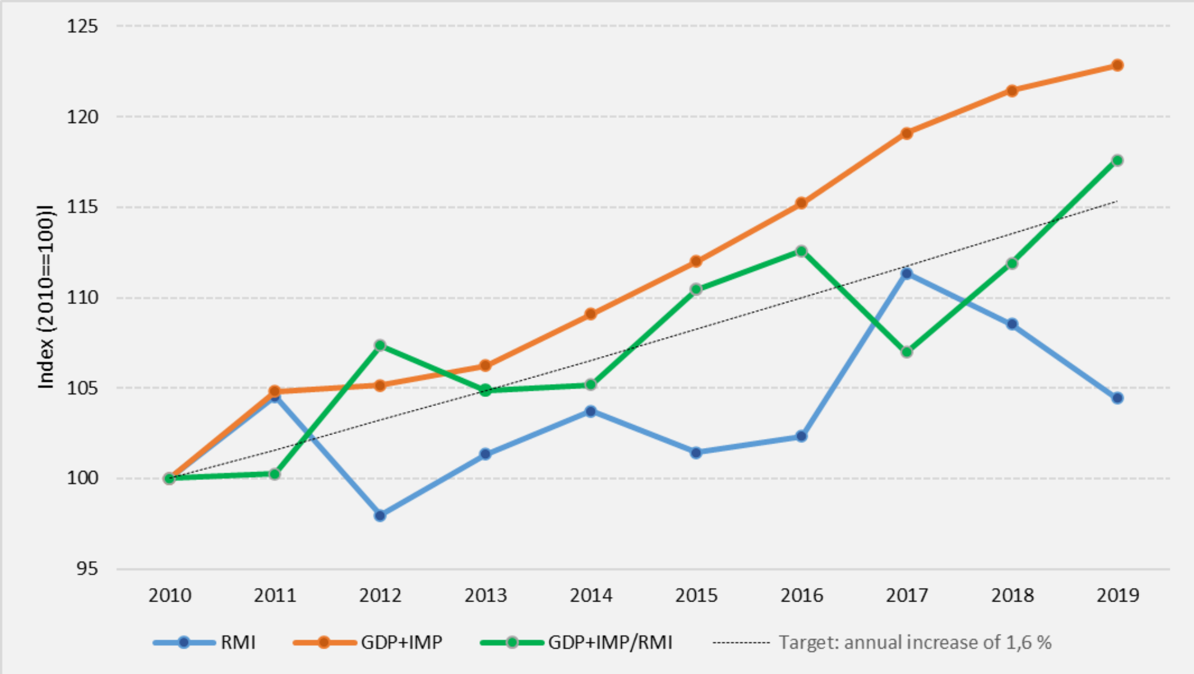
Figure 11: Raw material consumption (RMC) by raw material, 2019



Source: own results (ifeu/SSG)

If we look at raw material consumption broken down by raw materials (Figure 11), it becomes clear that it is dominated by non-metallic minerals at 44.4 %, and among these by sand and gravel (33.2 % of the RMC). Fossil fuels are dominated by lignite and petroleum with 7 % each, biomass by fodder crops with 4.5 % and metal ores by iron and copper with 4.7 % and 3.9 % respectively.

Figure 12: Development of total raw material productivity (2010-2019)



Source: own results ifeu/SSG

Total raw material productivity is an official indicator of the German Sustainability Strategy (German Government 2021) and part of the German Resource Efficiency Programme (ProgRess I-III) (BMUV 2020). The indicator is the ratio of the sum of gross domestic product and imports (in monetary terms) to raw material input (RMI in tonnes of RME). The political target is an average annual increase of 1.6% or a maintenance of the 2000-2010 trend until 2030.[1] The target was achieved on average until 2019, but in 2017 there was a significant decrease due to the increase in RMI (see Figure 12).

[1] Target according to the German Sustainability Strategy 2021 (German Government 2021) and the German Resource Efficiency Programme (ProgRess) II. The German Sustainability Strategy 2016 and ProgRess III (BMUV 2020) state a target of around 1.5 %.

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