European Citizens, Carbon Footprints and Their Determinants—Lifestyles and Urban Form

Vera Peters, Fritz Reusswig and Corinna Altenburg

Abstract In this study we explore the differences between carbon footprints of private households across three European countries. The assessment of CO_2 emissions for housing, mobility and food is based on a survey of 844 inhabitants of rural and urban areas in Scotland, Czech Republic and Germany. The relevance of urban form, household structure, socio-demographics and lifestyle characteristics is investigated in relation to area specific conditions that influence the energy demand but also determine its enviormental impact. We can see significant differences in the carbon footprint across the case studies, which can to a certain extend be related to varying income levels in Scotland, Czech Republic and Germany. But of course, there are other influencing factors on different levels: different structural factors, such as the respective energy mix of a country, the availability of district heating and eco-friendly products such as green electricity, the urban form and household structure. Without the support of the built environment and public institutions, it is mostly difficult for individual households to translate their pro-environmental preferences into real behavior, but the data also reveals that the actors' environmental values do have a direct influence on the level of CO_2 emissions in some areas like food and flight emissions.

Keywords Carbon footprints · Energy · Lifestyles · Urban form

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1 Introduction

Climate change is already underway and it will become more severe in the future. Although the really dangerous physical *impacts* of climate change will occur later in time, the economic *costs* of climate change have to be taken into account already now (Stern 2006; Ackerman et al. 2010; van den Bergh 2010). Extensive research on the impacts of climate change in Europe show that all regions will be affected, with Southern Europe most probably experiencing more severe and earlier damages (Ciscar et al. 2011).

The European Union as a major global emitter of greenhouse gases has taken over global responsibility by accepting a 8 % reduction targets (EU 15) under the Kyoto Protocol, and it has more ambitious targets of 20–30 % as part of the Europe 2020 Strategy (European Comission 2011a). The long-term perspective is to achieve a carbon-free economy until about 2050 (European Commission 2011b). Becoming a 'green economy' (Rifkin 2011) is a big challenge, as it will require different transformations:

- The European energy system will have to be restructured towards a 100 % renewable energy basis.
- The European building sector will have to adopt a zero emission or even carbon negative standard, which is a challenge especially with respect to the existing building stock.
- Mobility in Europe will have to become carbon neutral, relying on new engines and to a larger share on carbon neutral public transport.
- Production and consumption systems will have to reduce their carbon footprints significantly, e.g., by large efficiency gains, more recycling, or by developing completely renewable materials.
- European consumers will have to adopt greener lifestyles in order to purchase these new forms of energy and products.
- European cities will play a major role in this transformation process, as their metabolism and structure will by large determine the degree to which European citizens in- and outside cities can adopt greener lifestyles.

While there is a widespread consensus that the energy system needs a substantial 'greening', that energy efficiency gains will have to be achieved, and that all kinds of technological innovation is needed, many scholars and politicians hesitate to ask for lifestyle changes and the reflection of consumption patterns. However, we argue that without complementary and supporting changes in individual lifestyle and consumption Europe will not be able to meet its long-term climate policy targets (Reusswig 2010).

This raises various questions with respect to the capacity of European societies to achieve these goals, and to meet the associated challenges mentioned above. Of particular interest is the question whether European citizens are ready and able to reduce their individual carbon footprints, and if and how their willingness and ability to do so is influenced by some structural constraints, namely the 'urban form'.

In a wide sense 'urban form' comprises all structural features of the built environment (including infrastructures) that influence individual choices and behaviors. Whether or not individuals choose a bus or train to commute to their workplace for example is clearly dependent upon the availability and the costs of public transportation—among other things. Whether or not people decide to heat their homes with a district heating system obviously depends upon the availability of such an option. If green products are not on offer, or not at affordable prices, people will find it hard to change their consumption habits in an environmentally friendly way. The density of a city has an influence on both travel patterns and patterns of energy use, and so forth. While the general coupling of lifestyles and consumption patterns on the one hand and the urban form on the other is widely accepted, it is not clear how exactly these connections work.

2 Approach and Methods

2.1 General Approach

The main research interest of the European project GILDED ("Governance, Infrastructure, Lifestyle Dynamics and Energy Demand: European Post-Carbon Communities") was to analyze variances of household energy use across Europe and to identify if European citizens felt the necessity to change their energy consumption habits and lifestyles due to the needs of climate change mitigation. For that reason, three dimensions of comparison—and thus of possible variance—were introduced:

- We were looking at case study regions in five *different countries* in the European Union (United Kingdom, The Netherlands, Germany, Czech Republic and Hungary), as country differences in availability of services, energy prices and income level, political boundary conditions, and cultural traditions influence the choices of individuals.
- In every country, our case study was sub-divided into an *urban* and a *rural* sub-sample in order to control for the contextual influence of the urban form. We have chosen European mid-size cities [Aberdeen (UK), Assen (NL), Potsdam (D), Czeske Budějovice (CZ), and Debrecen (H)] and their rural hinterlands, so we cannot draw conclusions with respect to larger cities (e.g. European metropolises).
- Across the whole sample, the households were studied according to a *lifestyle segmentation approach* in order to take different socio-economic and cultural conditions of individuals into account. The lifestyle segmentation approach was only applied in the German, Scottish and Czech case study, which is the reason why we exclude the Dutch and Hungarian dataset from the current analysis.

2.2 Sampling

The data derives from a survey conducted from February to May 2011. The households had already been questioned in 2010, because one goal of the project was to test a social psychological intervention and its potential to decrease emissions over one year. We omit this aspect of research for the purpose of this chapter.

