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Interactive analysis of individual consumption patterns with regard to raw-material availability: The web tool My Raw Material World

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GWS DISCUSSION PAPER 2016 / 02

**Interactive analysis of individual consumption patterns with regard to raw-material availability
– The web tool My Raw Material World.**

Gerd Ahlert

Frank Hohmann

Michael Lettenmeier (WI)

Christa Liedke (WI)

Mark Meyer

Sören Steger (WI)

Impressum

AUTHORS

Gerd Ahlert, Mark Meyer, Frank Hohmann

Tel: +49 (541) 40933-170, Email: ahlert@gws-os.com

Michael Lettenmeier, Christa Liedtke, Sören Steger,

in collaboration with Jola Welfens, Kathrin Greiff, Jens Teubler, Johannes Buhl and Michael Schipperges

Wuppertal Institut für Klima, Umwelt, Energie GmbH

Döppersberg 19, 42103 Wuppertal, Email: michael.lettenmeier@wupperinst.org

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1 INTRODUCTION

The sustainable use of natural resources has been intensively discussed in politics and businesses during the recent years (i.a. Giljum et al. 2014, Fischer-Kowalski et al. 2011, Bringezu & Bleischwitz 2009). This discussion has been triggered by price fluctuations in commodity markets due to the increasing global consumption of raw materials such as oil, coal, steel, copper and other metals and thus to sustainability challenges.

In 2050, more than nine billion people will be expected to inhabit the earth. According to forecasts, this population increase might boost the global economy to grow by an average annual rate of three percent until 2030. At the same time, emerging countries' industrialisation processes will further contribute to increases in global raw material consumption triggered by a growing global consumer class (Ward & Neumann 2012).

Against this background, the European Union (EU) aims to increase resource efficiency by 20 percent until 2020. The German federal government has adopted a pioneering role here with its raw materials strategy "ProgRes" from the beginning of 2012 (BMU 2012). The challenges for transformation to a low resource economy and society were described by Meyer (2007), Schmidt-Bleek (1993, 2007) reflecting the limited environmental space which produces via natural services our welfare. Last argumentation links to discussion and estimation of the natural burdens described by Rockström et al. (2009).

While the problem of overexploitation of natural resources is discussed in politics and business as well as in science on the macro level, the sensitisation of German consumers towards the principles of sustainability and global fairness with regard to their own raw material consumption is less strongly on the micro level of individual and households needs (Lettenmeier et al. 2014, Baedeker et al 2014, www.ressourcen-rechner.de, Liedtke et al. 2013). In contrast to climate change and energy issues for the critical raw material problems on household level so far, only initial concepts for raising awareness exist. For example the EU project SuslabNWE (Sustainable Living Lab North West Europe, www.suslabnwe.eu) analysed households resource consumption in detail and showed a great variety in social practices and connected resources (Baedeker et al. 2014, Greiff et al. 2016) as well as the finish studies of household consumption (Kotakorpi et al. 2008, Lettenmeier et al. 2014).

The research project "Global nachhaltige materielle Wohlstandsniveaus" (Globally sustainable material prosperity standards) analysed material needs for German households' inventory with durable consumer goods (Ahlert et al. 2015). The project (duration: September 2012 – October 2014) was commissioned by the German Federal Environment Agency (UBA) and funded by the German national environmental research plan (project no. FKZ 371114105)

Based on these findings, prototypical household endowments can be classified within the boundary conditions of global fairness and sustainable resource use. The applied classification scheme is based on the methodological concept of availability corridors that was developed and implemented over the project term by the Institute of Economic Structures Research (GWS) and the Wuppertal Institute for Climate, Environment and Energy.

The methodological and empirical research has been accompanied by software development: A handy, easy understandable and instructive web tool ("My Raw Material World") in German language has been established that illustrates the main findings of the research project in an intuitive way. Users can experience the research topic "raw material consumption and sustainability" in the context of their own household equipment and identify the implied material needs of individual consumption patterns.

2 THE WEB TOOL AT A GLANCE¹

A major aim of the project was the development of a web tool that sensitises its users to their own consumption decisions in favour of globally fair and sustainable use of resources. The web tool is more than just a simple calculator. It contains valuable background information about the durable household goods and materials. Furthermore, it gives advice to help users to consume resources more sustainable.

Given that, the web tool should address a general public, where usability and understandability were key design issues of the graphical user interface. The prototypically established web tool thus features an easy-to-follow menu structure. Scientific expertise is not required to understand the textual content.

On start-up, the web tool shows a menu bar at the top of the screen, which is visible and accessible at any time. A tab control shows additional menu entries, which may appear depending on the previously selected main menu entry (see Figure 1).

Figure 1: Main menu structure of the web tool

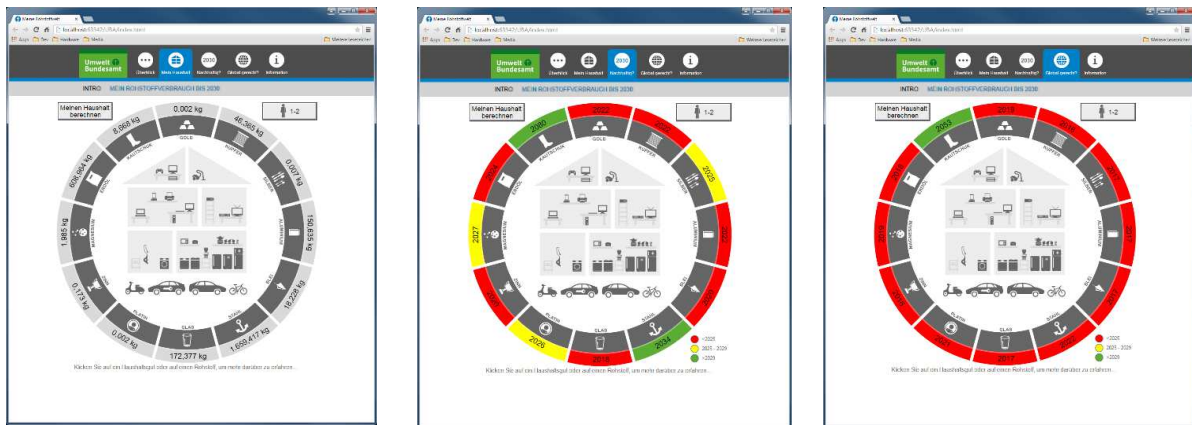


Source: Own figure

The visualisation depends on the selected main menu entry (see Figure 2). The result display is realized by a circle, containing a symbol for each of the priority raw materials combined with the total amount of the respective raw material in kilograms (comp. Figure 2). Within the raw material circle, the household is represented by a picture of a house furnished with all 24 durable goods.

