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Socio-economic dimensions of the Bioeconomy

Selected findings for trends in the recent past

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Table of Contents

1 INTRODUCTION

In this documentation, the socio-economic dimension of the German bioeconomy (BE) is reported for the recent past. The presented findings were developed as part of the project SYMOBIO (homepage: https://symobio.de/), a research project funded by the Federal Ministry of Education and Research (BMBF) as part of the concept of "Bioeconomy as Societal Change". The research consortium is working to create the scientific basis for monitoring the bioeconomy (BE) in Germany by a systemic understanding and modelling of the German BE with respect to sustainability aspects on a national and international level.

Work packages of SYMOBIO deal with the footprints agricultural land use, forestry wood, water and GHG emissions. In addition to this, the project deals with the challenges in monitoring the social and economic sustainability dimensions of the BE. To assess the sustainability of the BE a set of indicators has to be defined and quantified that simultaneously look at the economic, social and environmental sustainability of the BE (see Egenolf, Bringezu 2019). Hence, one part of the project is to identify and assess key indicators that show the impacts of the BE on the (global) environment due to domestic use and/or production. The indicators for the socio-economic dimension are presented in this documentation.

One of the key challenges to assess indicators for the BE the lack of explicit data for BE in statistical classifications and some of the new parts just emerged over the last years. Different sectors such as agriculture or forestry can mainly or exclusively be attributed to the BE. For other sectors and activities such as fuel use or electricity production, part of the sector belongs to the BE, other parts not. Therefore, the socio-economic performance of the BE cannot be directly observed from official statistics, but for certain parts of the BE the relevance of BE activities (within the activity at hand) has to be assessed, using secondary statistics. As already discussed in D 2.6.1, the assessment of BE-shares on the base of IO-Tables is one of the options to deal with this challenge (Distelkamp et al. 2017). In chapter 2 of this report, the methods and data sources for the assessment of BE-shares are described. These BE-shares will mainly be applied in chapter 3 when examining macroeconomic indicators. The subsequent analyzes are essentially based on the database EXIOBASE 3.4, which is also described in the following chapter.

Main emphasis of this paper is to assess past trends for selected indicators that deal with the economic and/or social sustainability of the BE in Germany. Socio-economic indicators have been identified that reflect the global value chains. The indicators can be divided into a) macro-economic indicators like employment and value added (see chapter 3), b) indicators on food security – food situation, price development and share of food consumption covered by domestic production (see chapter 4) and c) indicators on sustainable consumption and production – material footprint, material imports & exports, total raw material productivity and per capita meat consumption (see chapter 5).

2 DEFINITIONS, DATA SOURCES AND METHODS

The German Bioeconomy Council defines bioeconomy as "the production and utilization of biological resources (including knowledge) to provide products, processes and services in all sectors of trade and industry within the framework of a sustainable economy"[1]. The BE is thus a sector that cannot be rediscovered in the established national and international statistical classifications of economic sectors (WZ, NACE, ISIC).

The primary sector, consisting of agriculture, forestry and fisheries, can be fully assigned to the BE because it is based on the production of biological resources. In addition, the processing of biotic raw materials, i.e. in particular the food, beverage and tobacco industries, the wood and cork industry, papermaking and paperboard manufacturing and the leather industry can also be fully assigned to the BE (see Bioökonomierat 2009 and European Commission 2012). The assignment and estimation for downstream economic sectors, whose production activities are only partially attributable to the BE, is more difficult. This is above all because the products consist – either in mass or in monetary units – of a large number of biotic and non-biotic inputs and are processed in several steps, as is the case for example in the chemical industry. The fundamental question of whether parts of trade and services (such as retail trade in foodstuffs or catering trade) are also attributable to the BE is handled differently (see Bracco et al. 2018). There are various definitions of the BE as well as differences in the methodology for share estimates of only partially bio-based industries or products (Efken et al. 2016, Ronzon et al. 2017a). However, the shares are important in terms of consistency and comparability for calculating socio-economic indicators.

To calculate footprints and analyze the socio-economic development, we use multi-regional input-output tables (IOT) and the GRAM (global resource accounting model) approach (see Lutz et al. 2012, Flaute et al. 2017, Wiebe et al. 2012, 2016). We apply the MRIO-Database EXIOBASE 3.4, which contains data for the period 1995 to 2011 (Wood et al. 2015). The spatial structure comprises 44 countries and 5 country aggregates for the rest of the world. At the sectoral level, a distinction is made between 200 product groups[2]. The multiregional IOT of one year thus contains over 96 million data points for the individual trade links.

[1] http://biooekonomierat.de/en/bioeconomy/

[2] There is also a dataset that differentiates between 163 industries. However, the authors decided to use the differentiation in product groups to measure the respective BE shares. See full explanation and more details in Flaute et al. 2017.

Table 1: Sectors in EXIOBASE and affiliation to BE

	BE section	Related sectors		
		Name	ISIC-Code	Number of elements in EXIOBASE (pxp): t(otal) or p(artly)
BE narrow definition	Primary BE sectors	Agriculture, forestry, fishery	01 – 05	19 t
BE narrow definition	Secondary BE sectors (first-stage processing of biomass)	Manuf. of food & beverages, tobacco	15, 16	12 t
BE narrow definition		Manuf. of leather, wood, pulp & paper	19 - 21	6 t
BE narrow definition	Manufacturing	Manuf. of textiles & wearing apparel	17 - 18	2 p
BE narrow definition		Manuf. of printed matter	22	1 p
BE narrow definition		Chemistry & manuf. of rubber & plastics	24,25	5 p
BE narrow definition		Manuf. of furniture & manuf. nec	36	1 p
BE narrow definition	Energy	Manuf. of petroleum prod.	23	6 p
BE narrow definition		Manuf. of charcoal, biogasoline, biodiesel & other liquid biofuels	24e - i	5 t
BE narrow definition		Electricity gen. by biomass	40.11.g	1 t
BE narrow definition		Biogas	40.2.e	1 t
BE wide definition	Trade	Retail & wholesale trade services with BE products	50b - 52	3 p
BE wide definition	Transport	Transportation of BE products	60 - 62	5 p
BE wide definition	Hotels & restaurants	Restaurant services	55	1 p
BE wide definition	Waste	Incineration, biogasification, composting, land application & landfill services with BE products	90	11 t & 4 p

Source: Own compilation

As already mentioned, there are several classifications of the BE. Some institutions use a wide boundary and include also trade, transport, hotels and restaurants as well as waste (for example Bioökonomierat 2009), others use a narrow boundary, which includes only the direct processing of biological products (Dries et al. 2016). Therefore, in our analysis, we also distinguish between a narrow and a wide definition of BE.

The results of the indicators depend on the shares of BE in final demand for each of the 200 product groups, not only for the country itself but indirectly via imports also from other countries. We therefore use an algorithm to identify the BE-shares primarily using EXIOBASE data without additional external sources. The calculation of the shares is based on the MRIO calculation and does not resort on qualitative data, which essentially distinguishes our approach from previous ones.

In analogy to e.g. Ronzon et al. (2017a) and Efken et al. (2016), those production areas are first to be identified that have a BE share of 100 percent. The definition of the BE mentioned above is applied to the structure (ISIC 3.1) on which the EXIOBASE dataset is based. For example, agricultural, forestry and fishery products, which are differentiated into 19 products in EXIOBASE, are all bioeconomic, while textiles and furniture can only partially be counted as BE (see Table 1).

In a further step, BE shares are determined for those product groups of the economy, which can only be partially attributed to the BE, but which are at least partially devoted to the further processing of biotic raw materials. In order to be able to ensure a consistent calculation of these bio-economic components, the EXIOBASE data set is used. The basic idea of the following approach of consumption-based accounting is to apportion the BE share that is embodied in a product through the global production chains. In this concept, a wooden chair does not only contain the wood (and the waste from cutting the tree, as far as is not economically used elsewhere) but also biofuels that have been used to transport the chair, the paper for the transport box(es) and other non-BE inputs as the conventional fuel. In the end, the accounting takes place at the level of 200 homogenous products with monetary relations as weights.