Due to the large study areas the households were determined by cluster sampling and visited personally by a drop-and-collect method. The response rate was not as high as we hoped for (Table 1) which probably had a couple of reasons: the CO_2 calculator that was part of the questionnaire was long and detailed, it took quite an effort and amount of trust to reveal these details of the household. We were not able to send a pre-notification, which most probably would have improved the response rate.

There are also some important constraints regarding the representativeness of the data: in all three countries the data is biased towards older respondents. Also, in Germany the share of respondents with a high formal education and high income is considerably larger than it generally is in Potsdam and its corresponding rural area Potsdam-Mittelmark.

2.3 CO_2 Calculations

Carbon dioxide emissions are the main driver of anthropogenic climate change. Along with the current academic status quo, we hereby define a general carbon footprint as the direct and indirect greenhouse gas emissions measured in tons of CO_2-equivalents, which are required to satisfy a given consumption (Minx et al. 2009). For our CO_2-e calculations we used an extensive questionnaire that included

Table 1 Response rates per country for 2010 and 2011

		Czech Republic	Germany	Scotland	Total
2010	Total target sample	5,000	1,842	6,340	
	Number of questionnaires returned	500	543	1,099 (489*)	2,142 (1,532)
	Response rate	10 %	29 %	18 %	
2011	Number of questionnaires returned	309	320	279	908
	Drop-out rate between 2010 and 2011	38 %	41 %	43 %	
	Number of respondents a CO_2 footprint could be calculated for	292	300	252	844

* 489 respondents out of 1,099 were given the whole survey material, including the CO_2 calculator

information on the energy sectors housing (heating and electricity), mobility (car, air travel, train and coaches, public transport) and food. Calculations were based in part on electricity and heating bills, in part by an assessment through self reported behavior and information on the households' infrastructure (e.g., type of heating system, annual mileage, room temperature, preference for organic products).

Indirect emissions from modes of transportation other than personal motorized vehicles (e.g., flights see Jardine 2009) and food consumption were included. Regarding food emissions the lifecycle emissions that can be attributed to food items were estimated. We had to exclude indirect emissions embodied in other consumer goods as data is not as robust for all GILDED countries. The following criteria had to apply for the carbon calculator used by GILDED:

- It should be based on the data of each individual household as opposed to geo-consumptive data which represents meta-footprint data on a regional level. We thus have chosen a consumption based approach as opposed to a primary energy balance based approach (cf. Minx et al. 2009), which allows us to include emissions from product lifecycles, independent to where they have been generated. This is important given the high relevance of trade for the European economy.[1]
- The right balance between accurateness and length of the tool had to be found: there is a trade-off between the appropriate length of surveys still being accepted by households and the accurateness of the final carbon footprint.
- It had to be based on CO_2-equivalents as opposed to only CO_2 emission factors: CO_2-equivalents also take into account the impact of other GHGs such as methane, which is especially important in the domain of food production.

We adopted the methodology of the CO_2 calculator developed by Schächtele and Hertle (2007) and used by German Environmental Agency (UBA), but also made use of national CO_2 calculators in order to take the particularities of national energy systems into account, e.g., with respect to the CO_2 intensity of the national energy mix.[2]

[1] It should be noted that experiences with lifecycle assessment based product carbon footprints that we have been involved with reveal that currently we can only operate with estimates or rather generic data that do not account for product specific differences. For example it makes a big difference whether orange juice comes from Spain or from dry concentrate from Brazil, however most calculators use a generic emission value for 'orange juice' (cf. the German Product Carbon Footprint Pilot Project, www.pcf-projekt.de).

[2] See: http://carboncalculator.direct.gov.uk, http://kalkulacka.zmenaklimatu.cz.

3 Results on Differences Between the Case Studies' CO_2 Footprint

3.1 Overview of CO_2 Differences Between Cases Studies

Based on the above outlined GILDED methodology the carbon footprints per household and per capita were calculated. As can be seen in Fig. 1, the average per capita emissions differ considerably in the three countries. We see an average per capita consumption in our study regions of 6.1–8.0 tons of CO_2 per year, with Czech households at the lower and Scottish households at the top end.

It needs to be noted that these results vary from other national results as emission from consumption and public infrastructure are not taken into account. In the German case, one would roughly have to add 3.75 tons CO_2-e for consumption and 1.1 tons CO_2-e for public emissions in order to end up at the national average of about 11.0 tons per person (Klimaktiv n.d.).

Comparing the total distribution of CO_2 footprints (Fig. 2) especially the range in the Scottish sample is apparent.[3] The extreme values represent respondents that have exceptionally high emissions mostly due to frequent air travel or because of inefficient usage of coal for heating. They are partly responsible for the high mean value in the Scottish sample, but the Scottish median is also considerably higher than in the other two countries: 6.7 tons compared to 5.9 in the German and 5.4 in the Czech sample. There is also relatively little variance in the Czech data.

It is interesting to see that in Europe today we can already find households with individual carbon footprints in the range of 2–3 tons per capita and year—not only in the Czech Republic, but also in Germany and Scotland. If we accept the long-term goal of 2 tons per capita that we need to reach by 2050 in order to meet the 2 °C goal adopted by both the EU and the member states of the UNFCCC, these individuals are quite close to that target already today. It is clear that they only represent a minority, and that indirect emissions from consumption and public infrastructure have to be added to our results, but still the existence of relatively low-carbon lifestyles in Europe today is an encouraging sign and needs further research.

3.2 Factors Influencing Individual CO_2 Footprints

As mentioned in the introduction, various factors influence the consumption and lifestyle choices of individuals, thus leading to different private carbon footprints.

[3] Extreme values and outliers were generally not excluded from analysis, only when they resulted from apparently false information. For the most part however the large variance of CO_2 emissions represents reality. It was checked if differences between groups resulted from single extreme values. Such instances however did not emerge for the analysis of this chapter.