¹ A German-language version of the web tool is publicly available at the following web address: <http://resourcetool.gws-os.com/>

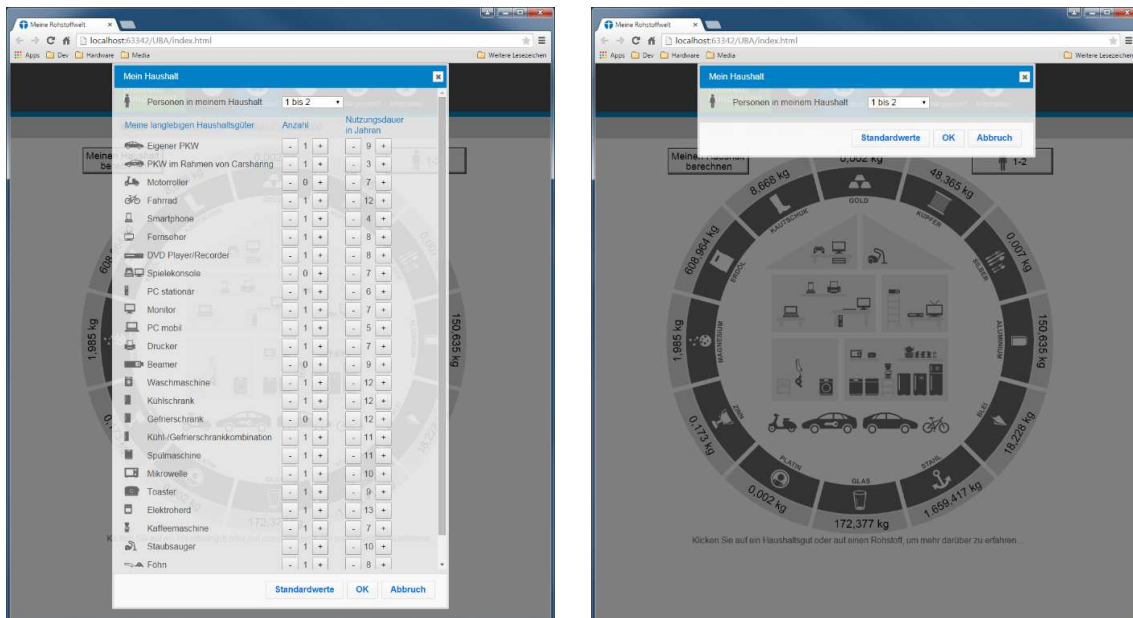
Figure 2: Visualization of results



Source: Own figure

Within the tool the analytical focus is the inventory of durable household goods at the individual household level. Therefore the internet application contains an interactive part in the selection menu “My Household” (see Figure 3). There the user is able to insert the quantity of his or her household equipment of durable goods and the expected useful lives. The pre-setting of the useful lives and the quantity of the household equipment are based on the findings of the survey – the user only has to readjust and, when indicated, to rectify the number of persons living in his or her household. Thus, in the selection menu “My Household”, the user can analyse his or her own consumption patterns in terms of the raw material inventory of durable household goods quantitatively.

Figure 3: Editor for household inventory and the product specific useful lives of the consumer durables



Source: Own figure

On this basis the web tool calculates both resource inventory and future availability of the

raw materials and shows the result in the outer ring of the circle-based result illustration design. Clicking on the icons for the goods opens a product-specific fact sheet and on the icons for raw materials a raw material-specific fact sheets.

The selection menus “Nachhaltig” (“Sustainable“) and “Global gerecht & Nachhaltig” (“Globally fair and sustainable“) present overshoot years under the premise of the correspondent scenarios instead of the amount of the raw materials (see Figure 6). The overshoot years are arranged in the circle of raw materials, too. For a better intuitive understanding, they are highlighted in colour: Green stands for overshoot years after the year 2029, yellow for overshoot years in between 2025 to 2029 and red for all years before the year 2025. In these selection menus, the user is able to retrieve the raw material-specific and product-specific fact sheets, too. By changing the quantity of the household equipment and the expected useful lives, the user can discover playfully how to shift the overshoot years further backwards.

As already mentioned, the web tool includes a selection of 24 durable household goods² such as white goods (for example dishwashers, refrigerators and freezers), but also televisions, smartphones, computers, cars and bikes. In a pre-selection for the raw materials, the most important 12 raw materials were identified. These priority raw materials have a certain criticality with regard to the future security of supply and environmental aspects and they can be found in the above mentioned goods in a relevant quantity. The tool excludes both the energy raw materials required for running the goods and raw materials that are used upstream in the production process of the goods but not included any more in the good itself (Liedtke et al. 2014).

An important basis of the calculations is the concept of availability corridors. These availability corridors specify for each raw material the quantity that is expected to be available by 2030. These results of economic and technological considerations can be connected with ecological targets (Bringezu 2014, Lettenmeier et al. 2014, Meyer 2007). Besides a “Business-as-Usual” projection, two scenarios are analysed: The scenario “Sustainable“, which additionally assumes a reduction in resource extraction on the year 2000 levels up to 2030, and the scenario “Globally fair and sustainable“, which also anticipates a worldwide equal per capita distribution of the corridors in addition to reducing the level of resource extraction. For the calculation procedure, these corridors are used as per capita values and result – multiplied by the number of persons – in a household budget, which is provided up to 2030. An illustration of some detail results is given in the next section.

In addition to the availability corridors, raw material inventories of household goods play an important role. They specify for each of the 24 durable household goods the amount of the 12 raw materials the specific product contains. In order to map an apt consumption of raw materials by 2030, information about the expected useful life is needed, too. For most household durables, no adjuvant information about the average expected useful life is publicly available. Because of this, a representative panel survey was conducted, which determined the expected useful life for each of the 24 household goods (see Ahlert et al., 2015, p. 129).

² Selection criteria have been the criteria of quantity, environmental impact, and security of supply incl. global shortage.

Table 1: List of durable household goods and raw materials used in the web tool

No.	Durable household good	No.	Raw material
1	Car	1	Gold
2	Scooter	2	Copper
3	Bicycle	3	Silver
4	Mobile phone / Smartphone	4	Aluminium
5	TV	5	Lead
6	DVD player / recorder	6	Steel
7	Game console	7	Glass
8	Personal computer	8	Platinum
9	Monitor	9	Tin
10	Mobile computer	10	Magnesium
11	Printer	11	Oil for plastic
12	Projector	12	Rubber
13	Washing machine		
14	Refrigerator		
15	Freezer		
16	Freezer / refrigerator combination		
17	Dishwasher		
18	Microwave oven		
19	Toaster		
20	Electric cooker		
21	Coffee machine		
22	Hoover		
23	Hairdryer		
24	Cutlery		

Source: Own figure

A combination of raw material inventories with the quantity of household equipment and useful lives, provides the individual raw material consumption of the private household. A comparison with the corresponding availability corridors respectively the total physical raw material household consumption budget per capita shows whether the household's consumption is sustainable in the sense of the given restrictions until the year 2030: If the household uses up its budget earlier, there is a sustainability gap. This gap can be illustrated by the overshoot year – the year in which the household has already used up its budget.³

³ The concept of Earth Overshoot Day was first conceived by Andrew Simms of the UK think tank New Economics Foundation, which partnered with Global Footprint Network in 2006 to launch the first global Earth Overshoot Day campaign.