BE shares thus show to what extent the partial BE sectors receive inputs from BE sectors. In relation to the sum of all material inputs, the respective share of BE results.

From the 9800 x 9800 MRIO table of one year (EXIOBASE: 49 countries and regions, each with 200 commodity groups = 9800), the 9800 x 9800 A-matrix is considered, representing the inputs, i.e. the use of intermediate goods of sector i (row) in monetary units needed for the production of sector j (column).

In the first step, for each product group that is a part of the BE, those rows are summed up that report on 100 percent biotic inputs. This sum $(\sum a_{BIO,j})$ is put into relation to the sum of all material inputs ($\sum a_{MAT,j}$= sum of all primary and manufacturing inputs[3], which delivers the preliminary BE share.

Since the product groups that are partially associated with the BE also provide an input related to the BE, a second step must be executed, in which the diagonal element is also partially added. The preliminary calculated BE shares are multiplied by the input coefficients of the product groups that are partially related to the BE. The sum of all inputs associated with the BE is again divided by the sum of all material inputs, whereby the diagonal element is added in this step.

$$bioeconomy\ share_j = \frac{\sum a_{BIOi,j}}{\sum a_{MATi,j}}$$

3 The calculation of the sum of all material inputs exclude the diagonal elements from summation.

This results in a proportion between 0 and 100%, which indicates the affiliation of the respective product group to the BE. This calculated proportion varies over time and also between the different countries. All further calculations and evaluations on the BE depend on the apportioning of the product groups to the BE.

Finally, the BE shares must be determined for those sectors of the economy whose activity is primarily made possible by the use of biotic raw materials and their further processing. Trade and transport of food are mainly affected in this area. The EXIOBASE classification does not distinguish between wholesale and retail trade in foodstuffs and trade in other goods.

In order to estimate the BE share in retail trade, household consumption expenditures on agricultural and forestry products, fisheries, food, beverages and tobacco products, as well as wood and wood products (excluding furniture) are first summed up ($\sum Consumption_{BIO}$). These are related to total household consumption expenditure on retail sales of goods ($\sum Consumption_{trade}$) [4].

In the case of transport services, on the basis of the input-output linkages, the share of deliveries to the complete BE production areas is finally analyzed on all deliveries of the respective transport service (= production value).

There are some product groups in which the described algorithms result in shares that are not consistent with BE shares of official statistics. This is related to entries made in EXIOBASE that are less precise than official national statistics. In these cases, the data of the official statistics are used, which are implemented exogenously into the calculation. This is the case for chemical industry and fuels. For the chemical industry, we use the OECD Inter-Country Input-Output (ICIO) tables and calculate the bio-economy shares using the same algorithm as with the EXIOBASE data. To calculate the BE share of fuels, we use data from the United Nations Energy Statistics Database (UNdata) and calculate the share of biofuels on total fuels in final consumption for each country.

At this point, the BE-shares for each product group in each country is defined, which enables the calculation of the defined indicators. The respective calculation with potential additional data sources are described in the respective (sub)chapters.

Although EXIOBASE delivers data as of 1995, we report from 2000 on. In the first research efforts, full datasets have been developed for 2000 (in EXIOPOL) and 2007 (in CREEA) (Flaute et al. 2017). Data for other years may have been partly extrapolated. In those cases, where we use additional data sources, we also report on the current border until the last year with available data.

[4] This includes all raw, semi-finished and finished goods except mineral oil and motor vehicles. For these two groups of goods, there are separate trade sectors in the classification system (commercial vehicle, motor vehicle, retail trade services of motor fuel).

3 MACROECONOMIC INDICATORS

The German Federal Ministry of Food and Agriculture attributes numerous goals and guiding principles for a sustainable BE in its “National Policy Strategy on Bioeconomy”. One of these goals is “securing and creating employment and value-added, particularly in rural areas” (BMEL 2014).

This chapter looks at how the goal of securing and creating employment and value-added through BE was achieved in the years 2000 to 2011. In order to analyze more precisely which part of the BE influences macroeconomic indicators, different BE divisions have been defined. An overview has been presented in the previous chapter (Table 1). There are divisions, that can be counted for the narrow definition of BE; (1) primary products (products of agriculture, fishery and forestry), (2) secondary products (first stage processing), (3) manufacturing (further processing) and (4) energy (biogas, biofuels and electricity by biomass). In addition, the BE components of (5) trade, (6) transport, (7) hotels and restaurants and (8) waste are also to be considered, if a wide BE definition should be applied.

In the following analysis, we will not explicitly focus on rural areas, because there are no detailed statistics about macroeconomic indicators in different regions. The differentiation of several BE divisions however gives an impression about the economic development in rural areas, as agriculture, forestry and fishery mainly takes place in rural areas. In 2015, the rural areas contributed 63% to the national value added in agriculture, forestry and fishery. With regard to employment, the contribution of rural areas was 61%. Compared to economy-wide contributions of rural areas (25% for value added and 29% for employment) at least the basis of the bio-economy shows an above average relevance for the economic development in rural areas (Data of the statistical offices of the federation and the federal states[5] with own calculations). There is a lack of data considering the processing sectors as well as for the service sectors. Therefore, unfortunately, a more detailed analysis of rural areas is not possible. However, it is assumed that at least the first stages of processing are also mainly in rural areas, as costs for sites and transport would be higher otherwise. It is important to pay attention to employment and value added while extending an economic field and BE offers an approach to counteract the still ongoing migration to the cities in Germany.

We compare the results of our calculation concerning employment and value added of the German BE with the results of previous calculations, especially those of Efken et al. 2016, Ronzon et al. 2017b and Van den Pas 2015.

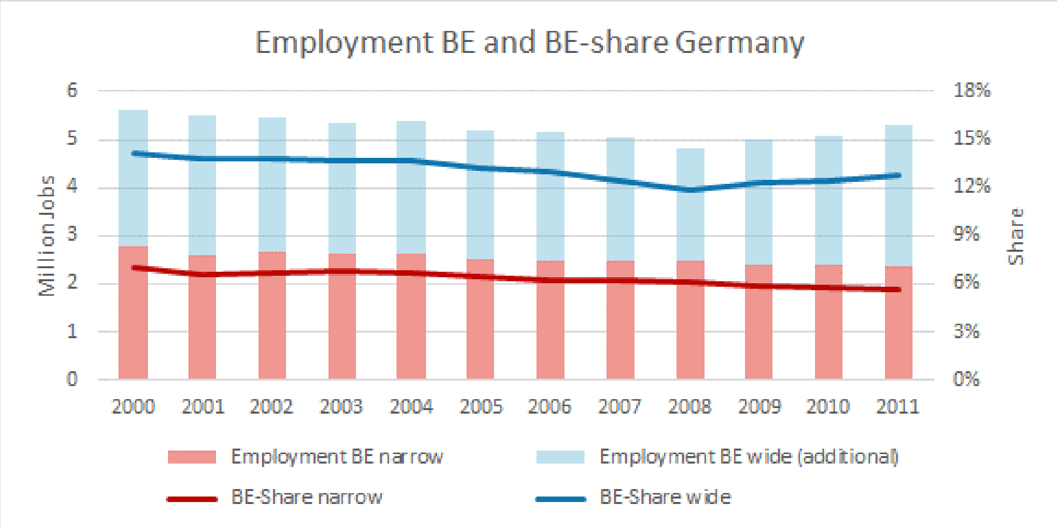
3.1 EMPLOYMENT

A central indicator for the socio-economic dimension of the BE is employment. EXIOBASE reports the number of employed persons (employees and self-employed) for each product group. By applying the BE-shares, we get the number of employed persons

[5] Volkswirtschaftliche Gesamtrechnungen der Länder VGRdL, Reihe 2, Kreisergebnisse Band 1, latest data of august 2017

in the entire BE and put them into relation to total employment in Germany (Figure 1).