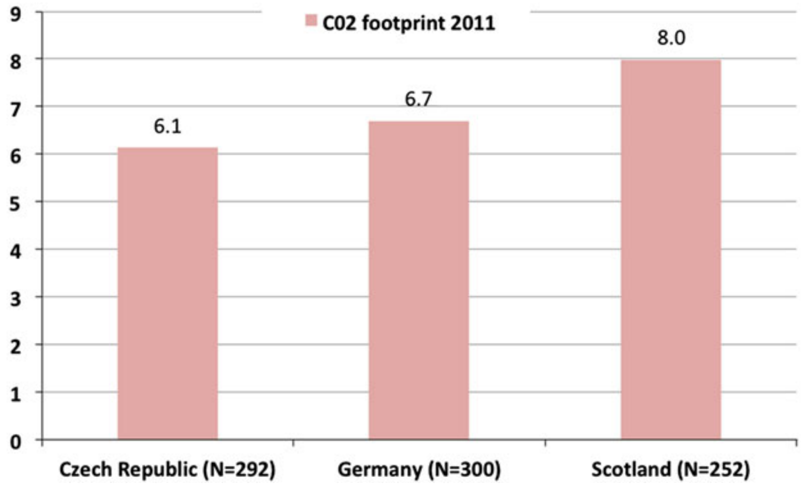

Fig. 1 CO_2 footprint (housing, mobility, food) average per country in tons CO_2-e per year per capita (2011)

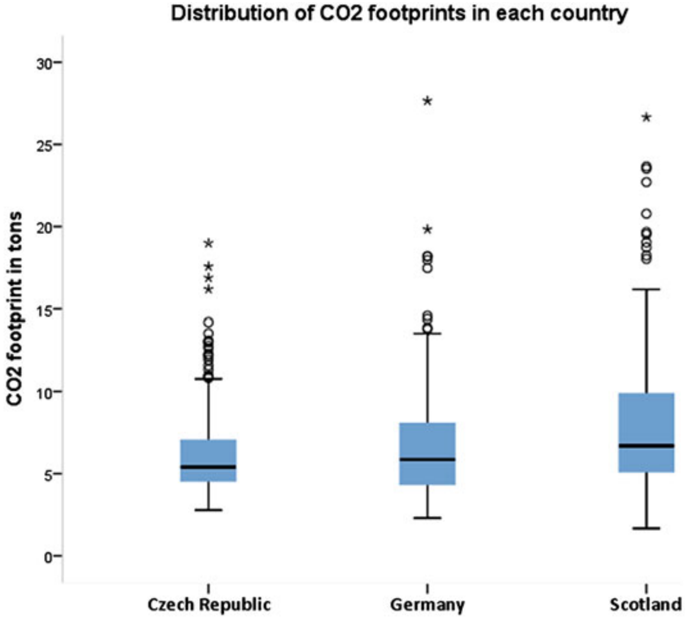

Fig. 2 Boxplots of the CO_2 footprints (in tons CO_2-e per year per capita), the *black band* represents the median, the colored *box* ranges from the 25th to 75th percentile and the *upper* and *lower* whisker show the 1.5 interquartile range, *circles* representing outliers, *stars* extreme values (2011)

Some of these factors are listed below, together with the average per capita emissions associated with that characteristic (Table 2).

We can see that indeed several of these characteristics are associated with the level of overall emissions. A first interesting result can be derived from our general indicator of the urban form, i.e., the residential *location* of households in either a city or its rural hinterland. Here we seem to find some confirmation for a global pattern described by Satterthwaite (2008): in more developed countries (in terms of economic performance), we find that city dwellers have lower per capita emissions than rural dwellers. This is a double effect of the higher densities and efficiencies in cities on the one hand, and of a rather high level of income and infrastructural development of suburbs and peri-urban regions in places like the US or Western Europe, on the other: here modernization and urbanization processes have also affected the 'hinterlands', but lower building densities and higher mobility demands have led to relatively high emissions.

We can also see that the *type of house* affects par capita emissions significantly. As one would expect, detached or terraced houses in all countries have higher emissions than appartement buildings. The largest difference can be found in the German case study region, with about 2 tons difference between house dwellers and inhabitants of flats. In the Czech Republic, we still find a difference of 0.7 tons.

Household size also affects the emissions. Across all countries there appears to be a negative linear relationship between the increasing number of people living in a household and their per capita emissions. This effect holds due to the economy of scale of private households. Given the trend towards smaller household sizes—an effect of both individualization processes and demographic changes in modern societies—we can thus predict *ceteris paribus* a growth trend of per capita emissions in Europe. This finding supports the idea of additional measures—either in terms of efficiency, or in terms of more renewable energy sources, or of more sufficient lifestyles—in the private household sector in order to meet Europe's reduction targets.

No clear trend can be observed with respect to formal education levels and per capita emissions. In Germany and Scotland a slight positive correlation exists, but in the Czech Republic we can see that highest educational levels show slightly smaller emissions. While age and gender also do not offer an unambiguous influence, income is confirmed also by this data to be a very important predictor for individual GHG emissions. This holds true at least for Germany and Scotland: while the lowest income quintile emits 5.6 (Germany) or 5.7 tons (Scotland) respectively, we find the top income quintile emitting 8.0 (Germany) or even 10.9 tons per year (Scotland). In the Czech Republic, the association is less marked.