In the case of the sustainability gap, the overshoot year lies before 2030. In all other cases, the budget reaches out over 2030 and will not be overdrawn.

3 DATA, CONCEPTS AND METHODOLOGIES APPLIED WITHIN THE WEB TOOL

An important basis of the calculations is the concept of availability corridors. These availability corridors specify balances for each raw material and the quantity that is expected to be available by 2030. In addition to the available corridors, raw material inventories of household goods play an important role. They specify for each of the 24 durable household goods the amount of the 12 raw materials the specific product contains.

3.1 RAW MATERIAL BALANCES OF DURABLE HOUSEHOLD GOODS IN THE CONTEXT OF ALTERNATIVE AVAILABILITY CORRIDORS CONCEPTS

The first step of the project was to analyse the material balances of 24 durable household goods and to develop a priority list of the most important raw materials based on different criteria. The analysis of the material balances initially led to a total list of 63 materials, which was reduced to 34 materials (e.g. by converting individual types of plastics into oil equivalents) for further analysis. 12 of the 34 materials were selected to be studied in detail and became part of the web tool. By the use of this tool, users can check the material requirements of their current and future household equipment based on selected durable goods.

The selection of materials was based on the criteria of quantity, environmental impact, and security of supply incl. global shortage. Individual rankings were compiled for each of the criteria. The environmental relevance was assessed by using the two input-oriented indicators of absolute cumulative energy demand (CED) and absolute abiotic material input ($MI_{abiotic}$). All materials, which have been in at least two of the four individual rankings among the top 15, were included in the final compilation of the priority list.

Quantitative relevance was based on specific material contents of the analysed durable household goods, multiplied by the amount of household goods sold in Germany 2010. The amount of material required for these selected goods in Germany was placed in relation to the respective amount of global production of primary raw materials in 2010.

Environmental relevance was considered as a result of the multiplication of the specific CED and $MI_{abiotic}$ coefficients of analysed materials with the respective amount of material, which resulted from the sold numbers of the 24 household goods in Germany in the year 2010.

Table 2: Availability corridors summed up per capita for the period 2010-2030

2010-2030	Availability corridor (kg per person)		
	BAU (Baseline)	Sustainable	Globally fair & sustainable
Aluminium	88.3	57.6	13.5
Copper	27.5	19.0	3.2
Gold	0.0011	0.0008	0.0005
Raw Steel	2482.0	1757.3	641.3
Palladium	0.0005	0.0004	0.0002
Platinum	0.0017	0.0012	0.0006
Tin	0.0469	0.0473	0.0112
Lead	7.2	5.0	1.5
Zinc	0.32	0.22	0.06
Silver	0.0057	0.0039	0.0009
Chrome	0.39	0.25	0.02
Magnesium	1.86	1.26	0.43
(Sheet) Glass	55.2	31.3	20.7
Oil for Plastics	304.7	296.0	100.7
Cotton	186.6	153.9	66.8
Natural Rubber	40.1	31.0	18.1

Source: Own calculations

Security of supply and global scarcity were measured by an additively composed index of four equally weighted indicators: a) static lifetime, b) global demand pulse by future technologies, c) share of global primary and secondary products, and d) recyclability. Each of the four sub-indicators could receive a value of 0; 0.3; 0.7 or 1.

For the 12 priority raw materials the expected global availability was estimated until the year 2030 using the trend projection of the (primary) production volumes for the years 2000 to 2012 (BAU), a sustainability scenario, in which the mining or production volumes will return to year 2000 levels until 2030 and thirdly the global fairness scenario, in which besides sustainability also uniform global per capita shares in 2030 are assumed.

Based on the estimated global population growth until 2030 and the proportion of the selected durable consumer goods in the respective global material demand, we were able to calculate a per capita value that is mathematically available for every German citizen for their consumption of durable household goods until 2030. Overall, for the selected materials these availability corridors were calculated for three scenarios (Business-as-usual (BAU), Sustainable, Globally fair and sustainable, see

Table 2). The scenario "Sustainable" reflects the current high differences in per capita consumption across the world, whereas the scenario "Globally fair and sustainable" assumes uniform global per capita shares in 2030.

The different scenario corridors are the basis for the web application, which allows users to determine the resource requirements of their household equipment. With the help of this web tool users can assess whether their household equipment corresponds with the available amount of materials within these corridors. In addition, users can determine, which household equipment, and which life span of those household goods, would be necessary to comply with these limits.

Within the research project two methodological proposals were developed: First, it was assessed how these availability corridors can be translated into "material budgets", which can be used to calculate e.g. "overshoot days". This calculation approach describes the availability of raw materials both within the annual budget per person as well as in the total budgets for a period such as from 2010 to 2030. Within the web tool, the stock of household goods was only associated with typical life spans, and therefore included replacement investments until 2030. However, it would also be possible to estimate the effects on the personal material budget of each individual material by real or planned new acquisitions in the future.

From an ecological point of a view, reduction targets for total raw materials, which are extracted from the environment, as well as targets for reducing potentially negative environmental impacts, should be preferred to reduction targets for individual materials in order to prevent problem shifting by substitution. The decisive criterion for calculations is the concept of functional equivalence, as it is given for example with the units of greenhouse gas (GHG) emissions-potential or primary energy consumption. Analogously raw materials can be expressed by their primary material equivalent (i.e. as material input (MI) or Total Material Requirement (TMR)), or as a raw material equivalent, i.e. as a cumulative raw material equivalent (RME). To this end, the weight of the raw materials is only of minor relevance. A simple adding of the amount of steel and gold makes little sense, whereas an addition of MI or RME equivalents is useful for interpreting results (i.a. Liedtke et al. 2014).

Therefore, a second method was developed based on functional equivalence values. In order to use the respective equivalent values as a budget until 2030, however, an absolute target for the target year (in this case 2030) needed to be defined. Such targets are currently in the political debate. Therefore, a possible reduction target, which is currently being discussed in the PolRes project (10 tonnes / person for $TMC_{abiotic}$ in 2050, corresponding to 5.2 tonnes / person for RMC), was applied. It should be noted that these targets refer to total resource requirements per person, and not just the portion that is required for the production of durable household goods.