Figure 1: Employment by bioeconomy in Germany



Source: EXIOBASE 3.4 and own calculations

Employment in EXIOBASE is not counted in full-time equivalents, it takes into account the total number of persons working in the relevant sectors, so part-time-workers are fully included, which is also the case in Efken et al. (2016).

The narrow definition of BE includes products of all three processing stages (primary, secondary and manufacturing) and bioenergy. Over time employment in the narrow definition of BE declines continuously, while within the wide definition of BE, the BE-share of employment declines until 2008 and increases afterwards. The wide definition of BE includes additionally the BE-share of waste, hotels and restaurants, transport and trade. Between the years 2000 and 2011, employment in the BE by narrow definition decreased by 16% from 2.8 to 2.3 million (Figure 1), while employment in the BE by wide definition decreased only by 6% (5.6 to 5.3 million), due to the increase after 2008. These results are in contrast to Efken et al. 2016, who report growing employment in the BE by 30% between the years 2002 and 2010.

To check the validity of the results of our calculations and classify them, we compare them with results of previous analyzes. All outcomes for employment in the BE depend on the definition of BE, which is different in every analysis as already described in detail in chapter 2, nevertheless the comparison provides a first classification of the results.

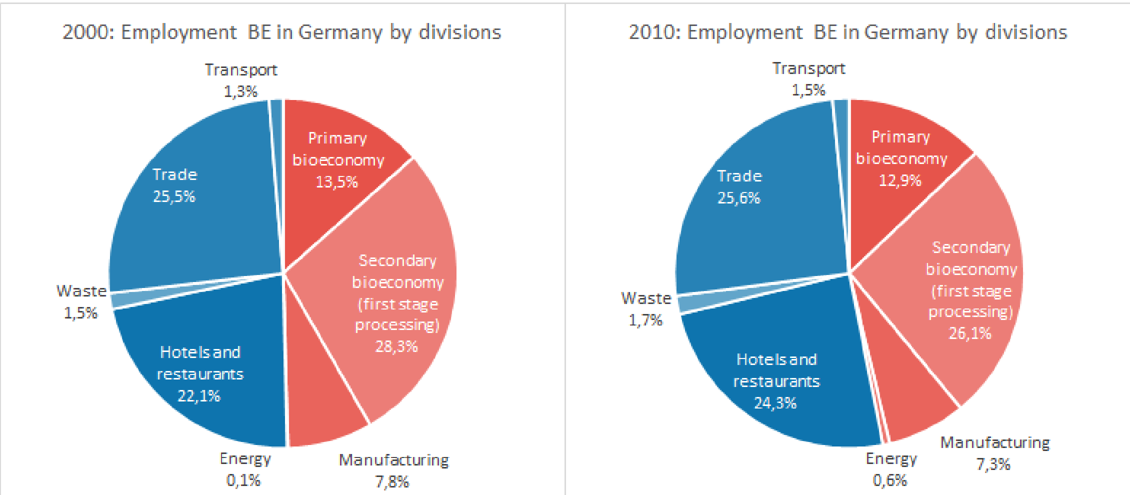
Table 2: BE-share in employment – Comparison of results of selected years

BE-share employment	1995	2002	2010	2011
Narrow definition of BE	8.2%	6.7%	5.8%	5.6%
Wide definition of BE	14.4%	13.8%	12.4%	12.8%
Efken et al. 2016		9.9%	12.4%	
Ronzon et al. 2017b			5.4%	
Van den Pas 2015	8.0%			7.0%

The BE-share of the wide definition of BE in 2010 has the same height as the numbers reported by Efken et al. (2016), while the value of 2002 differs by nearly 4 percentage points. In addition, according to our data, there has been a decline in employment, whereas data analyzed by Efken et al. (2016) show an increase. Shares reported by Ronzon et al. (2017b) and Van den Pas (2015) are close to our narrow definition. According to Van den Pas (2015), there is also a decline in employment and the results show similar values as in the narrow definition of BE.

In a next step, we analyze the BE employment in the different defined divisions of BE to see how the contributions might have changed. We compare the years 2000 and 2010, because data seems more reliable in 2010 compared to 2011. The share of the primary BE has been slightly reduced from 13.5% in 2000 to 12.9% in 2010. Secondary BE, i.e. the first processing stage, shows the highest shares with 28.3% in 2000 and 26.1% in 2010.

Figure 2: Employment by bioeconomy in Germany divided by divisions



Source: EXIOBASE 3.4 and own calculations

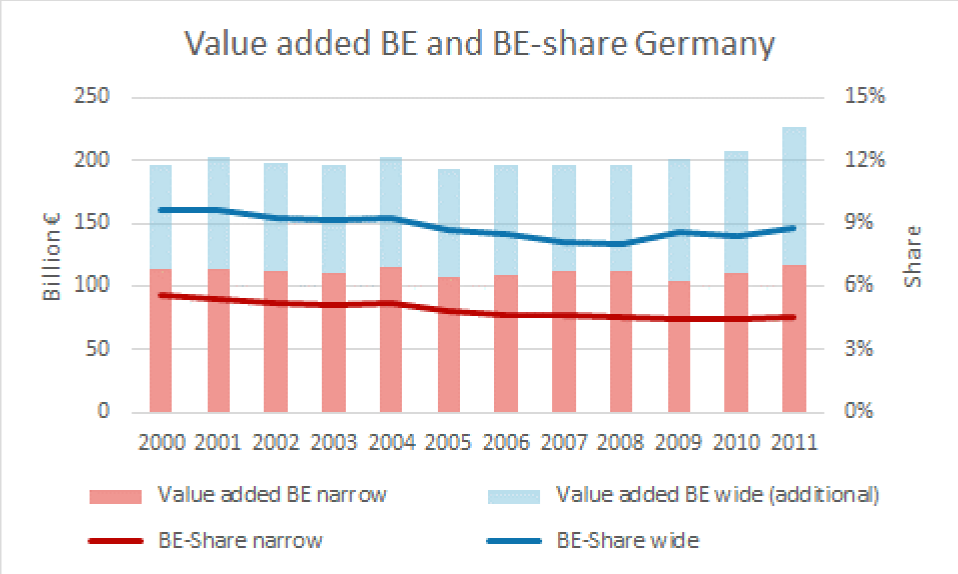
The proportions of employment in the different sectors of the BE have shifted from 2000 to 2010. The proportion of the sum of products and processed products (primary, secondary, manufacturing) has declined, especially in favor of hotels, restaurants and trade. This might be because part-time work has increased in service sectors (see also Efken et al. 2016) and no full-time equivalents are considered, so the share of these divisions increased.

3.2 VALUE ADDED

The level of gross value added of BE serves as an indicator for the impact of the BE on the overall economy. The gross value added is not explicitly stated in EXIOBASE, but it can be calculated: It is the result the sum of net taxes on production, compensation of employees and operating surplus.

By applying the BE-shares (see chapter 2), the BE specific value added can be identified and set in relation to the total gross value added of Germany, which is shown in the following graph.

Figure 3: Gross value added by bioeconomy in Germany



Source: EXIOBASE 3.4 and own calculations

For sectors of the narrow definition of BE, value added remains almost constant over time, but BE-share of the gross value added declines continuously. Between the years 2000 and 2011, gross value added of the BE rose by 15% (197 billion to 227 billion) for the wide definition with the highest increase from 2010 to 2011. For the narrow definition it rose only by 3% from 114 billion to 117 billion. This might be because of the upward trend for divisions of the wide definition in the last years. The value added in 2004 is relatively higher than in the rest of the period. This can be explained by an increase in bioenergy value added of 26% from 2003 to 2004.