3.3 Lifestyles and CO_2 Emissions

Up to now we have used the term 'lifestyle' in a rather vague sense, referring to the consumption patterns of private households. Nevertheless, the term does have a

Table 2 Average CO_2 footprints differentiated by contextual, household and socio-demographic characteristics (2011, in tons CO_2-e per year per capita)

	Czech Republic	Germany	Scotland
Contextual characteristics			
Urbanity	(Rural: 53 %)	(Rural: 46 %)	(Rural: 52 %)
Rural	6.5	7.1	8.6
Urban	5.7	6.3	7.2
Household characteristics			
People in Household	(M = 2.9)	(M = 2.6)	(M = 2.3)
1	8.8	7.5	10.0
2	6.6	7.4	8.3
3	5.8	6.2	6.7
4	5.3	5.2	5.5
5+	4.4	5.3	5.1
Type of house	(*House*: 63 %)	(*House*: 70 %)	(*House*: 85 %)
House detached	6.5	7.3	8.2 (not differentiated)
Semi detached house	6.1	6.8	
Terraced house	6.9	8.2	
Flat 2–3 stories	6.0	5.8	6.5
Flat multi story	5.4	4.9	
*Equivalent net income**	(M = 600 Euro)	(M = 1,500 Euro)	(M = 1,700 Euro)
Lowest income group	5.4	5.6	5.7
2nd lowest income group	7.0	6.0	6.9
Medium income group	5.4	6.6	8.1
2nd highest income group	6.9	7.0	8.3
Highest income group	6.5	8.0	10.9
Sociodemographic characteristics of respondent			
Gender	(Female: 52 %)	(Female: 46 %)	(Female: 46 %)
Male	6.2	6.4	8.1
Female	6.0	7.1	7.8
Age	(M = 46)	(M = 54)	(M = 58)
18–30	5.7	6.2	5.2
31–40	5.6	5.5	7.1
41–50	6.1	6.5	6.5
51–60	7.4	7.6	9.4
61–70	6.4	7.2	8.5
71+	5.3	6.6	8.2
Formal Education	(Tertiary: 16 %)	(Tertiary: 47 %)	(Tertiary: 16 %)
No or primary education	4.6	–	–
Secondary lower	6.3	6.7	7.2
Secondary higher	6.3	6.5	7.0
Tertiary	5.9	6.9	9.3
Employment status	(Retired: 24 %)	(Retired: 35 %)	(Retired: 43 %)
Employed (all also halftime)	6.3	6.4	8.0
Retired	6.2	6.9	8.3
Housewife/-man	4.5	9.6	3.9
In training/school/studying	5.5	5.4	7.0
Momentarily unemployed	7.4	6.9	4.7

* For the estimation of equivalent net income the households' income was weighted according to the new OECD scale, however in a simplified way since we lacked information on the age of each household member: the estimated monthly disposable income of a household is divided by people in the household: 1st person counts 1, each further person 0,5 (according to the new OCED Scale children under 14 years are only accounted as 0.3)

rather specific meaning which was mainly, developed during the 1970s and 1980s in consumer research and the social sciences (Earl 1986; Otte 2004). Here, the concept of lifestyle was meant to detect group specific ways of leading and interpreting one's individual way of life, thus including 'objective' and 'subjective' dimensions. Examples for the former would be income or consumption patterns, while value orientations and attitudes would be examples for the latter. In modern sociology, the concept of lifestyle aims at a modernized concept of social inequality that encompasses the mental dimension (attitudes and values) as relevant aspects of social differentiation (Müller 1992; Schulze 1992). French sociologist Pierre Bourdieu (1976) has made a famous attempt in that direction. While Bourdieu has provided us with an inspiring, both analytically stringent and very colorful picture of the French society of the late 1960s, contemporary sociology and some market research institutes inform us about recent changes in lifestyles. The social milieus approach by the Germany-based Sinus Institute[4] for example combines data on the social structure of individuals (such as income or educational level) with information about their values and life goals. As a result, Sinus obtains 10 different social milieus, i.e. 'like minded' social groups that show internal similarities with respect to their social situation and values (SINUS n.d.).

Regarding energy-related behavior the lifestyle approach was able to explain certain differences in behavior patterns, such as travel behavior, especially leisure mobility: e.g., analysis has shown group differences regarding the mode of transportations (Beckmann et al. 2006) and holiday destinations (Otte 2004). Lifestyle research also suggests significant group differences on factors influencing direct energy use at home, e.g., the requirements of accommodation (Schneider and Spellerberg 1999) and the amount and kind of electronic appliances (Bohunovsky et al. 2011). However, it has yet to be shown if different energy patterns result in different levels of overall consumption and emissions between the groups.

Based on this work we developed a comparable typology of lifestyle groups, combining information on the economic resources of our respondents (equivalent net income) with information about their values (traditionality, hedonism/materialism, self-fulfillment and environmental awareness) and consumption preferences (thriftyness, materialistic, hedonistic, sustainable). A two step cluster analysis was applied for each country in order to detect groups with similar lifestyles as defined here by the interaction of economic resources, general values and consumption preferences. As we were interested in the differences between the groups regarding their ecological orientation (Fig. 3), we created an index that ranges from high to low agreement to sustainability values and consumption practices (x-axis). Combined with the vertical resource axis (high-low equivalent income) we obtained a two-dimensional social space. The size of the 'bubbles' indicate the groups' share in the national sample, their color the case study region they belong to. The

[4] See: http://www.sinus-institut.de/en/.