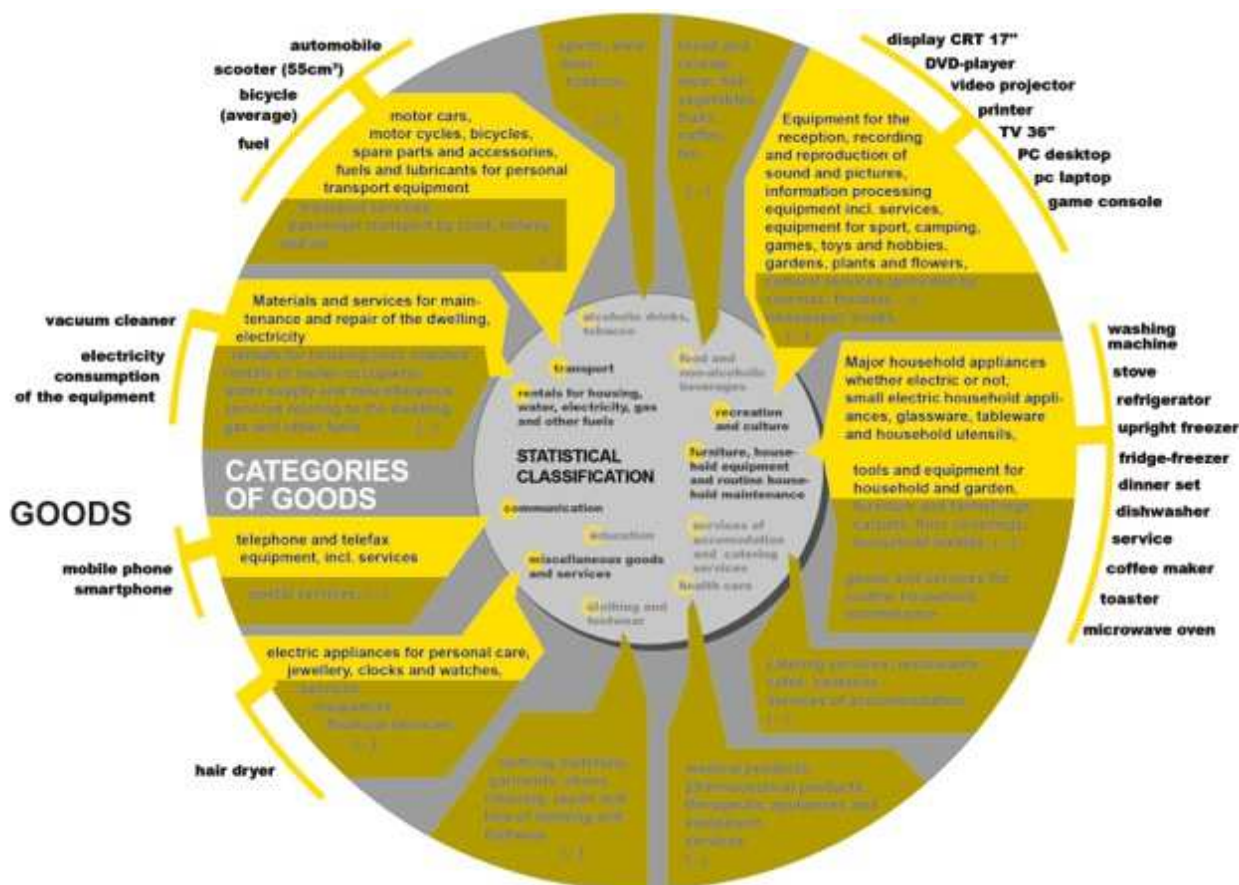
The proportion of the amount of resources used for durable household goods in the total raw material requirements per year is a critical control variable in determining availability corridors as well as material budgets. The derivation of this share on the basis of the apparent consumption of 24 selected durable household goods a) leads to very different percentages depending on the material analysed and b) tends to underestimate the shares since the selection of household goods covers relevant shares, but not the complete consumption of private households with durable goods. Another critical aspect of this method

is the use of material balances that do not correspond with the current material composition of household goods. Therefore, an alternative method has been described to quantify the share of household goods of total material consumption: By using an extended input-output (IO) table (Watson et al. 2013), it is possible to determine the share of different categories of final use, such as private households, on raw material consumption.

3.2 INVENTORIES FOR RAW MATERIALS INCORPORATED WITHIN DURABLE HOUSEHOLD GOODS AND SOCIO-ECONOMIC CONSUMER DIFFERENCES

In accordance with the aims of the project, a concept for material prosperity standards of globally sustainable levels of raw material use, incorporated in durable household goods, was developed. In order to compare this level with actual or average household inventories, typical raw material inventories were assigned to different household types.

Figure 4: System boundaries and selected household goods. The goods named in the outer circle and the product groups marked in bright yellow, were covered.



Source: own depiction

System boundaries were derived from the complex system “household” according to the requirements of the project. Starting from the complete system, a stepwise reduction to a

group of products was conducted, which has previously been analysed in accessible literature or studies of the Wuppertal Institute. Additional requirements like typologies of usage of possible goods or relevance of their masses (in comparison to the entire household equipment) could only be assessed qualitatively as the available literature is limited and neither allows for broad nor strongly diversified inventories of goods (Liedtke et al. 2013). No specific variants of goods could be derived (e.g. energy saving TV compared to conventional TV) but common groups of products can be displayed via examples of goods (e.g. TV and games console from the product class of entertainment appliances). The time horizon displays the momentary ownership of inventoried goods (stock of equipment). Coupling consumption statistics (e.g. COICOP) with life cycle inventory data or manufacturer information on raw material content of goods was not possible in a fully consistent way. Furthermore, the statistical classification of product groups and goods does not sufficiently represent demand or activity fields of households (see Lettenmeier et al. 2013). Thus, currently only one approach is available that allows to take households' activities and decision making into account in a way that is adequate to their relevance in terms of resource consumption (Liedtke et al. 2015, Baedeker et al. 2014), but compatibility to statistical product group settings and their TMC compared with the activity profile of households doesn't exist (Liedtke et al. 2013). Therefore, to analyse actions of households in the medium or long term, possibilities to reduce the gap between statistical analysis and the actual lifeworld of households should be developed .

The system boundaries were derived in eight steps. Starting from a maximal system "household"⁴ first product groups were preselected that allow assuming a high correlation between resource use and consumption. Criteria for the qualitative selection in an internal expert workshop were high resource use⁵, high share in consumption of German households and durable abiotic goods. In the next steps system elements were excluded that would have complicated data gathering significantly or would have weakened the consistency with other work packages: the production phase, biotic raw materials, home infrastructure and usage. Energy use of household goods and vehicles were included in this step but not in the final web tool. The goods to be inventoried were chosen along the preselected product groups, based on data availability. Figure 4 shows the resulting system boundaries and selected household goods. The system derived here only represents an exemplary look at the entire system household. Hence, statements and derived options for action can also address only parts of household consumption.