Meanwhile, the BE-share of value added declined for both definitions, which means that the total gross value added of Germany has risen even more.

The results can't be compared to those of Ronzon et al. (2017b) in the Bioeconomy Report for the EU, because turnover is considered instead of value added. Turnover does not represent the real value added, because it includes double-counting (Ronzon et al. 2017a).

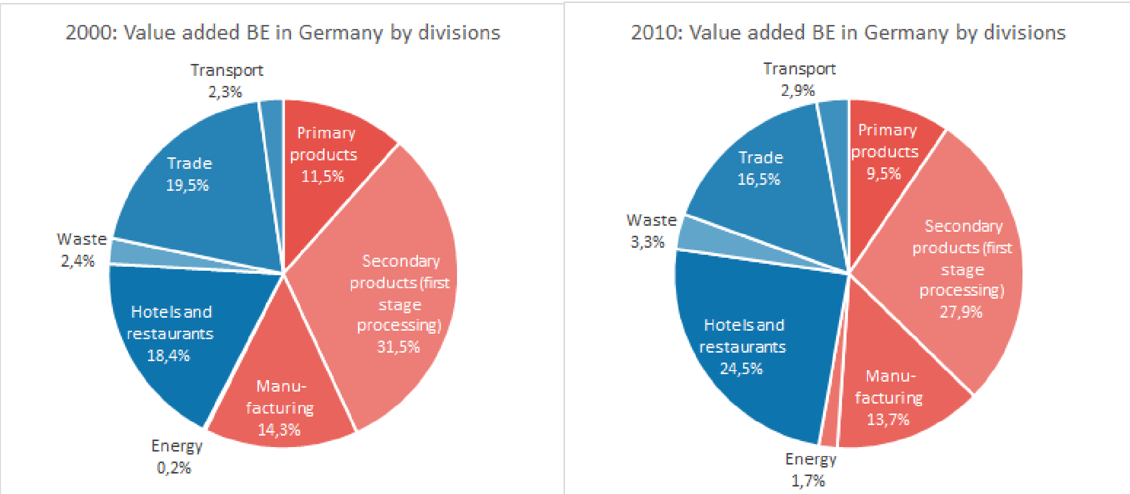
Table 3: BE-share in value added - Comparison

BE-share value added	1995	2002	2010	2011
Narrow definition of BE	6.2%	5.2%	4.4%	4.5%
Wide definition of BE	10.2%	9.3%	8.4%	8.7%
Efken et al. 2016		5.7%	6.0%	
Van den Pas 2015	6.3% (of GDP)			4.9% (of GDP)

Out of the comparison of the results in employment, we could see that Efken et al. follow rather the wide definition of BE. By comparing the value added, values are more similar to those of the narrow definition. As for employment, the BE-share is rising in Efken et al., while our results show a decline. The results in Van den Pas (2015) are similar to ours for the narrow definition.

We compare the contributions of the various BE divisions to identify changes in the composition of BE value added contribution.

Figure 4: Value added by bioeconomy in Germany divided by divisions



Source: EXIOBASE 3.4 and own calculations

The proportions of BE value added in different BE divisions have shifted between 2000 and 2010. The sum of the proportion of primary, processed products and trade has got smaller, while the proportions of hotels and restaurants, transport, energy and waste increased. In terms of energy and waste, this can be explained by the German Renewable Energy Sources Act and the Renewable Energy Directive of the European Union.

4 FOOD SECURITY

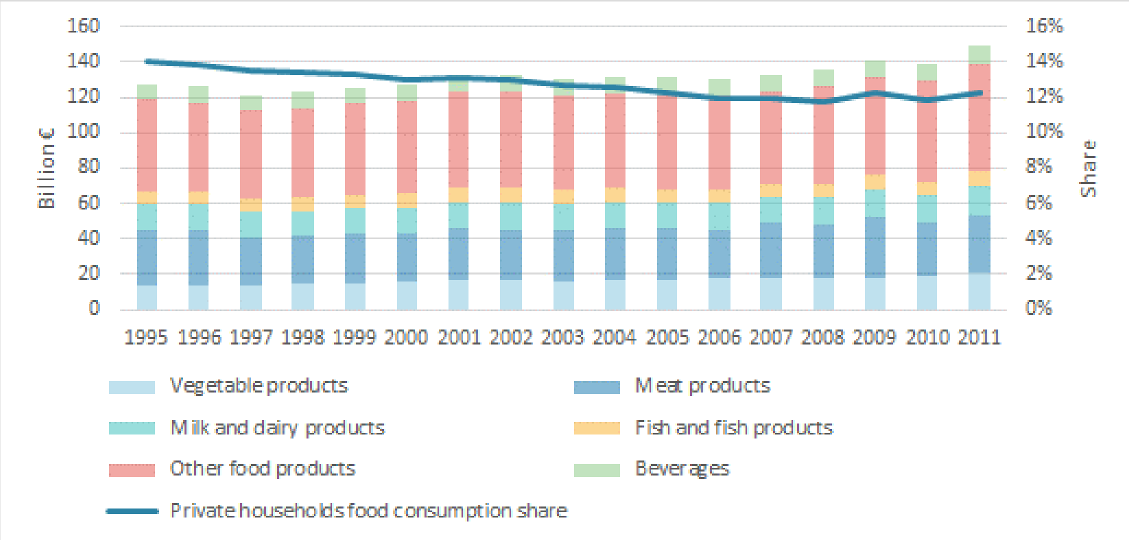
The respective goal and guiding principle of the National Policy Strategy on Bioeconomy is “a secure supply of high-quality food to the population in Germany; beyond this, within the scope of what is possible, a contribution towards securing the supply of food globally” (BMEL 2014). Food security is given a higher priority than the production of raw materials for industry and energy. This applies not only to the German strategy, but also internationally, which can be seen for example in the determination of the sustainable development goals (SDG). Food security is therefore a global key objective that is becoming increasingly important with a growing world population

To monitor this topic Egenolf & Bringezu suggest to look at three criteria: the food situation, price developments and self-sufficiency rates (Egenolf & Bringezu 2019, p. 10). All three criteria are examined in the following subchapters.

4.1 FOOD SITUATION

Food consumption of private households is used to analyze the food situation in a country and therefore serves as an welfare indicator (Zezza et al. 2017). The following figure shows the share of consumption expenditures on food products in total expenditure of private households and the kind of food on which the money is spent. The numbers are in current prices.

Figure 5: Private households consumption expenditures for nutrition in Germany



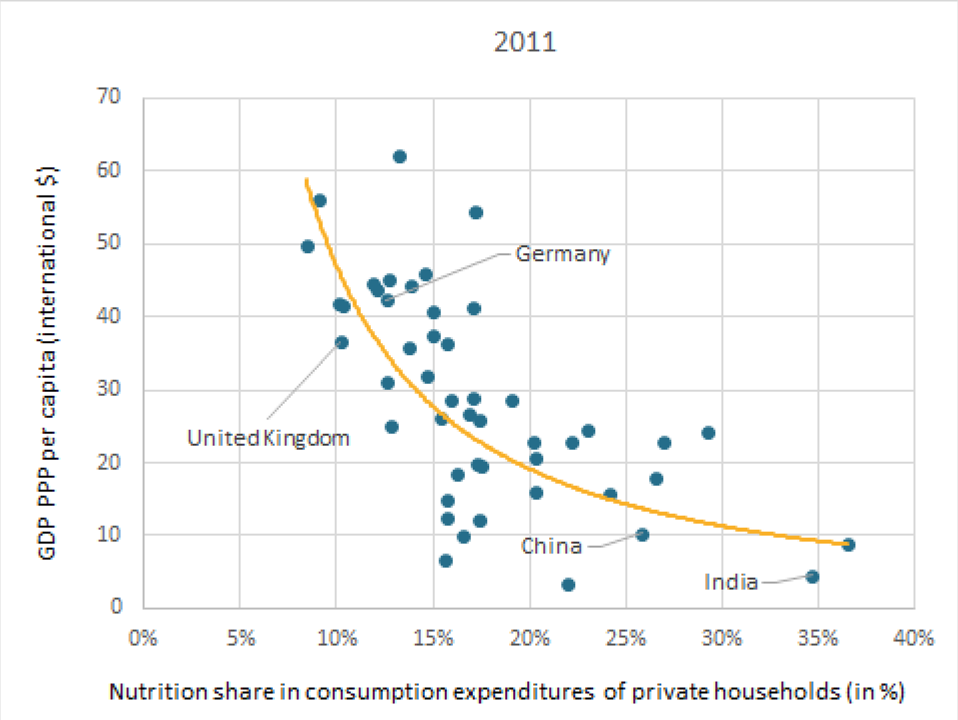
Source: EXIOBASE 3.4 and own calculations

