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Understanding Socio-metabolic Inequalities Using Consumption Data from Germany

Antonia Schuster[a] and Ilona M. Otto[a,b]

[a]Potsdam Institute for Climate Impact Research, Potsdam, Germany; [b]Wegener Center for Climate and Global Change, University of Graz, Graz, Austria

ABSTRACT

The Earth's population of seven billion consume varying amounts of planetary resources with varying impacts on the environment. We combine the analytical tools offered by the socio-ecological metabolism and class theory and contribute to a novel social stratification theory to identify the differences in individual resource and energy use. This approach is applied to German society, we use per capita greenhouse gas emissions (GHG) as a proxy for resource and energy use and investigate socio-metabolic characteristics of individuals from an economic, social and cultural perspective. The results show large disparities and inequalities in emission patterns in the German society. For example, the GHG in the lowest and highest emission groups can differ by a magnitude of ten. Income, education, age, gender and regional differences (Eastern vs. Western Germany) result in distinct emission profiles. We question the focus on individual behavioral changes and consumption choices to reduce carbon emissions instead of structural changes through political decisions. We argue that emission differences are directly linked to the effects of inequalities and class differences in capitalist societies. Our research results show that natural resource and energy consumption are important for explaining social differentiation in modern societies.

KEYWORDS Inequalities; carbon emissions; social metabolism; class theory; planetary boundaries

Introduction

Environmental and climate pressures affect our quest for global sustainability. The concept of Planetary Boundaries, developed by Rockström et al. (2009), sets environmental boundaries for a safe operating space for humanity which allows preconditions to be set for sustainable development and the development of a more unified approach for working towards global sustainability. As stated in the IPCC report (Pachauri et al. 2014), anthropogenic

CONTACT Antonia Schuster schuster@pik-potsdam.de Potsdam Institute for Climate Impact Research, Telegrafenberg A56, 14473 Potsdam, Germany

greenhouse gas (GHG) emissions are at their highest level in history and human influence on the climate system is proven. The world is likely to warm, even with current mitigation commitments and international pledges, and substantial changes in the terrestrial system are to be expected. Consequently, there is a demand for collective human action (Steffen et al. 2018), constructive political decisions and systemic changes to avoid further negative impacts. To address these issues, this research paper focuses on the climate change boundary that has already been transgressed.

To transfer or divide global responsibility and give guidelines to the political arena, especially with regard to inequality (see, e.g. Gore 2015) and climate justice, recognized concepts such as the Planetary Boundaries should be made accessible to decision makers.

In the identification of sources of high emissions, the individual becomes regrettably often a focal point (Otto et al. 2020), whereby the concept of human agency is related to lifestyle changes (Van Vuuren et al. 2018), changes in institutional structures and in the rules of the games people play (Farmer et al. 2012). It thus plays an important role in identifying transformational potential to be incorporated in socio-ecological system models. Empirical research on inequalities in resource and energy use is often concerned with correlations between lifestyle carbon emissions and socio-demographic factors, such as income. In this context, a clear structural critique of the capitalist mode of production and the resulting inequalities is lacking. Additionally, social justice concerns are neglected substantively, as well as any class struggle implications. As an example, the Oxfam report (Gore 2015) asserts that the richest ten percent of the global population is responsible for almost half of all total lifestyle consumption emissions. A similar picture emerges in the EU, whereby the total emissions of the richest ten percent have actually increased since 1990 (Gore and Alestig 2020). The question of how these wealth inequalities arose and continue to arise is in the background, as well as the lifestyle-related emissions that result from class membership and consciousness.

In this paper, we attempt to understand the profiles of individuals who are responsible for high emissions and to understand what constitutes the realities of the emitters, from a multi-dimensional, rather than a purely economic perspective. We seek out social and cultural factors that determine emissions using Pierre Bourdieu's theory of capital.

We focus on Germany as a country representing Western post-industrial societies and ask if emission groups exist in the German society and if these groups are apparent in empirical data. We focus on Germany, as a high emission core capitalist society and are aware of the international context in terms of resource consumption patterns and their environmental impact of globally interwoven production chains. This analysis is therefore only an approximation.

We attempt to gather sound scientific knowledge through statistics using cluster analysis, principle component analysis and descriptive statistics based on existing data from the German Federal Environment Agency (UBA). The initial assumption is that human beings do not have uniform socio-metabolic profiles and do not use equal shares of natural resources or contribute equal shares of emissions (Otto et al. 2019) – a huge disparity between and within societies exists, showing previously unidentified patterns of inequality. CO_2 is used as a proxy to detect different emission patterns. The conceptualization of the metabolism approach and the contribution to possible socio-metabolic classes gives the research a natural perspective, primarily by highlighting the limitations of systems and organisms.

The paper is structured as follows: Firstly, we provide some theoretical background on class theory including a socio-metabolic perspective; Secondly, the knowledge gained is statistically evaluated and applied to real data. All findings are then discussed, and results of this work are evaluated in terms of recommendations for further research on downscaling Planetary Boundaries, environmental action and climate mitigation policies.