In a next step, the raw materials incorporated into selected household goods and the resource use for their electricity and fuel demand were quantified. Additionally, the yearly demand of cotton in German households was quantified as an example of biotic resources. First, data on material composition and sources with additional information were analysed to assign all materials quantitatively to one of the following classes: Metals, plastics, other substances (e.g. silicates) and complex material systems (e.g. electronic parts that could not be further itemised). This resulted in a comprehensive database of raw materials for 24 household goods (one good each), divided into 94 sub-groups of materials, ranging from

⁴ The concept „household“ was defined as a private community consisting of one or more persons; provision of needs is based on agreement between these persons.

⁵ Decisive for material resource use here was the estimated Total Material Requirement (TMR).

ABS plastic to Zinc. Referring to masses and substance groups of the 0-level, 62.3% are metals, 22.6% plastics, 12.6% other substances (incl. 6.8% silicates) and 2.5% complex material systems. Within the group of metals ferrous metals are dominant. Passenger car has the highest mass of app. 1.2 tonnes.

The resource demand of fuels used by German households' vehicles was quantified by using data of DIW Berlin (Kunert and Radtke, 2011) and of the German Federal Statistical Office (Statistisches Bundesamt, 2011), regarding the mileage of German private households. Average fuel demand for 14 car types in 7 car classifications (each for petrol and diesel) is based on data by ADAC (2013). Inaccuracies of calculations result from differing information in Kunert and Radtke (2011) and Statistisches Bundesamt (2011), as well as lack of data on specific car types. Smaller deviations also resulted from using an average fuel density for conversion into masses of raw materials. These inaccuracies were discussed. The fuel demand of German households resulted in 776 kg of fuel per year. Quantification of abiotic resource demand for electricity in German households was conducted for the reference years 2011, 2015 and 2030. The conversion of electric energy into raw materials is based on German gross power mix and primary energy use (according to BMWi, 2013 and DLR, 2012), mineral coal units (SKE) and heating value of (fossil) energy sources. To determine the future power mix Scenario 2011A was taken from the study by DLR (2012).

In a final step, the physical consumption of households has been combined with social characteristics. A method was presented that is capable to household types or social milieus with demands for raw materials through dimensions and data sets. Thus 16 raw materials in 13 household goods could be assigned in volume to different household types. In the course of doing so, the database had to be modified to fit the high level of aggregation. Results show significant differences between typical households in Germany regarding raw material demands in durables and commodities. Dominant characteristics in equipment, primarily passenger car as a durable and fuel as a corresponding commodity, do not level the differences. Thus group 1 (middle class mainstream) and group 2 (young adults) still deviate by 6%, while group 3 (established) and group 4 (families in rural areas) hardly differ in average. Between group 5 (underprivileged) and group 6 (elitists) in contrast a difference of almost 96% shows.

Looking at raw materials, the lowest deviation shows between iron and bitumen (48% or 53% difference respectively between highest positive and lowest negative deviation). The largest deviations show in fuel (223%). Finally, equipment and consumption levels of prior work packages are reflected in the differentiated raw material inventories. Addressing different household types can thus be based on these results.

3.3 MERGING RESULTS ON RAW MATERIALS FOR CONSUMER DURABLES AND HOUSEHOLD CONSUMPTION PATTERNS

The results on raw materials (section 3.1) and households (section 3.2) have been merged. The results concerning raw-material-specific availability corridors for the "baseline" BAU scenario, the "sustainable" scenario and the "globally fair & sustainable" scenario have been used. Concerning households the raw material inventories and equipment for 7 socioeconomic household types, which have been identified for a total of 24 consumer durables,

have been utilized (see example in Table 3). The combination of these results allows an estimation of individual raw material consumption due to durable goods equipment in the global context of scarcity of raw materials and planetary boundaries.

Table 3: Raw material balances and consumption and overshoot years for the socio-economic household type 1 (negative values have been marked red)

Socio-economic household type 1		Gold	Copper	Silver	Aluminium	Lead	Steel
Globally fair total assets of raw materials in kg per household 2010-2030	Baseline	0.0021	54.9	0.011	176.6	14.4	4,964.1
	Sustainable	0.0016	38.0	0.008	115.1	9.9	3,514.6
	Globally fair & sustainable	0.0011	6.4	0.002	27.1	3.1	1,282.5
Total consumption of raw materials in kg per household 2010-2030		0.0029	77.1	0.010	251.0	27.8	2,575.0
Household's actual balance in 2030: Total assets - total consumption of raw materials in kg	Baseline	-0.0008	-22.2	0.001	-74.3	-13.5	2,389.1
	Sustainable	-0.0013	-39.1	-0.002	-135.9	-17.9	939.6
	Globally fair & sustainable	-0.0019	-70.7	-0.008	-223.9	-24.7	-1,292.5
Overshoot year	Baseline	2025	2025	2033	2025	2021	2050
	Sustainable	2022	2020	2026	2020	2018	2039
	Globally fair & sustainable	2018	2012	2014	2012	2012	2020
Socio-economic household type 1		(Flat-) Glass	Platinum	Tin	Magnesium	Oil for Plastics	Natural Rubber
Globally fair total assets of raw materials in kg per household 2010-2030	Baseline	110.4	0.0034	0.094	3.7	609.3	80.2
	Sustainable	62.6	0.0023	0.095	2.5	592.0	62.0
	Globally fair & sustainable	41.4	0.0012	0.022	0.9	201.3	36.3
Total consumption of raw materials in kg per household 2010-2030		285.6	0.0029	0.221	2.0	992.4	12.6
Household's actual balance in 2030: Total assets - total consumption of raw materials in kg	Baseline	-175.2	0.0005	-0.127	1.7	-383.1	67.6
	Sustainable	-222.9	-0.0006	-0.126	0.5	-400.3	49.4
	Globally fair & sustainable	-244.2	-0.0017	-0.198	-1.2	-791.0	23.6
Overshoot year	Baseline	2018	2034	2019	2049	2023	2143
	Sustainable	2015	2027	2019	2036	2023	2113
	Globally fair & sustainable	2013	2019	2012	2019	2014	2070

Source: own presentation

Product-specific useful lifetimes of consumer durables have been also taken into account. Due to the fact that (beyond information on cars) they could not be identified in intensive desk research they have been collected in the course of a representative household survey by the market research institute 2hm (Mainz). The interviews included the following questions:

- How many people live in your household?
- What is the average monthly net income of your household in total?
- Which of the following consumer durables do you or members of your household have today?
- When did you buy these consumer durables resp. when did you receive them?
- Did you buy these consumer durables new or second-hand?
- What do you expect, how long will you still use these consumer durables before they will break for example, or you will replace them by a more modern device with additional functions?
- And once (regardless of your current property of consumer durables), on the basis of your entire previous experience: After how many years do you usually replace the following consumer durables?

The results of this household survey concerning the useful lifetimes form part of the basis for calculating the already mentioned overshoot years.