The share of food products on overall consumption decreases continuously from 14% in 1995 until 2008 and then remains at about 12%. The distribution of different food product groups is always about the same, with the non-specific group "other food products" always accounting for the largest contribution, followed by meat products. Milk and dairy products rank third at the beginning of the time series, in which respective consumption increased by 11,5% until 2011. Nevertheless, the proportion of vegetable products is already larger in 1997 and increased by 52.4% until 2011. Thus, vegetable products also account for the highest increase from 1995 to 2011, the smallest increase was accounted for meat products with only 4%.

Household consumption expenditures for food is the product of the amount of food consumed and current food prices. Therefore, statements in physical units or in constant prices over time are not possible.

For a monitoring, it is interesting to evaluate the food situation in an international comparison. The following figure represents where all countries and regions are in GDP and nutrition share in consumption expenditures of private households.

Figure 6: International comparison of food situation



Source: EXIOBASE 3.4 and World Bank[6]

It can be seen that the German share of consumption expenditures on nutrition is rather low by international standards, while the GDP per capita tends to be in the upper range. One can also see that there is a connection between these two variables.

Information about imported and domestic products are reported in chapter 4.4 in the context of the self-sufficiency rate.

4.2 PRICE DEVELOPMENT

Food is a basic need of mankind and usually is over-represented in the basket of con-

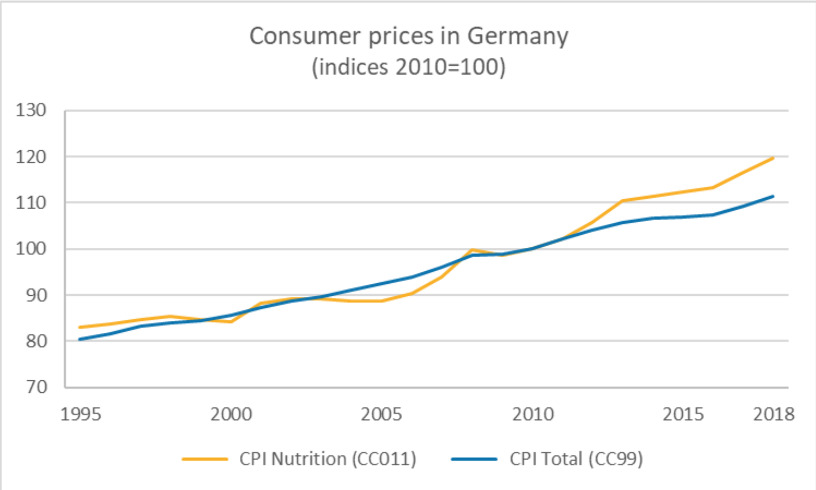
[6] World Bank GDP, PPP (current international $) Available online: https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD [accessed on January 17,2019]

sumer goods of poor and deprived households. Therefore, (above average) price increases of food commodities result in undesired social consequences.

The first indicator for price developments that has been used in the recent past is the development of consumer price index for nutrition. Figure 7 shows the development in Germany from 1995 to 2018.

For the national level one can observe, that the consumer price index for nutrition shows an above average increase since 2012. Whilst from 2010 to 2018 nutrition commodities became more expensive by 19.6% (+2.3% p.a.), the average price increase was only 11.4% (+1.4% p.a.).

Figure 7: Consumer prices nutrition in Germany



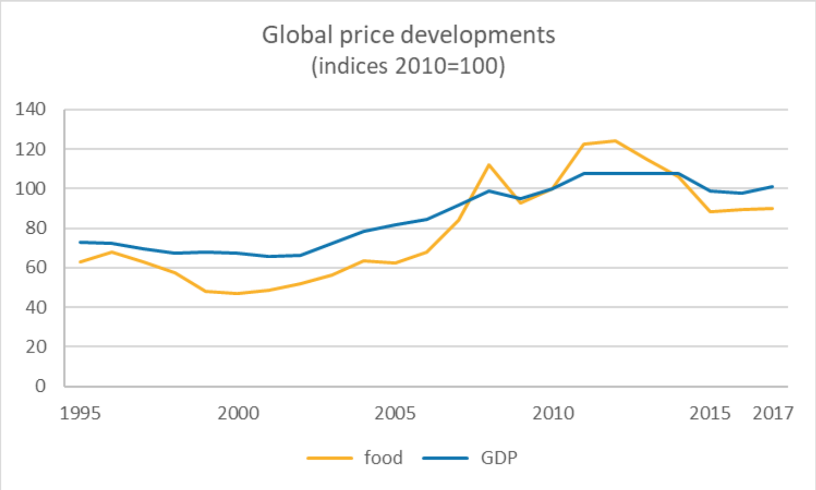
Source: Own illustration based on Destatis[7]

The second figure for the criteria price developments, the global development of food prices (Figure 8), deals with world market prices and is related to the Sustainable Development Goal (SDG) 2 “End hunger, achieve food security and improved nutrition and promote sustainable agriculture”.

The figure shows that the observation of persistent price increases in the period since 2012, as discovered for Germany, does not apply on a global scale. On the contrary, according to World Bank data from 2010 to 2017, world market prices for food decreased by 9.8% (-1.5% p.a.). In the same period the price deflator of the world GDP remained almost stable. Hence from a global perspective recent price developments do not indicate accelerating food security concerns.

[7] Statistisches Bundesamt (Destatis) Database. Available online: https://www.destatis.de/DE/ZahlenFakten/Datenbanken/Datenbanken.html [accessed on January 22, 2019]

Figure 8: World market prices for food



Source: Own illustration based on World Bank[8,9]

4.3 SHARE OF FOOD CONSUMPTION COVERED BY DOMESTIC PRODUCTION

Our third focus with regard to food security issues receives the question in how far food consumption in Germany is covered by domestic production.

In this regard the „Bundesanstalt für Landwirtschaft und Ernährung“ (BLE) publish self-sufficiency rates for different food commodity groups. They show the ratio between domestic production and domestic consumption. A ratio of more than 100% indicates, that domestic production exceeds domestic consumption and means that Germany is a net exporter of the respective commodity.

The left chart of Figure 9 shows respective assessment results of the BLE for three food commodities: cereals, meat and milk. Except the results for meat in the years up to 2005 all these rates exceed 100%. For vegetables and fruits assessments of the BLE are currently only available for one year but they show substantial lower values than for the other three commodities: In 2016 for vegetables the self-sufficiency rate in Germany was 37% and for fruits only 21.7%.