Understanding Class Differences in Modern Societies

Western conceptualization of class has been strongly connected to the doctrines of Karl Marx and Max Weber (Singh et al. 2013). For Marx, classes relate to ownership of, and control over, the means of production. He distinguishes three major classes of modern society based on the capitalist mode of production: A class of laborers who simply own their own labor power, a class of capitalists owning the means of production and a class of landowners. The respective income sources are wages (workers), profits (capitalists) and land rents (landowners).

However, the stratification of classes does not necessarily occur in its pure form: intermediate classes (petite bourgeois and peasants) blur the dividing lines (Marx and Engels [1967] 1894).

Marx aims to show how the inherent logic of a capitalist mode of production transforms labor into wage labor and the means of production into capital – namely through the separation of means of production from labor – class differences, inequality and a divided society are the consequence. Max Weber was more aware of the complexity of society (Singh et al. 2013) and that the central character of capitalism is not only the class character. Even though Weber's concept of social structure refers to Marx theory, it is more a combination of three components in social stratification: class, status, and power (Ritzer 2004). However, the role of natural resources and the interaction between humans and nature was not sufficiently incorporated into their ideas. In other words, Marx and Engels did not fully consider the exploitation of nature or resource use in their theoretical approaches to capital accumulation. They only incorporated the appropriation of human labor surplus without dealing with the appropriation of the accumulated wealth of nature (Martinez-Alier 1987).

Resource depletion, overused or under-provided global commons, and major environmental problems are ignored and disconnected from social differentiation theories. The material interdependence between organisms and the environment is only perceived in the use of nature by humans (Fischer-Kowalski 1998). Material approaches to social stratification from the 19th century are an example of many other approaches from modern sociology which have not considered society-nature interactions and, with that, natural parameters as causes or consequences of social activities (Fischer-Kowalski 1998).

Different class theories have been developed for various countries, often influenced by Marx' or Weber's way of thinking (see, e.g. Dahrendorf [1959]; Giddens [1973]). Another approach to identifying class differences is that of social metabolism.

It considers the limitations of the planet, thinks in cycles, and understands the transformations within systems. It uses empirical information about biophysical variables and focuses on the important role of nature. Natural systems co-evolve with human interventions and exert pressure upon societies to keep on changing (Fischer-Kowalski 2011). Fischer-Kowalski (1998) describes how humans have their own metabolism and that they need to (at least) sustain it, or they will simply die. As social animals, humans solve this problem collectively and societies sustain, at least, the total metabolism of their members. Any surplus cannot be used for the production of more cells, so the extension of the concept takes place in recognizing a new form of interaction with the environment, which is not a direct exchange, but effected by the way humans organize themselves. Through activities such as breeding, agriculture, construction and production, humans create and maintain this social metabolism (Ayres and Simonis 1994; Fischer-Kowalski 1998). The proposition that humans, as heterotroph organisms, take material from the environment and return it in a different form (Fischer-Kowalski 1998) is crucial for the understanding of energy and material flows. Social metabolism refers to the manner in which human societies organize their growing exchanges of energy and materials with the environment (Fischer-Kowalski 1997, 2000; Martinez-Alier 2009). Generally, human use of energy can be divided into two main categories. The first is the endosomatic use of energy as food, and the second is the exosomatic energy use of energy for cooking and heating, and to create the artifacts and machines of human culture (Otto et al. 2020). Exosomatic energy use by humans goes far beyond biological requirements. The dimension that has not been sufficiently explored by social differentiation theories is therefore the metabolic profile of social classes; the access to resources and the preservation of an individual's own metabolism vary greatly between people and metabolic differences are manifested in class differences in modern societies.

The outflow of materials such as fossil fuels and other minerals increased substantially during industrialization. From 1850 to 2000, global CO_2 emissions increased 125-fold (Boden, Marland, and Andres 2009) and with around 80 percent by weight of the total annual outflow of materials, CO_2 is making the atmosphere the largest waste reservoir of the industrial metabolism (Matthews et al. 2000). This immense increase in emissions naturally occurred with industrialization of the global North, and associated effects of exploitation and inequality. The paradigm of constant growth continues to exist and the associated outsourcing of resources or emissions intensive industries today distorts towards a perceived improvement in national emissions balances. However, Otto et al. (2020) propose dividing societies into classes that are not based, for example, on the ownership of and the control over the means of production, but on their metabolic profiles. The resource and energy use patterns can be directly linked to GHG and can be used to identify GHG hotspots. Estimates show that the wealthiest 0.5 percent of the human population is responsible for more lifestyle-related carbon emissions than 50 percent of the poorest. The global middle class constitutes about 10 percent of the human population but is responsible for about 20 percent of the global lifestyle-related carbon emissions (Otto et al. 2019). However, the focus continues to be on the individual, with the consumer being portrayed as a scapegoat, and less on the unjust structures that result in inequalities in resource consumption.