Table 3 shows an example of the raw material balances as those have been consumed by the socio-economic household type 1 (middle class mainstream) according to the availability corridors shown in

Table 2. Due to the slightly more generous availability corridors in the baseline resp. business-as-usual (BAU) scenario, the overshoot year in the corresponding scenario is at least equal to, but usually more far away than the overshoot year of the "sustainable" and "globally fair and sustainable" scenario. Nevertheless, the material account for over half of all raw materials is unduly burdened, so that already in the baseline scenario partly significant sustainability gaps occur. Due to the strict requirements of the sustainability scenario the overshoot years are smaller for all raw materials except for tin and oil and for even more raw materials the budget is exhausted before 2030 – only the credit for steel, magnesium and natural rubber extend beyond the year 2030. In the more restrictive scenario "globally fair and sustainable" no account keeps until the year 2030 – apart from the relatively uncritical natural rubber.

4 THE WEB TOOL IN DETAIL

The web tool – <http://resourcetool.gws-os.com/> – is more than just a simple calculator. During the design stage, it became apparent that the tool should not only act as a passive accounting tool based on previously calculated resource inventories and household types. Instead, the web tool should inspire potential users to reflect their own consumer behaviour with regard to resource sustainability by adjusting their household inventory (quantities, expected useful life). It also contains valuable background information about the durable household goods and materials. Furthermore, it gives advice to help users to consume resources more sustainable.

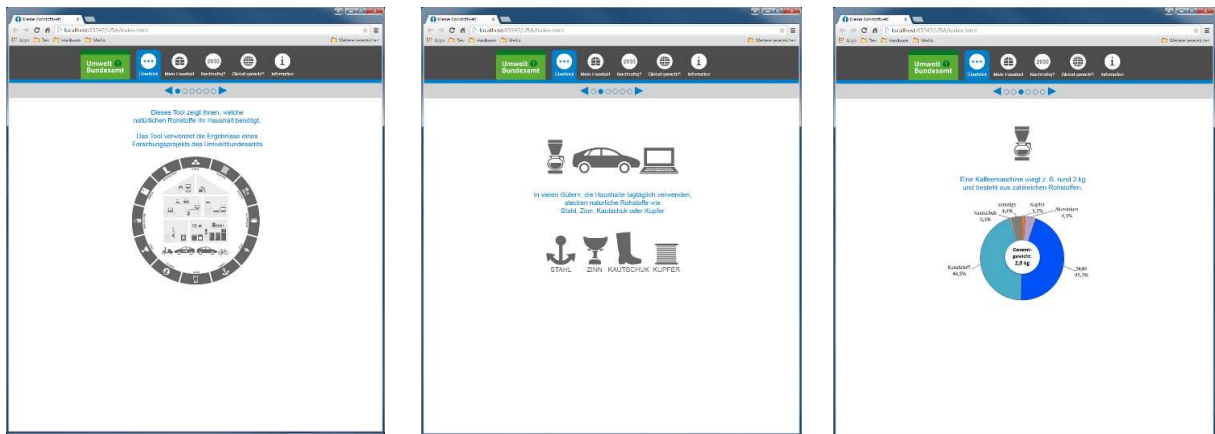
Given that, the web tool should address a general public, where usability and understandability were key design issues of the graphical user interface.⁶ The prototypically established web tool thus features an easy-to-follow menu structure. Scientific expertise is not required to understand the textual content. To prevent information overflow, the tool contains a selection of the 24 most common household durables and twelve raw materials (Table 1). Therefore, the web tool is suitable for users aged 14 and older who are interested in the topic of globally fair and sustainable use of resources.

On start-up, the web tool shows a menu bar at the top of the screen, which is visible and accessible at any time. A tab control shows additional menu entries, which may appear depending on the previously selected main menu entry (see Figure 1).

The web tool does not force its users to follow a certain processing sequence. Instead, a user may activate any menu entry at any time. The web tool then recalls the content of previously activated submenu entries automatically. On first start-up, the web tool activates the main menu entry "Überblick" ("Overview") which gives an introduction regarding the key messages and key features of the tool (see Figure 5).

⁶ The content, didactic and structure of the web tool was a common interaction and development process between UBA and the project consortium. As theoretical background the open exploration scenario method and open didactical exploration method (Bliesner et al. 2014) has been used. The graphical user interface was developed in close cooperation with s.c.z. Kommunikationsdesign (Bremen).

Figure 5: Introductory pages of the web tool

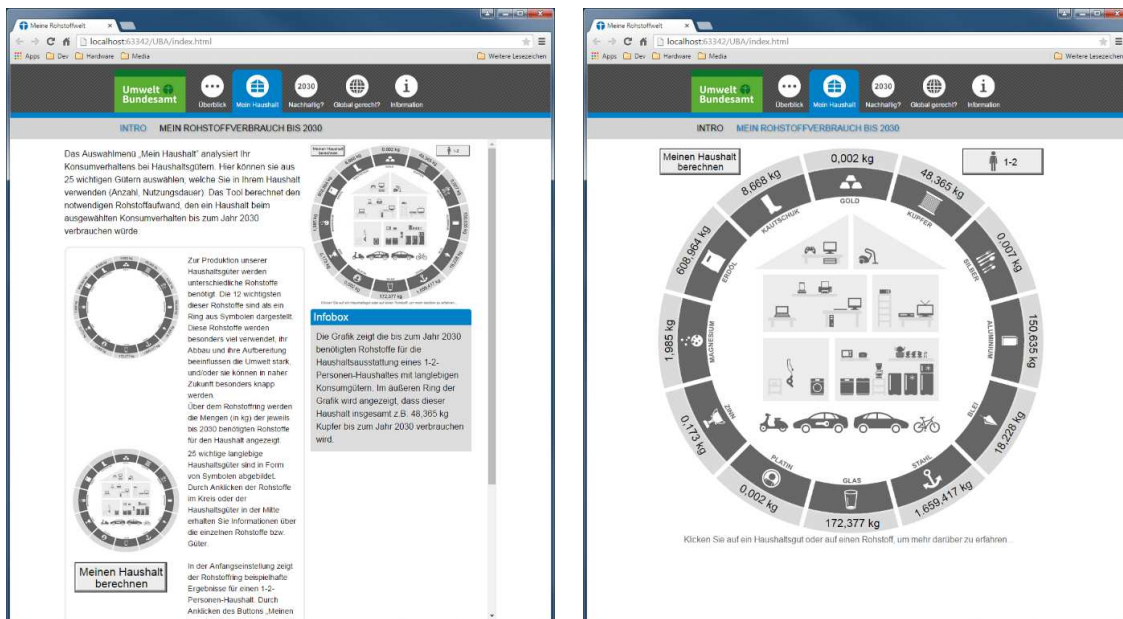


Source: Own figure

The structure of the following three main menu entries “Mein Haushalt“ (“My household“), “Nachhaltig?“ (“Sustainable?“) and “Global gerecht?“ (“Globally fair?“) is identical. Each of them contains two tab sheets named „Intro“ and “Mein Rohstoffverbrauch bis 2030“ (“My resource consumption until 2030”) (see Figure 6).