In the right chart of Figure 9 the BLE-values are contrasted with own assessments based on FAO data in combination with the EXIOBASE-MRIO data. These assessments ask for the Material footprints (= RMC[10]) “Cereals”, “Meat” and “Milk” of Germany and relate

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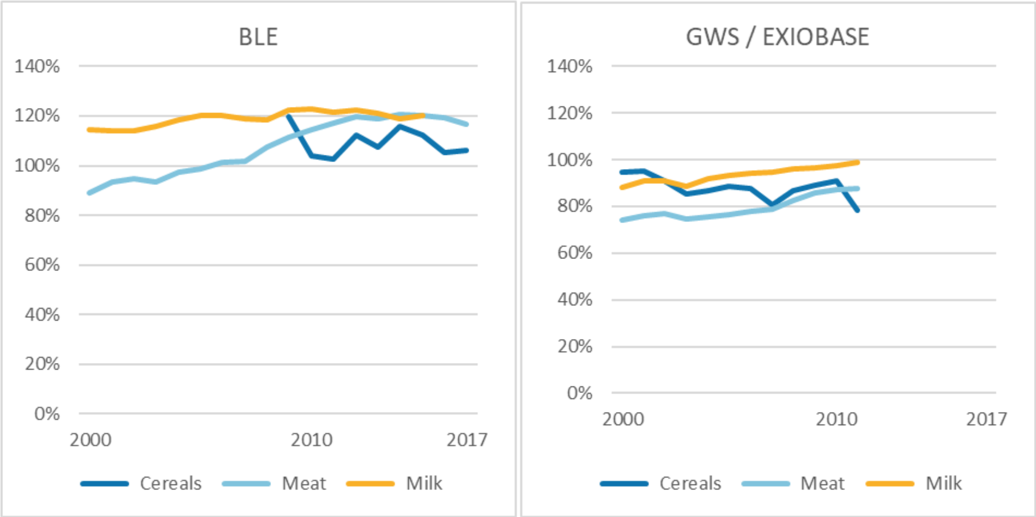
[8] World Bank Commodity Price Data Available online: https://databank.worldbank.org/data/databases/commodity-price-data [accessed on January 17,2019]

[9] World Bank, World Development Indicators. Available online: https://databank.worldbank.org/data/reports.aspx?source=world-development-indicators [accessed on January 17,2019]

[10] The Material Flow indicator „Raw Material Consumption” (RMC) usually is not applied for primary livestock products like meat or milk. But nevertheless this principle of indicator calculation can also be applied on primary livestock if the respective production quantities (in physical terms) are known. Therefore the EXIOBASE dataset was supplemented by FAO Data on primary livestock production.

these demand figures to the respective domestic production values.

Figure 9: Self-sufficiency rates in Germany



Source: Own illustration based on BLE[11] and own calculations based on FAO[12] and EXIOBASE 3.4

The results of EXIOBASE assessments data show for each category lower values than in the respective BLE data. The most likely reason for these discrepancies is that the MRIO assessments account for the whole global value chains that are involved in meeting domestic final demand in Germany.

[11] Bundesanstalt für Landwirtschaft und Ernährung (BLE) Nationale Versorgungsbilanzen. Available online: https://datenzentrum.ble.de/versorgung/ [accessed on January 17,2019]

[12] Food and Agriculture Organization of the United Nations (FAO) Agriculture Production data domain. Available online: http://www.fao.org/faostat/en/#data/ [accessed on January 17,2019]

5 RESPONSIBLE PRODUCTION AND CONSUMPTION

The topic of responsible production and consumption represents one of the 17 sustainable development goals (SDG 12), adopted by all United Nations Member States in 2015. In this regard, to decouple economic growth from resource use and environmental degradation is seen as one of the key objectives (United Nations 2018).

To monitor progress towards responsible production and consumption patterns the UN applies the indicator “material footprint”. This indicator “refers to the total amount of raw materials extracted globally — across the entire supply chain — to meet […] final consumption demand. People rely on such materials to meet basic needs — for food, clothing, water, shelter, infrastructure and many other aspects of life.” (United Nations 2018)

Beyond this the German BE strategy (BMEL 2014) itself explicitly mentions the goal of “sustainable consumption on the part of consumers, as a part of the bioeconomy’s value chain”. And the German national sustainability strategy contains the goal of an efficient use of raw materials. The recent progress report for Germany (Statistisches Bundesamt 2018) allocates this topic to SDG 8 (decent work and economic growth) and looks at the indicator “total resource productivity”. This indicator looks at the raw material input (RMI) instead of the raw material consumption (RMC = material footprint) and relates it to an indicator for economic growth.[13]

Last but not least the conceptualization of an indicator system for assessing the sustainability of the BE by Egenolf & Bringezu 2019 quote six headline indicators for sustainable resource use (Egenolf & Bringezu 2019, p.10):

- (Agricultural) land footprint
- Forest footprint
- Water footprint
- Climate footprint
- Material footprint = Raw Material Consumption [RMC]
- Total raw material productivity

As the first four indicators of this list are covered by own work packages of SYMOBIO respective findings for historic trends for these headline indicators are not subject to the paper at hand and the following remarks cover only the material footprint as well as the total raw material productivity.

As the taxonomy of economy-wide material flow indicators might not be familiar to every reader, the following table gives an overview in this regard (see also Umweltbundesamt 2016).

[13] In this case the total price adjusted final consumption, fixed capital formation and exports of the economy.

Table 4: Taxonomy of economy-wide material flow indicators

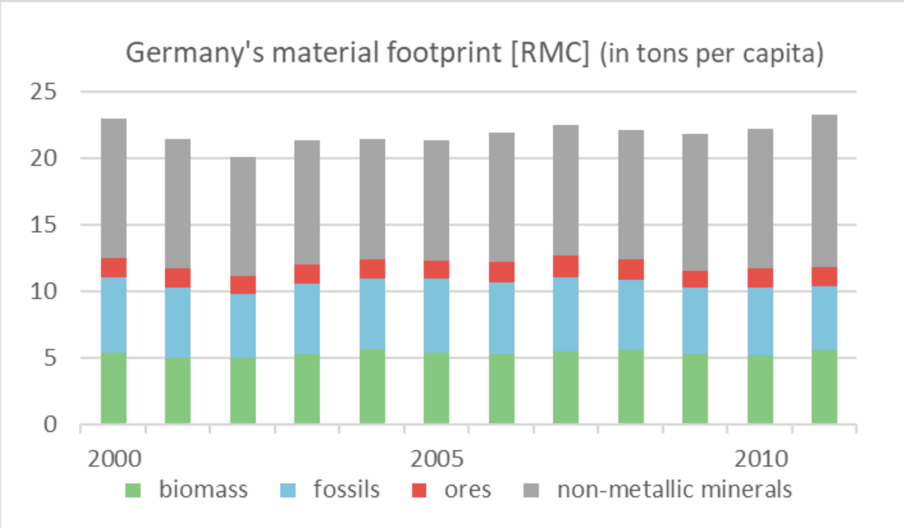
	Indicators relating to "**domestic extraction used**"		Indicators relating to "**domestic extraction used and unused**"
	Material footprint = Raw Material Consumption [RMC] = Global used extractions for domestic consumption and investment		Total material consumption [TMC] = Global used and unused extractions for domestic consumption and investment
+	Exports in Raw Material Equivalents [Exports in RME] = Mass of exports and their indirect material flows	+	Mass of exports and their indirect and hidden material flows
=	Raw Material Input [RMI]	=	Total Material Requirement [TMR]
-	Imports in Raw Material Equivalents [Imports in RME] = All used material flows in other countries, which are necessary to provide imported goods	+	All used and unused material flows in other countries, which are necessary to provide imported goods
=	Domestic Extraction Used [DEU]	=	Domestic Extraction Used [DEU] + Unused Domestic Extraction [UDE]
+	Mass of directly imported raw materials, semi-finished and finished goods		
-	Mass of directly exported raw materials, semi-finished and finished goods		
=	Domestic Material Consumption [DMC]		

Source: Own compilation

5.1 MATERIAL FOOTPRINT

The following figure shows the evolution of Germany's material footprint, expressed in tons per capita, in the period from 2000 to 2011. This indicator fluctuated in a range between 20 and 23 tons and no clear trend could be observed, neither with regard to the overall amount nor with regard to the material composition.