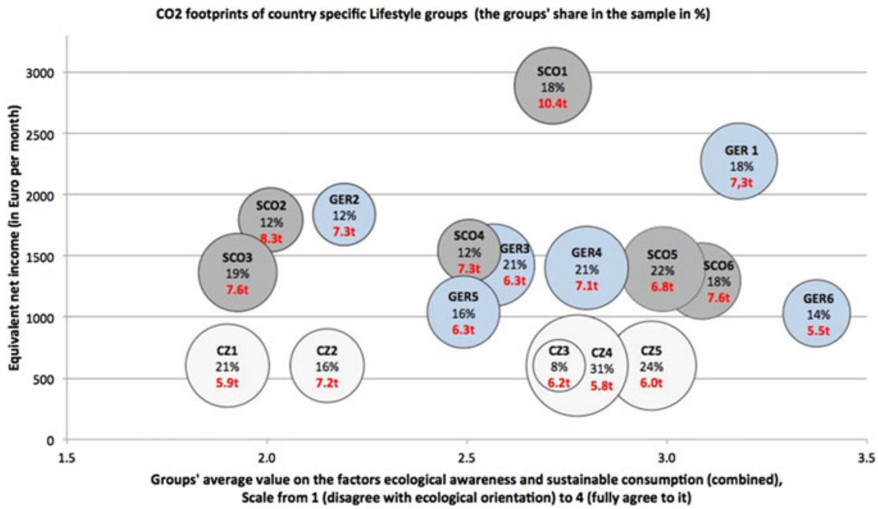

Fig. 3 Mean CO_2-e footprints (per capita per year) of country specific lifestyle groups in Germany (*blue*), Scotland (*grey*) and Czech Republic (*white*). Numbers represent the mean CO_2 emissions of the group. Percentages and size of the *bubbles* depict the share of the group in the sample (2011)

average per capita CO_2 emissions of the particular lifestyle group is indicated inside the bubble.

The results of the lifestyle analysis are interesting in various respects. First, we find that people with similar economic resources may have very different sustainability values and consumption orientations, and the other way around. For example in Germany there are two groups with high agreement to ecological values and preferences (GER1 and GER6), but they differ completely when it comes to their economic resources (Fig. 3, the two bubbles to the very right): this difference in living situation affects their value system—while the high income group GER1 combines ecological orientations with hedonistic interests and a focus on political correct consumption, the less affluent and older lifestyle group GER6 embeds ecological values in thriftiness and traditional values, like the focus on duties and orderliness. But the difference in economic resources apparently also affects these groups' energy consumption, seemingly regardless of their values: GER1 is also among the groups with the biggest CO_2 footprint in the German sample (7.3 t).

Similarly, the Scottish most affluent lifestyle group (SCO1) is the one with the-by far-highest ecological footprint. Another relatively high income group is the Scottish hedonic group SCO2: these respondents are fun and consumption oriented, without considering much environmental issues. SCO2 also has a larger average CO_2 footprint (8.3 tons), which might be connected to both, the comparatively high income or the values and consumption preferences (this will be further analyzed in the multivariate analysis).

The Czech lifestyle segmentation represents an exception: the two step cluster analysis did not identify like-minded groups with distinct income levels.[5] When looking at the Czech lifestyle groups there is no indication that environmental values and consumption preferences are connected to a lower CO_2 footprint; the two Czech groups that seem to have a rather low environmental awareness (CZ1 and CZ2, together 37 % of the sample) have a slightly larger CO_2 footprint, but it does not considerably differ from that of the other, more environmental aware groups.

Finally, comparing the 'overall' environmental awareness level between the countries does not help explaining their differences in CO_2 emissions. Even though differences across countries are significant (e.g. only 12% in Germany show very little interest in environmental matters, compared to 31% in the Scottish case), this variance does not help explaining the two country's differences in CO_2 emissions. For a large part of people lacking environmental orientation does not emit more than their eco-friendly counterparts. The environmental friendly groups do not stand out as emitting fewer emissions. Hence, different levels of environmental awareness in Scotland and Germany do not result in varying carbon footprint in our case studies.

On the other hand lifestyle analysis suggests that income can explain quite much of the level of CO_2 emitted—within and between countries. Considering the overall smaller CO_2 footprints of lower income groups, the low income level in the Czech sample might very well be connected to the Czechs generally lower footprint.

3.4 Multivariate Analysis of the Overall CO_2 Footprint

The influence of attitudinal and socio-demographic characteristics of the respondents, as well as household and context factors is tested by applying multivariate regressions for each country. For this purpose multivariate hierarchical regression analysis on CO_2 emissions was used. The influence of socio-demographic variables alone and combined with the lifestyle aspects were estimated in two different models (step 1 and step 2). The share of explained variance by each of the two models (R^2 and adjusted R^2) and the regression coefficient (β) of each explaining variable will be examined.

As it could be expected, in all of the three countries the overall CO_2 footprint can partly be explained by structural factors, but not by values and preferences (Table 3). Especially in Scotland socio-demographic characteristics of the respondents worked overall quite well as predictors of CO_2 emissions: 39 % of the personal CO_2 footprint could be predicted, foremost by the variables equivalent

[5] These results suggest that in the Czech case there is no connection between income and values as operationalized here. This most likely indicates a problem with transferring the lifestyle concept to the Czech cases study and needs further investigation. But for this particular purpose the use of the segmentation is still useful and seems legitimate, since the ecological values we are focusing on in this paper were tested as reliable for the groups.

Table 3 Summary of hierarchical regression analysis for socio-demographic and lifestyle variables predicting the CO_2 footprint per capita