The French sociologist Pierre Bourdieu postulates a social space in which he determines "social strata" groups in accordance with capital types. A distinction is made between social, economic and cultural (and symbolic) capital (Bourdieu 1986) and the social structure is determined by the distributional structure of capital. Social capital consists of valued social relations manifested in belonging to certain groups, networks or institutionalized relationships of mutual acquaintance and recognition. Economic capital represents capital that can immediately and directly be converted into money and may be institutionalized in the forms of property rights. Cultural capital refers to the consumption of goods such as pictures, books, machines, etc. It is assumed that a quantum of embodied cultural capital is incorporated in such goods. The embodied capital has been certified by an official agency possessing the authority to legally "warrant" its existence – that is, in the form of educational credentials (Pierre Bourdieu 1986). Cultural capital is mostly formed by school and family and its foremost characteristic is heritability. As such, it can make a substantial contribution to inter-generational inequalities across class locations. The reproduction of values and lifestyles (Pelikán, Galčanová, and Kala 2020) is relevant and is crucial in the intergenerational context, in terms of the inheritance of an ecological habitus. Cultural capital "comprises familiarity with and easy use of cultural forms institutionalized (e.g. through the university) at the apex of society's cultural hierarchy" (Di Maggio 2005, 167).

Finally, there is a symbolic capital which is rooted in honor and prestige (Bourdieu 1986). Different forms of capital should not be seen independently. Although Bourdieu himself does not connect his theory to the exploitation of nature, his theory can be applied in a socio-ecological context to investigate groups of individuals with similar metabolic profiles; the capital type evokes a particular habitus that results in a certain emission profile (Figure 1). Bourdieu's theory is useful for the examination of the emission groups to understand the realities of the emitters.

Research Methods

This research follows the social survey research design. We use data from the German Federal Environmental Agency (UBA) who collected the information on resource and energy use in different population segments and calculated carbon emissions corresponding to different activities. Germany was chosen due to being a major world emitter.

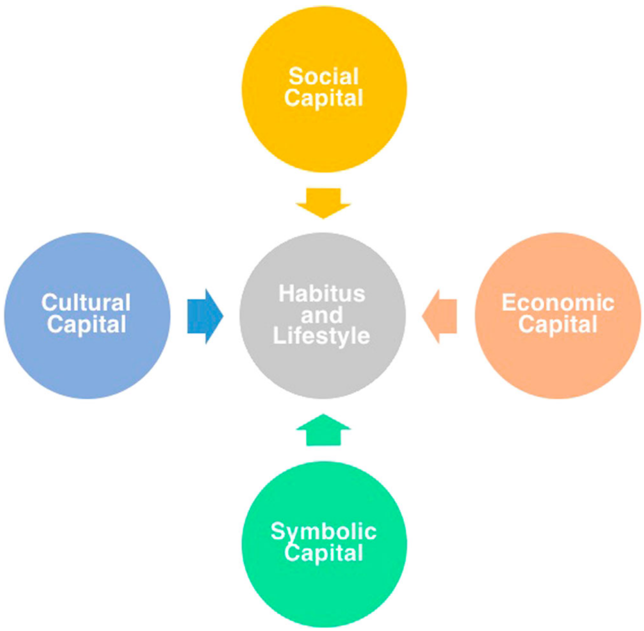

Figure 1. Distinct forms of capitals affect habitus and lifestyles (adapted from Bourdieu 1986).

To group individuals with similar patterns of resource and energy use, we use cluster analyses in three different sectors (housing, transport, and secondary consumption), using variable individual CO_2 emissions, to identify whether emission groups exist in Germany. The statistically differentiated emission groups were then analysed in each sector to identify economic, social and cultural differences between the groups, building on Bourdieu's theory of capital. For this purpose, ANOVA variance analyses were applied. The survey investigated 1012 individuals throughout Germany in 2016 and identified factors affecting individual consumption of resources (mainly energy). The data also show weaknesses in certain income groups, with people earning high to very high incomes, being underrepresented. Furthermore, the data allows only an approximation of the concept of analysis of capital types. To measure individual footprints, a calculator created by "Klimaaktiv" (KlimAktiv CO2-Rechner 2018) was applied by the UBA. The footprint calculator takes into account the greenhouse gases methane and nitrous oxide, with the corresponding climate impact of CO_2 (CO_2 equivalents or CO_2e), as well as the impact caused by air travel measured as flight equivalents. Household energy consumption is not homogeneous and differs both in terms of (i) direct energy (i.e. electricity, gas, gasoline, etc.) and GHG emissions (derived from direct energy consumption); and (ii) indirect energy (used to produce goods and services) and indirect GHG emissions (embodied in final goods and services that cause emissions during their production). This is a methodological challenge. The use of top-down or bottom-up methods attempt to highlight these differences. Top-down studies use data from consumption-based emission inventories, while bottom-up studies vary according to the different development stages of countries (Santillán, de la Vega Navarro, and Islas Samperio 2021). For developed countries, it is possible to work with life-cycle data for products. The technical report by UBA shows a detailed account of different emissions, for example, the energy required for production, transport and storage of food products. Generally, the scope of the assessment has to be limited and certain impact categories have to be defined. Different emissions are converted into equivalent figures, i.e. kg CO_2-eq (indicator of potential global warming due to the emission of greenhouse gases into the atmosphere). These are categorized as the impact category of global warming. Other impacts due to the release of gases such as nitrogen oxides and sulfur oxides are represented by the impact category acidification of soil and water and thus considered separately. The social-metabolic class theory takes up this research framework of investigation and focuses on the category global warming, which is only possible within the scope of this work.