Figure 10: Germany's material footprint per capita



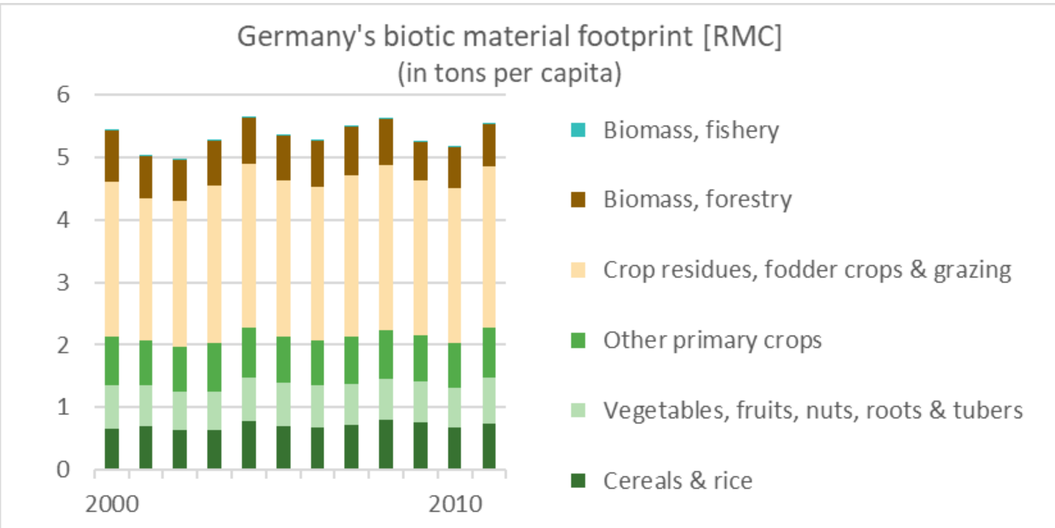
Source: Own assessment and illustration based on EXIOBASE 3.4

Compared to assessments by the federal statistical office these figures are 35 to 40% higher. Reasons for these deviations are rooted in differences in the data backgrounds as well as in the used assessment methods.

Compared to assessments for the UNEP-IRP, based on a different MRIO data background, our EXIOBASE-assessments show minor differences. E.g. for 2010 our EXIOBASE assessments for Germany calculate an overall material footprint of 1.797 Gigatons. The respective assessment for UNEP shows a value of 1.752 Gigatons (see UNEP 2015).

The following Figure 11 shows the same observation, but this time only for the biomass. Again for the history neither an increase nor a decrease of the material footprint can be identified. The overall sum fluctuated between 5.0 and 5.6 tons per capita.

Figure 11: Germany's biotic material footprint per capita

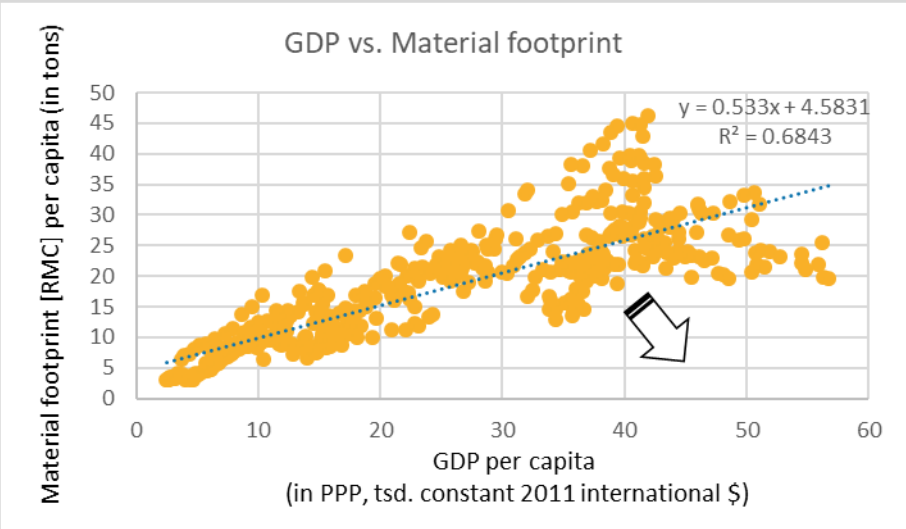


Source: Own assessment and illustration based on EXIOBASE 3.4

Our last attention with regard to the Material Footprint is focused on an international comparison for the per capita material footprints. The following figure shows the correlation between the Material Footprint per capita and the GDP per capita, measured in purchasing power parities. Basis for this diagram are on the one hand the Material Footprint assessments for all countries and regions in EXIOBASE with more than 5 Million inhabitants and for all years between 2000 and 2011. The related GDP figures have been gathered from the Database "World Development Indicators" by the World Bank.

As indicated by the arrow in the figure the aspired movement towards a Material Footprint of considerable lower than 10 tons per capita and a simultaneous increase in per capita GDP would imply a rather ambitious transformation that has no role model in history.

Figure 12: The correlation between Material Footprint and GDP



Sources: Own assessment and illustration based on EXIOBASE 3.4 & World Bank, World Development Indicators database.

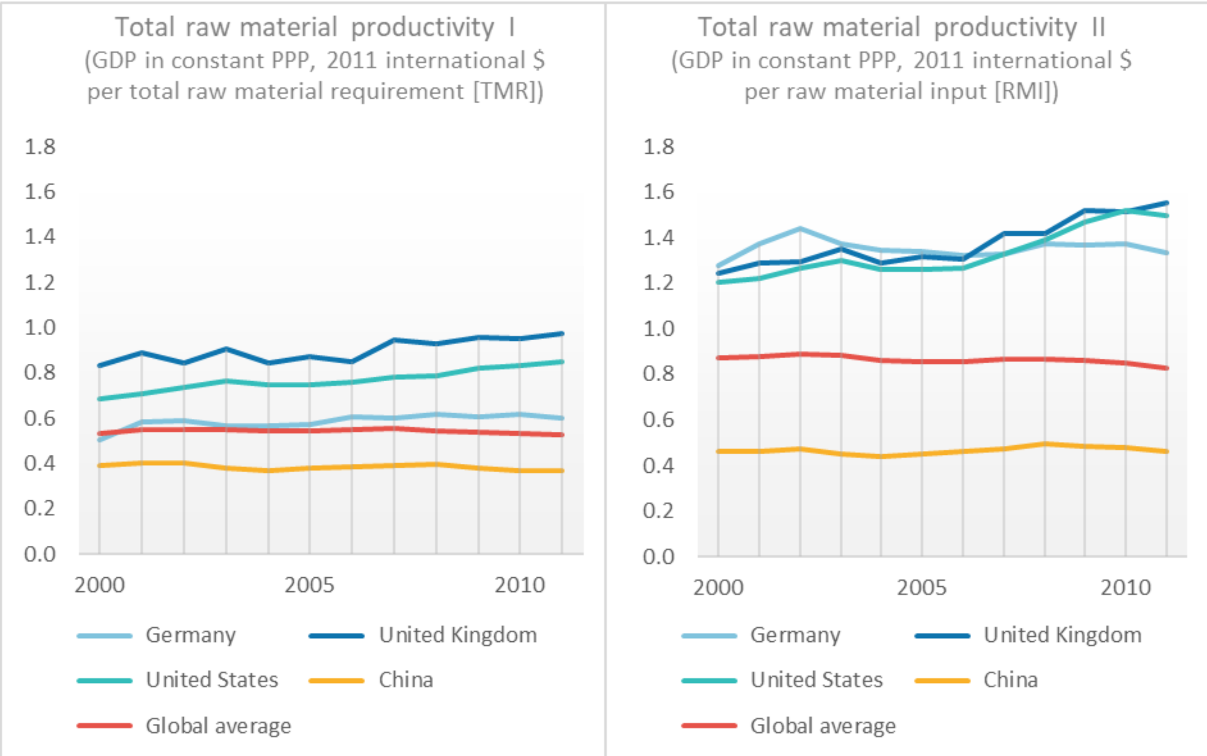
5.2 TOTAL RAW MATERIAL PRODUCTIVITY

Whilst the development of the Material Footprint is related to the ambition of an absolute decoupling in addition also a monitoring of progress towards a relative decoupling is very instructive. To do so, economy-wide resource material flow indicators are related to macro-economic indicators. Respective relations with the macro-economic indicator as numerator show the economy-wide resource productivity developments. Relations with macro-economic indicator as denominator show the development of economy-wide resource intensities.