Variables	Overall CO_2 footprint per capita								
	Czech Republic			Germany			Scotland		
	B	SE B	β	B	SE B	B	B	SE B	β
1st step	8.97	1.38		7.54	1.86		−0.59	1.44	
Equivalent income	0.00	0.00	0.07	0.00	0.00	0.27***	0.00	0.00	0.33***
Region (urban = 1; rural = 2)	0.37	0.46	0.06	0.23	0.40	0.04	0.75	0.33	0.14**
Type of house (house = 1–3; flat = 4–5)	−0.28	0.13	−0.17**	−0.61	0.13	−0.33***	0.30	0.14	0.14**
Gender (male = 1; female = 2)	−0.51	0.33	−0.09	0.22	0.32	0.04	0.00	0.32	0.00
Age	0.00	0.01	0.01	⁻0.01	0.01	−0.03	0.03	0.01	0.15**
Formal education	0.18	0.13	0.09	−0.14	0.26	−0.03	0.31	0.11	0.16***
Number of people in HH	−1.20	0.15	−0.50***	−0.76	0.16	−0.32***	−0.78	0.17	−0.30***
2nd step	8.98	1.42		7.50	2.01		−0.73	1.47	
Equivalent income	0.00	0.00	0.06	0.00	0.00	0.24***	0.00	0.00	0.31***
Region (urban = 1; rural = 2)	0.43	0.47	0.08	0.24	0.40	0.04	0.71	0.33	0.13**
Type of House (house = 1–3; flat = 4–5)	−0.28	0.13	−0.17**	−0.59	0.13	−0.32***	0.30	0.14	0.14**
Gender (male = 1; female = 2)	−0.58	0.35	−0.10	0.24	0.33	0.04	0.11	0.32	0.02
Age	0.00	0.01	0.02	0.00	0.01	−0.01	0.03	0.01	0.17**
Formal education	0.16	0.13	0.08	−0.18	0.27	−0.04	0.34	0.11	0.17**
Number of people in HH	−1.19	0.15	−0.50***	−0.76	0.16	−0.32***	−0.82	0.17	−0.31***
Values: Traditionality				0.10	0.18	0.04	0.30	0.16	0.10*
Values: Hedonism/Materialism	−0.16	0.18	−0.05	0.08	0.19	0.03	0.13	0.17	0.05
Values: Self-fulfillment	0.05	0.16	0.09	0.18	0.03	0.02			
Values: Environmental awareness	−0.35	0.21	−0.12	−0.15	0.19	−0.05	0.08	0.21	0.03
Consumption: Thriftiness				−0.23	0.19	−0.08	−0.15	0.16	−0.05
Materialistic consumption	−0.11	0.18	−0.04	−0.07	0.19	−0.03	−0.19	0.16	−0.07
Hedonistic consumption	0.21	0.18	0.07						
Sustainable consumption	0.11	0.20	0.04	−0.08	0.20	−0.03	−0.42	0.21	−0.15**
Explained variance by the models	Adjusted R^2 for step 1 = 0.241*** ΔR^2 for step 2 = −0.010			Adjusted. R^2 for step 1 = 0.255*** ΔR^2 for step 2 = 0.001			Adjusted R^2 for step 1 = 0.385*** ΔR^2 for step 2 = 0.008		

Note The dependent variable CO_2 p.c. was split in 10 categories of the same size so that the residues follow a normal distribution. Predictors were checked for multicollinearity: variance inflation factors (VIF) of all variables were < 2. *$p < 0.10$. **$p < 0.05$, ***$p < 0.01$. Pairwise deletion of missing data was used (this accounts also for all other regressions) income and household size, but also age and formal education on the one hand, region and type of house on the other. As for lifestyle effects, in the Scottish case it is indicated that sustainable consumption preferences have a small effect on the CO_2 footprint (−0.15**). In the Czech Republic and Germany the model is not at all improved if lifestyle aspects are included. Even though the variance in CO_2 footprints is overall considerably less well explained in Germany than in Scotland, income, type of house and household size also show rather strong effects, while the household size and type of household are apparently the only significant predictor in the Czech case.

Comparing these results to the descriptive, bivariate analysis it is interesting to see, that the weak association between the urban and rural region and the CO_2 footprint is diminished or weakened. Apparently the difference between the sites is explained by the other variables: income, size of household and type of house. One of the most interesting findings is the lack of connection between income and emissions within the Czech case study. For a better understanding of carbon footprints and their determinants we need a closer look at the different domains of household energy consumption. Figure 4 splits the overall carbon footprint of the three GILDED countries into separate domains: heating, electricity, car use, air travel and food. Questions on the use of public transport were only included in the German and Czech survey, so the results are shown separately.

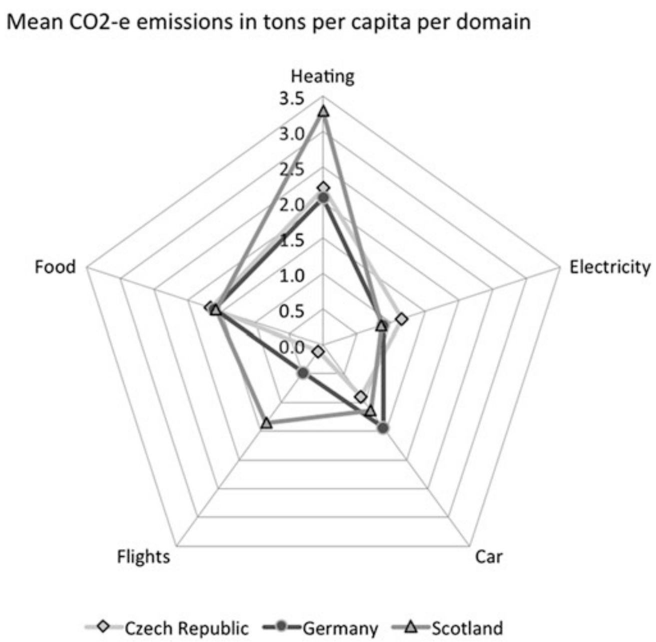

Fig. 4 Carbon emissions (in tons CO_2-e per year per capita) in different energy sectors (2011)

4 Sectoral Breakdown of Emissions

4.1 Heating

Emissions from space heating clearly dominate the total household emissions. Scottish emissions are on the top-end here, which can partly be explained by cold climate conditions in the Northern part of Scotland and partly by the high percentage of heating oil usage and heating with electricity (Fig. 5). Also, it reflects a high demand for refurbishment needs in the domestic sector—not only in Scotland, but also in the other countries.