For each of these menu entries, the content of the introduction tab shows some background information and gives hints on the usage (see Figure 6, left). The web tool uses a circle as main control (see Figure 6, right) showing the twelve raw materials in the outer ring and the 24 household goods inside of the ring.

Figure 6: Tab sheets of main menu entries



Source: Own figure

A user may adjust his or her household inventory by clicking on the button labeled “Meinen

Haushalt berechnen“ (“Calculate my household“). The web tool then displays a dialog with editable controls for quantities and expected useful life for each good. Additionally, the user may adjust the number of people living in his or her household by clicking the button located at the top right of the circle (see Figure 3).

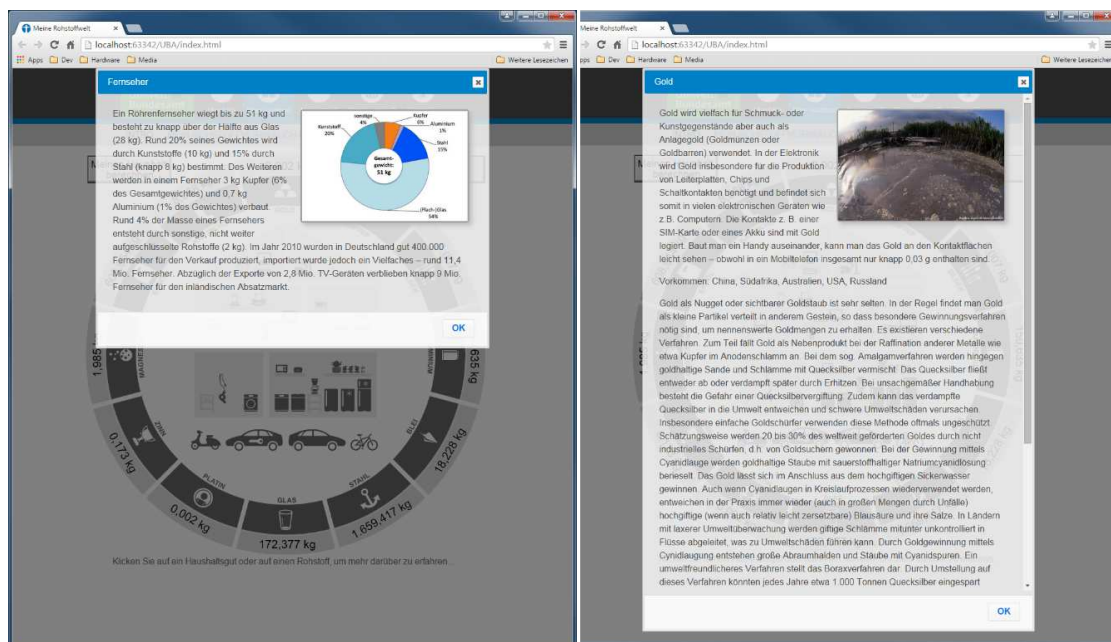
Depending on the household inventory, the web tool calculates both resource inventory and future availability of the raw materials and shows the result in the outer ring of the circle. The visualisation depends on the selected main menu entry (see Figure 2).

If the main menu entry “My household“ is selected, the outer ring displays the amount of kilograms of each of the twelve raw materials for the given household inventory (see Figure 2, left).

In case of the “Sustainable?“ main menu entry, calculations are based on the assumption that resource consumption patterns in 2030 are still the same as in 2000. The values shown in the outer ring describe up to which year each raw material will be available (see Figure 2, middle). For the main menu entry “Globally fair?“ the year values describe a situation, in which resource consumption up to 2030 is not only sustainable but also globally fair (see Figure 2, right). The visualisation uses traffic light colours red, yellow and green to easily distinguish critical from less critical raw materials.

For each household durable and each raw material, users may obtain valuable background information by clicking the respective icon (see Figure 7). The raw material fact sheets provide information on the raw material inventory of the specific product and some figures concerning the import and export of these products. Instead of the raw material inventories the product-specific fact sheets include also concrete recommendations for action on how to use these products and thus the implemented inventories of raw materials more sustainable.

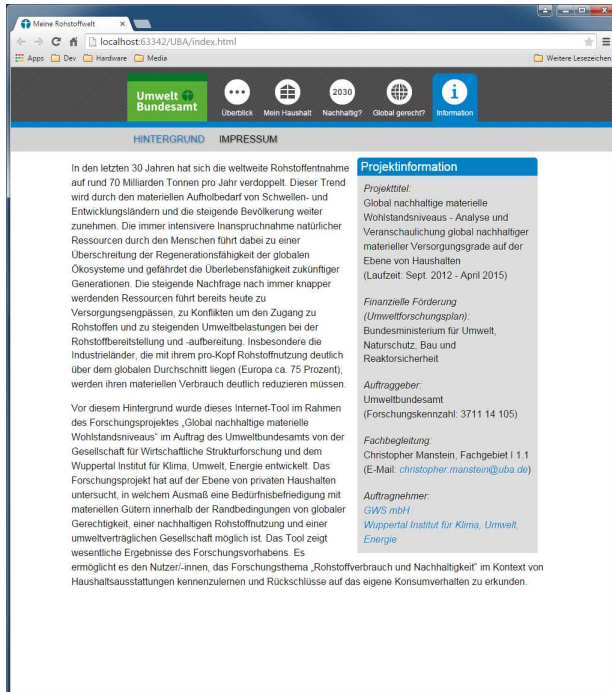
Figure 7: Background information about household goods and raw materials



Source: Own figure

The remaining main menu entry „Information“ shows background information about the project (see Figure 8).

Figure 8: Project information



Source: Own figure

5 CONCLUSIONS

In accordance with the aims of the project for the German Federal Environment Agency (UBA), a concept for material prosperity standards of a globally sustainable use of raw materials incorporated in durable household goods was developed.

It could be shown, for example, how the data base, which has been established within section 3.1, could be extended. With respect to the procedure chosen within section 3.2 for exemplary focusing on selected types of households and social milieus, it could be shown how this analytical framework could be utilized and further refined in the future. Also, the web tool, established over the course of this research project, could possibly be much more developed towards specific user groups or users in the future.

The results obtained in this pilot study can be expanded systematically in the future by further elaborating data analysis and calculation algorithms. The current version of the application only reports on the usage of 12 raw materials for 24 durable household goods. On the basis of the presented approach it is possible to expand this scope of reporting by further studies.

Furthermore, the web tool could be focused more tightly on specific user groups in future

revisions. The presented groundworks within section 3.2 provide first starting points for the exemplary focusing on selected types of households and social milieus. For future stages of extension it would be conceivable to ask the user a few questions first, in order to subsequently provide more individual, milieu-specific contents.