The selection of five socio-metabolic classes is based on the results of the centroid-based k-means algorithm which is a valid approach and widely used (Jain 2010). For k-means clustering the number of clusters is assumed or known (Doreian, Batagelj, and Ferligoj 1994), so that the k clusters are determined in advance. We used $k = 5$ relating to the theoretical input from (socio-metabolic) class theory (Otto et al. 2020). Pierre Bourdieu's capital theory was applied to make use of various capital forms to analyse differences between the clusters (For similar application examples see Prieur, Rosenlund, and Skjott-Larsen 2008; Wolf et al. 2009; Waitkus and Groh-Samberg 2017). To create three types of capital, principal component analysis (PCA) was performed. This is a multivariate statistical approach to structure, simplify and illustrate datasets; it reduces a large set of variables to a small set which generates a smaller number of highly meaningful linear combinations.

Economic capital consists of income and property valuations. Social capital is determined by incorporating socialization, the living together, belonging to a social group, type of employment as well as social commitments are encompassed. Cultural capital is based on education level. Related to this, we discuss the role of ICTs (Information and Communication Technologies); they are significant in terms of energy consumption but more importantly, in terms of this paper, they are considered a cultural asset. To check whether the clusters are statistically significantly different from each other ANOVA was applied as the standard method of analysis. As we used linear models (lm) in the ANOVA executions, the Gauss-Markov assumptions had to be met.

Results

The assumption that there is an extreme difference in consumption patterns between individuals in the German society and that they can be assembled in groups can be proven; individuals do not use equal shares of natural resources or contribute equal shares of emissions.

The paper focuses on three sectors: housing (heating and electricity), transport (every day and holiday trips) and secondary consumption (emissions occurring in food and clothing purchases). The results of the analysis of variance show that the clusters within the analysed sectors almost always differ significantly in their capital form. Social, cultural and economic capital all influence carbon footprints.

Housing

The k-means algorithm divided the respondents, who represent the German society, into five clusters based on their CO_2 (and CO_2e) emissions. The maximum was 17.41 CO_2e t/y for heating and 2.66 CO_2e t/y for electricity which shows emissions from heating are much higher than those of electricity. The energy source (e.g. coal, oil, gas) is particularly relevant. A secondary focus is on electricity consumption, as power generation is also directly related to CO_2 emissions. The main uses of electricity are cooling/freezing, cooking, dishwashing, washing and drying clothes, lighting, and differ across the groups. 89 percent of the population sample also stated that they were using normal electricity, while the proportion of green electricity consumers was just under nine percent. The huge differences in heating consumption determine emission group differences and increase steadily from emission group. Figures 2–4 show the number of individuals that have been assigned to the emission groups, and the averages and cumulative carbon emissions of each group. The highest emission group consists only of 12 individuals representing 1.1 percent of the whole dataset, but this group emits around 150 tons of carbon emissions per year purely for heating. In contrast, the two lowest groups together account for around 87 percent of the respondents and emit approximately 920 tons of carbon emissions per year for heating. On average, an individual in group five emits around 18 times more CO_2 than a person in group one.

For electricity a similar picture emerges, but to a lesser extent. In total terms, emissions are the lowest in the fifth group, but respondents in the fifth group emit double as much as respondents in the first emission group.

The total per capita energy consumption decreases with the number of individuals living in a household (Kleinhückelkotten, Neitzke, and Moser 2016). One person in a household has a per capita total energy consumption of approximately 16,000 kWh/y. If five persons and more live in one household, the per capita energy consumption is only about 12,000 kWh/y (Kleinhückelkotten, Neitzke, and Moser 2016). The average living space in the

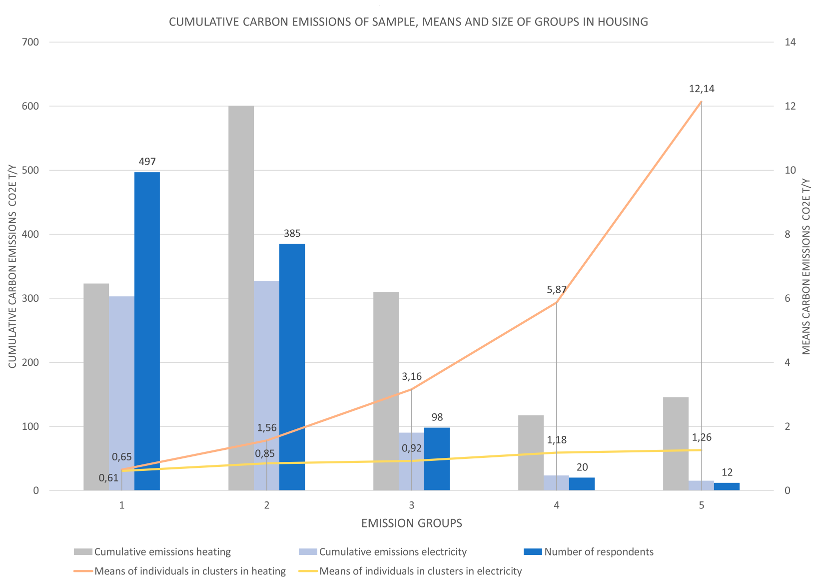

Figure 2. Cumulative and average carbon emissions in the housing sector.