The German and Czech results on heating emissions are fairly similar, even though the energy sources and therefore average emission factors are diverse. In the Czech Republic especially the large share of coal but also biomass and district heating is evident.

So, the emission factors hide the fact that Czech respondents actually consume less energy for heating. This has a lot to do with differences in household structure, with the Czech respondents more often living in larger households, resulting in less m^2 per person. The emissions of single households are disproportionally high, while in families emissions per capita are a lot lower.

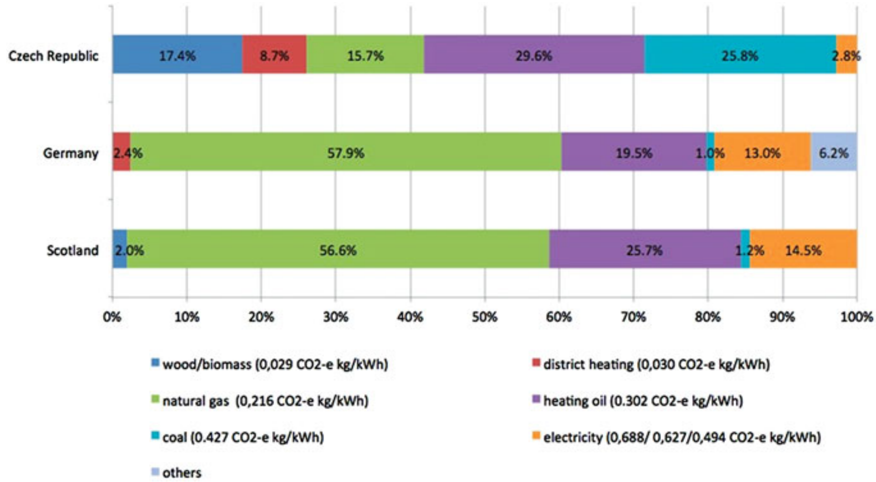

Fig. 5 Share of primary energy *sources* used for heating in the different countries (2011, in tons CO_2-e per year per capita), in *brackets* the emission factors of each heating source based on Klimaktiv 2.0 are presented (Klimaktiv n.d.). Coal emission factors depend on the use of coal or lignite. *Note* The emission factors of electricity depend on the country‘s electricity mix (see Table 4)

Table 4 Country's emission factors for electricity (2010), additionally the emission factor for green electricity based on Gemis 4.5 (Öko-Institut, n.d.)

German electricity mix	CO_2-e kg/kWh	0.627
Czech electricity mix	CO_2-e kg/kWh	0.688
UK electricity mix	CO_2-e kg/kWh	0.494
German green electricity	CO_2-e kg/kWh	0.04

4.2 Electricity

Electricity related emissions are highest in the Czech Republic, and nearly similar in the German and Scottish sample. This again not only reflects the quantity of electricity consumed (which in turn depends on the number and efficiency of appliances, as well as of consumer behavior), but also the energy mix of the respective countries (Table 4). The support for green energy would be a helpful measure to reduce household GHG emissions from electricity, as well as the spread of feed-in tariff systems. The German samples' mean electricity emissions are actually lowered quite substantially by the 19 % of the respondents that obtain electricity from green energy providers—compared to 8 % in the Scottish and only 0.3 % in the Czech case.

4.3 Car Use

By driving, the German and the Scottish respondents emit significantly more CO_2 than the Czech respondents. While in the more Western countries car related emissions exceed those of electricity, it is the other way around in Czech Republic. Looking into some of the direct determinants of the car related CO_2 emissions (Table 5) we can see some of the differences between the countries.

In Scotland there are few people without a car, but the car owners tend to drive a little less than their German counterparts. So overall the CO_2 emissions between these two case studies are quite the same. The Czech respondents on the other hand quite often do not own a car and if they have a car there is a rather high share of people who tend to drive it little (under 5,000 km annually), which is probably due to high gas prices. Interestingly, the Czech and German respondents use overall similar types of cars, very few consider their car an upper class car. In the Scottish sample the share of upper class cars is considerably higher.

4.4 Air Travel

Air travel is a very sensitive point in the household carbon footprint: one single long-distance flight may easily dominate the overall carbon footprint of an—

Table 5 Country differences in car owner ship and estimated number of km in the last 12 months (2011)

	Czech Republic	Germany	Scotland
Car ownership			
No car	18 %	9 %	8.6 %
Type of car			
Compact car	32 %	30 %	24 %
Medium sized car	64 %	66 %	61 %
Upper class car	4 %	4 %	15 %
Km in the last 12 months			
Mean km and standard deviation	11,328 (SD = 8,871)	13,854 (SD = 9,976)	12,900 (SD = 6,631)
5,000 km or less	29 %	15 %	12 %

Table 6 Country differences in the use of air transportation (2011)

	No flights (%)	Short flights (about 500 km) (%)	Medium distance flights (within Europe) (%)	Intercontinental flights (%)
Czech Republic	89	0	11	2
Germany	70	4	28	7
Scotland	54	21	30	20

Sums can be larger than 100 % due to multiple responses

otherwise—low-carbon household. In our case, the Scottish households have the largest footprint. As shown in Table 6 very few of the Czech respondents traveled by airplane in 2011. In Germany the number is also not very high, flights within Europe are most common. The Scottish respondents on the other hand use air travel fairly frequently, for short and long distances alike. This maybe due to the island position rather expensive train or ferry services in Scotland, combined with limited infrastructure in the Northern Scottish region.

4.5 Food

The countries' samples do not differ much regarding their mean food emissions, with Czech respondents at an average of 1.67 tons of CO_2, Scottish 1.58 tons and Germans 1.62 tons. Meat consumption as well as "alternative", lower emission products are consumed to a similar extent.