The following assessment looks at the relation between the GDP (in constant PPP) and (1) the total raw material requirement TMR and (2) the raw material input RMI. The left diagram of Figure 13 shows, that from 2000 to 2011 the total resource productivity on average grew by 1.7% p.a. in Germany. This progress is lower than in the USA (+2.0%

p.a.) but higher than in China and in the global average. In the global average we could observe a stagnating resource productivity and in China even a decline in resource productivity (-0.5% p.a.). But nevertheless, the diagram also shows an alarming low productivity value range for Germany, compared to other comparingly wealthy nations. This finding is especially pronounced for the relation between GDP and TMR. If we look instead at the productivity defined as fraction of GDP and RMI (right diagram of Figure 13) this alarming observation more or less disappears. The reason behind this finding is the above average importance of unused extractions in Germany that is rooted in the extraction of lignite in open-cast mines.

Figure 13: Total raw material productivity



Source: Own assessment and illustration based on EXIOBASE 3.4 & World Bank, World Development Indicators database.

6 CONCLUSIONS

Following the approach and data proposed in this paper, the results of the analysis show the importance of the socioeconomic dimension of BE in Germany. For this documentation of WP 4.1, initially historical trends are of interest. The ongoing work deals with a counterfactual simulation and the development of future trends.

We do not assume that the list of indicators described here is comprehensive, it is not a conclusive consideration and there are further indicators that might be of interest. However, the indicators presented here provide a first impression of the socio-economic dimension of the German BE in historic trends. The results were compared with previous analyzes and statistics.

It became clear that MRIO-analyzes provide an extensive view on socioeconomic indicators and also include indirect effects, which is not possible in national statistics. This is e.g. visible at the height of the material footprint.

For a comprehensive monitoring it has to be acknowledged, that the socio-economic dimension is only one part and has to be complemented by footprints of land, water, forest and GHG.

BE can be defined in a narrow and wide definition, results for both definitions have been reported. On macroeconomic level, service sectors play a significant role for BE and increased both in employment and value added, while producing divisions (primary, secondary, manufacturing) decreased. The role of energy and waste is still very small, but increased significantly.

While working with the EXIOBASE database, it was ascertained that some included data is not reliable when compared to other statistics. Therefore we had to resort to other databases and statistics at some stages. Nevertheless, it is still very useful to have such a detailed and balanced global database, otherwise the MRIO-Analysis would not be possible.

The implemented modeling approach is a powerful tool when using different definitions of the BE, because single sectors can be added or taken out. This is especially helpful for comparisons with other approaches and information from other databases.

International comparisons are easily possible, because the entire world is represented. This application could certainly be expanded at several points. The only restriction here is that the data validity has to be checked.

BIBLIOGRAPHY

Bioökonomierat (2009): Combine disciplines, improve parameters, seek out international partnerships - First recommendations for research into the bio-economy in Germany.

BMEL (2014): National Policy Strategy on Bioeconomy: Renewable resources and biotechnological processes as a basis for food, industry and energy. BMEL (Federal Ministry of Food and Agriculture), Berlin

Bracco, S., Calicioglu, O., Gomez San Juan, M., & Flammini, A. (2018): Assessing the Contribution of Bioeconomy to the Total Economy: A Review of National Frameworks. *Sustainability*, *10*(6), 1698.

Distelkamp, M., Lutz, C., Flaute, M., Maßmann, L. (2017): Indikatoren für ein systemisches Monitoring der Bioökonomie. Die sozio-ökonomischen Dimensionen.

Dries, L., Klomp, J., van Ophem, J., Zhu, X. (2016): Social science perspectives on the bio-economy. NJAS – Wageningen Journal of Life Sciences, 77, 1-4. doi: https://doi.org/10.1016/j.njas.2016.04.001.

Efken, J., Dirksmeyer, W., Kreins, P., Knecht, M. (2016): Measuring the importance of bioeconomy in Germany: Concept and illustration. NJAS Wageningen Journal of Life Sciences 77, pp. 9-17, 2016.

Egenolf, V., & Bringezu, S. (2019): Conceptualization of an Indicator System for Assessing the Sustainability of the Bioeconomy. *Sustainability*, *11*(2), 443.

European Commission (2012): Innovating for Sustainable Growth – A Bioeconomy for Europe. COM(2012) 60 final. Brussels.

Flaute, M., Lutz, C. & Distelkamp, M. (2017): Der Einsatz von MRIO zur Berechnung der Fußabdrücke von Nationen - Eine Anwendung der EXIOBASE-Datenbank. GWS Discussion Paper 17/07, Osnabrück, 2017.

Lutz, C., Bruckner, M., Giljum, S., Wiebe, K. S. (2012): Materials embodied in international trade - Global material extraction and global material consumption between 1995 and 2005. Global Environmental Change, 22(3), pp. 568-576.

Ronzon, T., & M'Barek, R. (2018): Socioeconomic Indicators to Monitor the EU's Bioeconomy in Transition. *Sustainability*, *10*(6), 1745.

Ronzon, T., Piotrowski, S., M'Barek, R., Carus, M. (2017a): A systematic approach to understanding and quantifying the EU's bioeconomy. Bio-based and Applied Economics 6(1), pp. 1-17, 2017.

Ronzon, T., Lusser, M., Klinkenberg, M.(ed.), Landa, L., Sanchez Lopez, J.(ed.), M'Barek, R., Hadjamu, G.,(ed.), Belward, A.(ed.), Camia, A.(ed.), Giuntoli, J., Cristobal, J., Parisi, C., Ferrari, E., Marelli, L., Torres de Matos, C., Gomez Barbero, M., Rodriguez Cerezo, E. (2017b): Bioeconomy Report 2016. JRC Scientific and Policy Report. EUR 28468 EN

Statistisches Bundesamt 2018: Nachhaltige Entwicklung in Deutschland. Indikatorenbericht 2018.

United Nations 2018: The Sustainable Development Goals Report 2018. https://unstats.un.org/sdgs/report/2018/overview/

Van de Pas, J. (2015): The bioeconomy: definitions and measurement. http://edepot.wur.nl/338454

Wiebe, K. S., Gandy, S. & Lutz, C. (2016): Policies and Consumption-Based Carbon Emissions from a Top-Down and a Bottom-Up Perspective, in: Low Carbon Economy, 7, pp. 21-35.

Wiebe, K. S., Lutz, C., Bruckner, M., Giljum, S. (2012): Calculating energy-related CO_2 emissions embodied in international trade using a global input-output model. Economic Systems Research, 24(2), pp. 113-139.

Wood, R., Stadler, K., Bulavskaya, T., Lutter, S., Giljum, S., de Koning, A., Kuenen, J., Schuetz, H., Acosta-Fernandez, J., Usubiaga, A., Simas, M., Ivanova, O., Weinzettel, J., Schmidt, J. H., Merciai, S., Tukker, A. (2015): Global Sustainability Accounting-Developing EXIOBASE for Multi-Regional Footprint Analysis. Sustainability, 7, pp. 138-163.

Zezza, A., Carletto, C., Fiedler, J. L., Gennari, P., & Jolliffe, D. (2017): Food counts. Measuring food consumption and expenditures in household consumption and expenditure surveys (HCES). Introduction to the special issue. *Food policy*, *72*, 1-6.