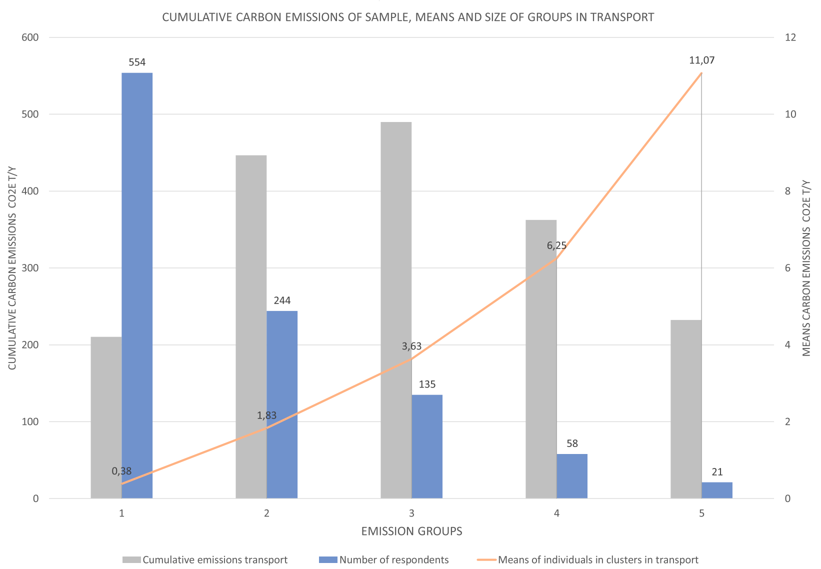

Figure 3. Cumulative and average carbon emissions in the transport sector.

survey is 86.8 m^2 (person weighted by age 53.9 m^2, unweighted: 40.7 m^2) (Kleinhückelkotten, Neitzke, and Moser 2016). In Germany, the Federal Statistical Office has estimated an average living space per inhabitant of 46.5 m^2

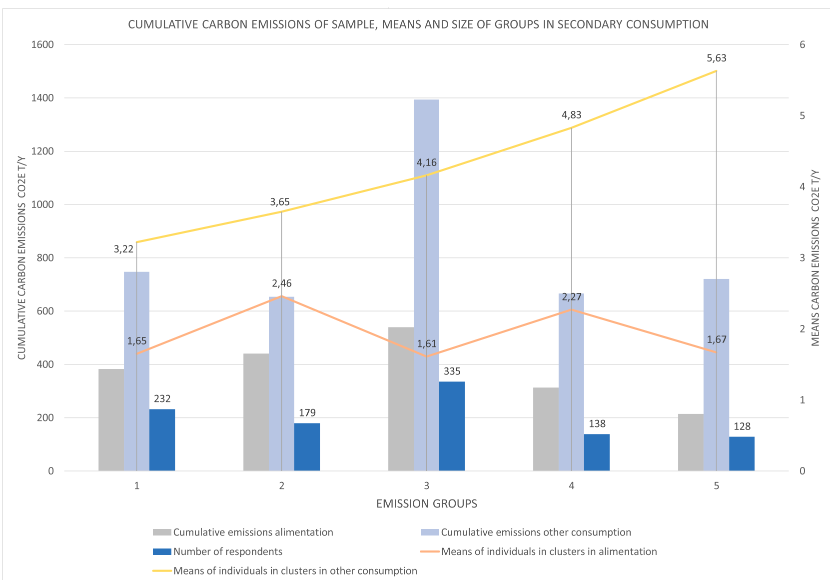

Figure 4. Cumulative and average carbon emissions in the secondary consumption sector.

in an apartment. This has seen a steady increase since 1999 (Statistisches Bundesamt 2018), but fits the numbers in the survey. From a technical point of view, the size, and not the type of housing is relevant. Interestingly, the size of the place of residence has no discernible systematic influence on the individual living space per person (Kleinhückelkotten, Neitzke, and Moser 2016). This suggests that individuals who live in rural areas do not automatically have more living space than those in urban areas. Results of regression analyses indicate that individuals who live in urban or rural areas have a similar total per capita energy consumption; although the energy consumption of individuals differs, the total consumption is similar (Kleinhückelkotten, Neitzke, and Moser 2016). Therefore, differences in emission groups in the housing sector for heating are not explained by place of residence; other characteristics of individuals are relevant, as explained later.

Analysis of variances generates a p-value of 0.04862 (F-value 2.3979, n = 1007), indicating a significant difference between the groups regarding economic capital. The Bonferroni Holm post-hoc test shows no directly linked differences and the determining significant level cannot be achieved (explainable by the weak significance). The differences regarding the carbon footprints in the housing sector cannot be securely attributed to economic inequality alone. Testing net monthly household income alone without any other economic determinants, results are not significant. This supports the assumption that wealth or income is not necessarily crucial to electricity and heating consumption or habits, even though the size of living space per person increases with income.