Alternatively, this tool could be advanced into a didactically optimised teaching material for education or an analytically optimised simulation tool for applied policy consulting.

For further optimisation of the analytical foundations, the following measures seem worth considering:

- Refinement and extension of the selection criteria for the prioritised raw materials.
- Refinement of the product list, e.g. into product-specific sub-groups.
- Extension of the web tool's reporting scope by an explicit consideration of the findings of quantitative socio-economic environment scenarios.

LITERATURE

- Ahlert, G.; Buhl, J.; Greiff, K.; Hohmann, F.; Lettenmeier, M.; Liedtke, C.; Meyer, M.; Schipperges, M.; Steger, S.; Teubler, J. & Walter, H. (2015): Global nachhaltige materielle Wohlstandsniveaus – Analyse und Veranschaulichung global nachhaltiger materieller Versorgungsgrade auf der Ebene von Haushalten. Abschlussbericht für FKZ 3711 14 105. UFOPLAN-Vorhaben im Auftrag des Umweltbundesamtes. Osnabrück und Wuppertal.
- Baedeker, C., Greiff, K., Grinewitschus, V., Hasselkuß, M., Keyson, D., Knutsson, J., Liedtke, C., Lockton, D., Lovric, T., Morrison, G., van Rijn, M., Rohn, H., Silvester, S. van Harinxma, W. & Virdee, L. (2014): Transition through sustainable Product and Service Innovations in Sustainable Living Labs: application of user-centred research methodology within four Living Labs in Northern Europe (Conference Paper IST 2014)
- Bliesner, A., Liedtke, C., Welfens, M.J., Baedeker, C., Hasselkuß, M. & Rohn, H. (2014): „Norm-Oriented Interpretation Learning“ and Resource Use: The concept of „open-didactic exploration“ as a contribution to raising awareness of a responsible resource use, in Journal Resources 3/2014, pp. 1 – 30, www.mdpi.com/journal/resources, DOI:10.3390/resources3010001, ISSN 2079-9276
- BMU-German Ministry for Environment, Nature and Nuclear Safety (2012): Deutsches Ressourceneffizienzprogramm (ProgRess). In Programm zur nachhaltigen Nutzung und zum Schutz der Natürlichen Ressourcen (German Resource Efficiency Programme (ProgRess). Programme for Sustainable Use and Protection of Natural Resources). Beschluss des Bundeskabinetts vom 29.2.2012, Berlin.
- BMWi (2013): Gesamtausgabe der Energiedaten - Datensammlung des Bundesministeriums für Wirtschaft und Technologie (BMWi). Zugriff unter <http://www.bmwi.de/DE/Themen/Energie/Energiedaten/gesamtausgabe.html>.
- Bringezu, S. & Bleischwitz, R. (2009): Sustainable Resource Management: Global Trends, DLR (2012): Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. Schlussbericht. BMU - FKZ 03MAP146.
- Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S. & Hennicke, P. (2011): Decoupling Natural Resource Use and Environmental Impacts from Economic Growth. A Report of the Working Group on Decoupling to the International Resource Panel, Available online: http://www.unep.org/resourcepanel/Portals/50244/publications/Decoupling_Report_English.pdf
- Giljum, S., Dittrich, M., Lieber, M. & Lutter S. (2014): Global patterns of material flows and their socio-economic and environmental implications: a MFA study on all countries world-wide from 1980 to 2009. Resources 3 (March (1)), 319-339. Available from: <http://www.mdpi.com/2079-9276/3/1/319>
- Greiff, K., Baedeker, C., Liedtke, C., Teubler, J., Buhl, J. & Wiesen, K. (2016): Material

Footprints, time use profiles and expenditures of Households of different social milieus – basis for behavior transitions.

- Kotakorpi, E., Lähteenoja, S. & Lettenmeier, M. (2008): Household MIPS. Natural resource consumption of Finnish households and its reduction. The Finnish Environment 43en. Ministry of the Environment, Environmental Protection Dep.
- Kunert, U. & Radke, S. (2011): Kraftfahrzeugverkehr 2010: Weiteres Wachstum und hohe Bedeutung von Firmenwagen. DIW Wochenbericht Nr. 48/2011 vom 30. November 2011.
- Lettenmeier, M., Liedtke, C. & Rohn, H. (2014): Eight Tonnes of Material Footprint – Suggestion for a Resource Cap for Household Consumption in Finland. Resources 3, 488-515.
- Liedtke, C., Bienge, K., Wiesen, K., Teubler, J., Greiff, K., Lettenmeier, M. & Rohn, H. (2014): Resource use in the production and consumption system - the MIPS approach. In: Resources, Vol. 3, 544-574. <http://dx.doi.org/10.3390/resources3030544>
- Liedtke, C., Baedeker, C., Hasselkuß, M., Rohn, H. & Grinewitschus, V. (2015): User-integrated innovation in Sustainable LivingLabs: an experimental infrastructure for researching and developing sustainable product service systems. In Journal of Cleaner Production, Vol. 97, pp. 106-116.
- Liedtke, C.; Buhl, J.; & Ameli, N. (2013): Designing value through less by integrating sustainability strategies into lifestyles, in: International Journal of Sustainable Design, 14 p., online first
- Liedtke, C.; Buhl, J.; & Ameli, N. (2013): Microfoundations for Sustainable Growth with Eco-Intelligent Product Service-Arrangements, in: Journal Sustainability 2013, Vol. 5, pp. 1141-1160.
- Liedtke, C., Lettenmeier, M., Buhl, J., Teubler, J., Greiff, K. & Schipperges, M. (2013): Discussing the usefulness of statistics for assessing the resource use of households. Paper presented at World Resources Forum on 6-9th October 2013 in Davos at Topic 4: Lifestyles and Education; Only presentation online [file]: <http://www.worldresourcesforum.org/files/WRF2013/Scientific%20Sessions/Christa.Liedtke.pdf>
- Rockström, Johan, Steffen, Will, Noone, Kevin et al. (2009): Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society, Vol. 14(2).
- Schmidt-Bleek, F. (2007): Nutzen wir die Erde richtig?. Fischer-Taschenbuch-Verlag: Frankfurt am Main.
- Statistisches Bundesamt (2011): Umweltökonomische Gesamtrechnungen: Weiterentwicklung der Berechnungen zum Energieverbrauch und zu den CO₂-Emissionen des Straßenverkehrs im Rahmen des NAMEA Rechenansatzes – Methodenbericht.
- Ward K. & Neumann, F. (2012): Consumer in 2050: The Rise of the EM Middle Class. HSBC Global Research, Global Economics.
- Watson, D., Acosta F., J., Wittmer, D., Schütz, H. & Gravgår Pedersen, O. (2013): Environmental pressures from European consumption and production: A study in integrated environmental and economic analysis. EEA Technical report No 2/2013.