Interestingly, the social capital or (current) social environment is highly significant in the housing sector. As the PCA shows, the current social environment which arises from social status (such as being a pupil, student, pensioner, unemployed, and housewife/househusband) is decisive. These results depict that the group with the lowest individual carbon footprint differs from all other groups according to social factors. It seems that the first group is fundamentally differently socialized to the others and that there is a decisive difference between the medium and higher groups, which may be responsible for the increasing carbon emissions. However, the two highest emission groups do not seem to be essentially different – social capital plays a lesser role here.

The last form of capital is cultural capital. The data to perform a sufficient analysis of cultural capital is absent so we have developed a new type of cultural capital, in the form ICT. Computer technologies have grown into new cultural assets, enabling us to extend Bourdieu's cultural capital through modern technology. The idea of using ICT is based on two research directions: (i) results regarding the usage of computers and the digital world with power consumption on site and externally, such as that required to fulfill digital actions like Google searches and (ii) the role played by the internet or computers/smartphones as opinion forming media.

To develop ICT as a new capital type, the following factors were considered: number of computers in the household, number of newly purchased computers in the last three years, daily hours spent on the computer in free time, and number of newly bought smartphones in the last three years. The number of hours spent daily in free time on the computer is the most relevant factor for variances (PCA). The *p*-value of 0.01083 (F value 3.2916, $n = 1001$) indicates the significant difference; individuals in different emission groups differ in the number of hours spent daily on the computer. This is not only from an energetic perspective (media use and carbon footprints) but also based on the influence the internet has on our cultural world (internet as cultural capital).

Transport

Most emissions for individuals range up to five tons CO_2e per year, with extreme emissions reaching values of 16.33. As with the housing sector, most of the respondents belong to the first emission group (554 individuals) with the lowest emissions, but twice as many (21 individuals) appear in the top emission group. A constant increase can be observed from group to group, which almost doubles between groups four and five. The majority of individuals have very low emissions when it comes to transport, although others have noticeably high emissions. The total CO_2 output is lower for 554 individuals in group one than 21 individuals in group five, representing a severe difference between the groups in this sector.

Kleinhückelkotten, Neitzke, and Moser (2016) give us an initial understanding of the clustering results; the main causes for high carbon emissions in the sector are comparatively large cars, their frequent use, and long holiday trips by car and plane. Factors that have the greatest influence on everyday mobility are gender, age and income. There is no obvious connection between the size of the place of residence and the energy consumption due to travel distances to work (average of mean: 2.7 km) and to the most frequently used shopping centers (2.4 km) are the same for cities and the countryside, making no differences in emission patterns between rural and urban population. Also, regional differences play a minor role, but it can be said that the south of Germany is more energy intensive when it comes to mobility, as well as the former FRG compared to the GDR. The highest emissions are found in the age group 30–49. For everyday mobility the income factor is less important, but there are still correlations; individuals with a net income below €1000 per month are responsible for approximately 950 kgCO_2e/y, individuals who earn greater than €3000 pm are responsible for approximately 2350 kgCO_2e/y (unweighted) (Kleinhückelkotten, Neitzke, and Moser 2016).

The same results occur regarding holiday trips; energy consumption increases with age until the 50–65 age group and decreases from age 65 onwards. There are differences between respondents from Eastern (former GDR) and Western Germany (former FRG). Income also plays a role because people with higher income travel longer distances on holiday.

Unlike in the housing sector, economic capital is highly significant (p-value = <2.2e-16 ***, F value = 57.979, n = 1007). There is a divide between the lowest two groups and the upper three groups. The separation into two opposing groups, namely those who can supposedly afford convenient mobility and travel, and those who do not have that financial option. Thus, the provision of economic capital is decisive for the mobility or the type of mobility and the wealthiest have extremely high carbon footprints because of their many large cars and frequent flying. In contrast to economic capital, the groups do not differ significantly in terms of their social capital. From a cultural perspective, higher education is correlated with higher energy consumption for everyday mobility and holiday trips (Kleinhückelkotten, Neitzke, and Moser 2016).

Secondary Consumption

The lowest value for CO_2 emissions with respect to food products is 0.81 tCO_2e/y, with the highest being 3.12 tCO_2e/y. For the consumption of other products it is 1.58 and 7.67 tCO_2e/y. For food, the range of carbon emissions is smaller because it represents an endosomatic energy use, meaning that the biological system or metabolism of humans does not differ much between individuals. The purchase of other goods, however, is a consumer behavior that is not necessarily related to natural needs, and thus determines the group structure in this sector. The clusters for secondary consumption cannot be as clearly ordered as in the previous sectors. The order chosen for the emission groups follows the rising emissions regarding other consumptions. The size of the groups is partitioned, with the medium group representing one-third of the respondents. Generally, the individuals are distributed more equally across the groups than in the other sectors, a linear or steady increase from group to group is not observed. One result of this clustering, particularly for food consumption, is that there is less inequality between groups. On the other hand, emissions from other products consumed steadily increase from group one to five. Totally, the top group, with only half as many assigned individuals, emits the equivalent carbon emissions as the bottom group. However, the range between the number of individuals in each group and the differences in averages of individual emissions are less marked than in the other sectors. These results show that the connection between metabolic needs and group affiliation is less important than analyses of (redundant) status symbols and lifestyles.

As in the previous two sectoral inquiries, results of the UBA research group (Kleinhückelkotten, Neitzke, and Moser 2016) are presented to include socio-demographic analyses; the only significant difference between the previous socio-demographic factors is between the sexes. Regression analyses show that, for example, the place of residence, is again not relevant for emissions arising due to food or other consumption. Men have a higher carbon footprint because they consume larger quantities of food, especially more meat. In principle, the eating habits within Germany are very similar across all age groups, income and educational level, and place of residence, with a generally high meat consumption. Regardless of gender, vegetarian or vegan diets are rare. In contrast to emissions occurring from food consumption, emissions from clothing purchases are greater in women than in men. They also increase with both the total number of people in the household and the number of those receiving income. Additionally, consumption is greatest in the 30–49-year-olds group. With the purchase of clothing, the inhabitants of the FRG emit more carbon emissions (157.0 kg CO_2e/y) in comparison with individuals from former GDR states (126.9 kg CO_2e /y). Here, both economic and social capital are significant. Regarding economic capital many cluster combinations show significant differences. Economic capital thus determines the purchasing of food products as well as consumer goods such as clothing, as indicated by the number and type of goods. A hierarchy of social affiliation, values or norms is created through the consumption or purchase of goods. The differences between groups in social capital are high. In the area of secondary consumption, the differences between groups are not due to the level of education (cultural capital), but rather to economic and social factors.

Discussion and Research Implications

Individual carbon emissions can be assembled into emission groups with distinct socio-metabolic profiles. These emission groups could be used to differentiate socio-metabolic classes in the German society, as proposed by Otto et al. (2020). However, more detailed research on the class formation process is needed to differentiate comprehensively socio-metabolic classes. This research and statistical analysis is a first step in this process.

Thus, Table 1 describes a possible group designation, the percentage of the German population in the sectors (distribution of individuals in the groups), and the percentage of consumption based O_2 emissions leaning on the division into socio-metabolic classes just referred to. The five groups are labeled as follows: bottom, lower, medium, higher and top emission group. The total results, in particular, confirm the expectation of a prevalent inequality in environmental impacts between groups; a small percentage of the population is responsible for extreme individual carbon emission.

Table 1. Emission groups for Germany in the sectors, percentage of survey respondents and percentage of consumption based CO_2 emissions.

Group No.	Emission groups	Housing		Transport		Secondary Consumption	
		% of survey respondents	% of consumption based CO_2 emissions	% of survey respondents	% of consumption based CO_2 emissions	% of survey respondents	% of consumption based CO_2 emissions
1	Bottom group	49	28	55	12	23	19
2	Lower group	38	41	24	25	18	18
3	Medium group	10	18	13	28	33	32
4	Higher group	2	6	6	21	13	16
5	Top group	1	7	2	14	13	15

In Germany, the per capita living space increases with income (Kleinhückelkotten, Neitzke, and Moser 2016) and respondents prefer to live on their own (41.1 percent) or in two-person households (34 percent) (Statistisches Bundesamt 2018). Excessive living space per person is ineffective from an energetic perspective, however, changing housing preferences through political means or incentives is difficult to achieve. Reduction of emissions in the housing sector are likely to emerge through decarbonization of energy infrastructure, including coal phase out, switching to renewable energy sources in general, and improved house insulation and energy efficient home appliances.

In the transportation sector, it is noticeable that the majority of the population travels little. The remainder, however, have extremely mobile lifestyles. This may be the result of two factors: (i) financial restrictions exist and many cannot afford a big car or vacation, and (ii) individuals are too busy satisfying their basic needs to have time to travel. Income is correlated with carbon emissions in the transportation sector (Kleinhückelkotten, Neitzke, and Moser 2016). Our results also show that economic capital is significantly responsible for group differences in the transport sector, whereas social capital is not. Travel and cars are status symbols, not only for the wealthiest, which emphasizes class identity and the attempt to dissolve class affiliation. The highest emissions in transportation arise in the 30–49 age group. The possible reasons could be that this age group has a fixed income (Finke et al. 2017), are cosmopolitan in outlook (Merkel 2017), but also are trying to establish themselves socially via status symbols. However, the debate on mobility-related emissions should clearly indicate that high income groups can buy their way out of mechanisms such as carbon pricing or afford to switch to e-mobility, and such policy implications clearly need to incorporate elements of social justice.

The analysis by Kleinhückelkotten, Neitzke, and Moser (2016) showed that men have a higher footprint in the transport sector than women. This could be due to the gender pay gap (Finke et al. 2017) and also, more men than women fly in their professions (Ciobanu, Lungu, and Veramendi 2016). It should be noted that a large part of the world's population has never flown and that these statements are very limited in regional terms. Finally, cars or motorcycles may be symbols of masculinity, reflecting dominant patriarchal structures. For the last sector, secondary consumption, CO_2 emissions from nutrition are not group specific. This implies that each group has individuals representing a wide variety of dietary habits. Poore and Nemecek (2018) provide evidence for the importance of dietary change to meet environmental targets. For Germany, Kleinhückelkotten, Neitzke, and Moser (2016) state that eating habits are the same across all regions or milieus. In the field of nutrition, the reduction of meat consumption has therefore the highest priority. Regression analyses reveal that the level of education, or cultural capital, is not decisive for food consumption. This raises the question of the role of environmental education. It also strengthens the fact that a high level of environmental knowledge and consciousness does not influence the decision making process for a sustainable lifestyle (Kleinhückelkotten, Neitzke, and Moser 2016). A fundamental cultural change would take much more time than is available in the face of climate change. Therefore, the climate impact of meat production should be consistently reduced through appropriate agricultural policies, even if this would increase the price of meat and meat products.

Furthermore, the respondents living in the former GDR consume less energy than individuals in the former FRG who also have higher levels of consumption (Kleinhückelkotten, Neitzke, and Moser 2016). This indicates a social and cultural legacy of the division, and maybe also represents an economic imprint arising from income disparity. There are still serious economic differences between Eastern and Western Germany that are clearly noticeable in wages. Although the wage gap between East and West Germany was narrowed quite rapidly in the early 1990s, this adjustment process came to a halt just as quickly (Kluge and Weber 2016). Since the turn of the millennium, the gap in gross wages and salaries has averaged €5.35 per hour. This is exceptional and might be a reason, as in other former socialist countries, frugality is not necessarily noticeable. One possible explanation could be that the free market economy in the FRG endorsed habits of intensive or mass consumption (Reckendrees 2007), whereas the planned economy in the former GDR forced the opposite.

Our research also suggests that the popularly used carbon footprint calculators should include energy consumption and emission hotspots related to the use of digital technologies and services. Data generation and storage, communication, connectivity or even progress in sustainable areas such as e-mobility are accompanied by enormous energy consumption in both the development and the use of technologies. The question of a purported added value of certain technologies for humanity tempts us to consider a new metabolic stage.

The technological development is also accompanied by an enormous consumption of resources (like rare earth elements), which shifts ecological problems to other regions of the earth.

Additionally, a detailed analysis of the role of gendered aspects needs to be performed, e.g. concerning the division of labor between men (paid work) and women (care work), whereby all points of origin of emissions should be included and not only those of households, but e.g. at the workplace. In addition, only binary gender aspects (Male vs Female) have been addressed so far in relation to consumption differences. This is related to data availability and should improve in the future. More focus should also be given to racialized aspects of energy and resource consumption, and thus consumption differences under distinct discriminating mechanisms. Advanced research methodologies, including the possibilities of critical race theory applications to quantitative methodologies through QuantCrit could be meaningful (Garcia, López, and Vélez 2018). Analytical frameworks (such as intersectionality) are applicable in understanding the diversity and complexity of the social structure and to uncover power structures. This is relevant both within a society and in the global context regarding an imperial mode of living (c.f. Brand and Wissen 2017) or disparities between the global north and south.

Conclusion

Based on the metabolism approach, we attempt to explore environmental inequalities in grouping a society into emission groups. What this approach fails to recognize, however, and what needs to be practiced further, is a Marxist approach criticizing the contemporary capitalist society, and the extent to which this critique can be integrated with an ecological critique that is dialectically connected. For Marx, sustainability was central to the future development of a communist society, and thus an "everlasting condition in the chain of successive generations" (Foster 1997, 292). Marx claimed that capitalism was exceeding the limits of such sustainability but implodes before such unsustainable development emerges due to its internal economic contradictions and the revolutionary role of the proletariat as a truly dominant factor in historical development (Foster 1997). Marx focused on the irrationality of capitalist exploitation of the soil versus the necessary forms of production under communism, and his concept of sustainability was a central vision of a future communist society. Saito (2020) also describes that the basic problem is not a mode of living but a mode of production, which tends to exploit people and nature. The metabolic shift is inherent in the logic of capital, whereby the imperial mode of production is constantly reproduced and its violence is made invisible. Marx's concept of an irreparable rift could be interpreted as a metabolic rift, which entails three different levels of metabolic shift: the material circulation within the metabolic cycle of nature (e.g. the disruption in the circulation of soil nutrient); a spatial rift (e.g. the antagonism between town and county); and a temporal rift (as in a rift between nature's time and capital's time) (Saito 2020). This level of analysis could be used as the theoretical foundation for updating Marx's theory of post-capitalism in the age of global ecological crisis (Saito 2020).

Finally, this paper demonstrated that the concept of Planetary Boundaries can be successfully linked with social differentiation theories and to a critique of capitalist societies. Class-based analysis can help us invalidate the specious Malthusian argument that population growth is causally related to environmental damage (exemplarily Ehrlich and Holdren 1971; Chontanawat 2019; Murtaugh and Schlax 2009). This perspective is particularly important to correct fundamental structural flaws and create a future in which egalitarian principles prevail and inequalities are reduced.

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