Table 7 Comparison of mean per capita CO_2-e emissions (in tons per year per capita) resulting from public transport and car usage in the German and Czech sample (2011)

	Czech Republic	Germany
Car emissions	0.9	1.4
Public transport emissions	0.1	0.04

4.6 Public Transport

The public transport domain is one where an increase of emissions would be seen as a positive shift, as this in large parts would reflect a modal shift away from the car. Interestingly, emissions from public transport are higher in Czech Republic, while in German the share of public transport emissions is minimal compared to the amount of car emissions. See Table 7.

5 Urbanity and CO_2 Emissions

5.1 Descriptive Results

Urbanity has been shown to be an important factor for the size of a household‘s CO_2 emissions. Looking into the urban and rural data separately should explain more of the variation in CO_2 emissions, especially regarding the different energy sources for heating, but also differences in car emissions, supposedly. Figure 6 shows the different emissions in urban and rural settlements.

In the German and Czech case study the rural areas have a larger footprint of about 0.8 tons, in the Scottish case the difference is bigger (1.2 tons). Evidently, in Germany and Scotland this difference mostly reflects higher heating emissions in rural areas and to a lesser extend also higher car emissions. When differentiating between rural and urban respondents it can be seen that especially the Scottish rural respondents tend to have very large CO_2 footprints. But also the urban Scottish respondents have a higher CO_2 footprint than their German counterparts, mainly because their more frequent use of flights.

The amount of air travel also distinguishes the German rural and urban households: in the rural area 83 % of the respondents did not fly while in the urban part it is much more common, almost every second respondent used a plane in the year preceding the survey (46 %).

In contrast the Czech rural and urban respondents only differ noticeably regarding their electricity emissions. This difference has to do with rural households heating water very often with electric boilers: 64 versus 32 % in the city. Another, smaller share of rural households also uses electricity and wood to heat up water (16 %). Contrary to that, the urban households’ warm water is often provided by the central heating station (i.e., district heating: 54 versus 1 % rural

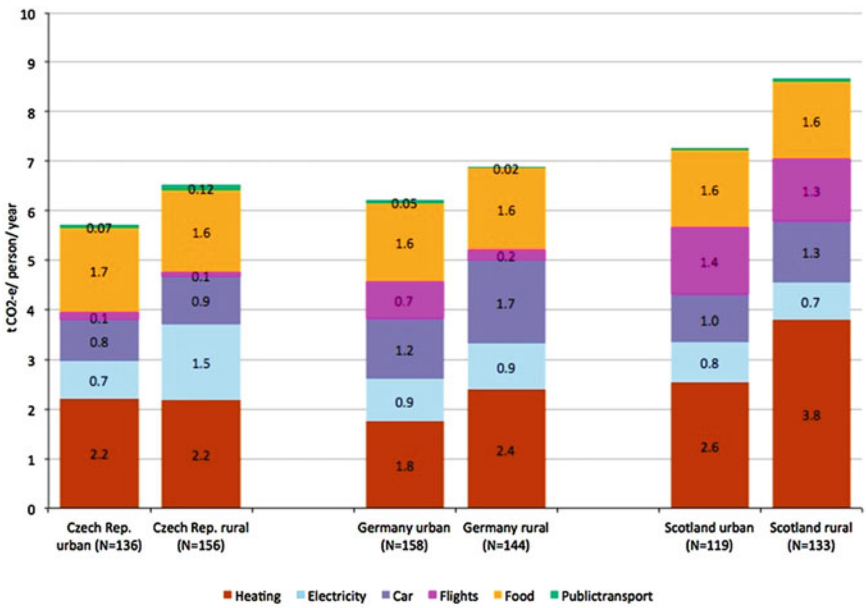

Fig. 6 Comparison of mean urban/rural CO_2-e emissions (per capita per year) for each country in the different energy domains (2011)

households). Their warm water emissions are thus included in the heating category, by that raising the urban heating emissions. Surprisingly car emissions are almost equal across the Czech rural and urban sites. The emissions from public transport suggest, that the Czech rural households are apparently not as dependent on the car as the rural households in the other countries. So the higher emissions from public transport compared to Germany mostly result from the frequent usage of public transportation of the Czech rural respondents.

5.2 Multivariate Analysis on Sectoral Emissions

In the German and Czech case, again, only structural factors turn out to be significant predictors for sector specific CO_2 emissions, with the exception of food emissions in Germany: food emissions in Germany and Scotland are barely explained by the first model—taking into account only structural factors—it improves significantly when horizontal lifestyle aspects are added. Sustainable consumption preferences (SCO: −0.29***; GER: −0.13*) and ecological awareness (GER: −0.20**) play a moderate role to explain food emissions, especially in Scotland. In the Scottish case lifestyle aspects also have a significant influence on flight and electricity emissions: flight emissions are negatively influenced by thriftiness ($\beta = -0.15$**) and sustainable consumption (−0.17**), and positively by hedonistic values (0.18**). CO_2 emissions by electricity are also negatively influenced by sustainable consumption preferences, albeit weakly (−0.10*).

Interestingly the results on Czech food emissions are very different from the Scottish and German ones: seemingly regardless of values and preferences Czech men tend to have higher food emissions (−0.19**), while older respondents (−0.20**) and respondents that live in households with more people (−0.24***) emit less by their nutrition. Gender also plays a role with regards to car emissions: Czech and German men tend to have a higher fuel consumption than women (CZ: −0.26**; GER: −0.15**); in the Czech case gender is actually the only variable that shows a significant effect on car emissions.

In Scotland on the other hand, car emissions are influenced by living in the rural area (0.21**) and by household size (−0.36***), but also by equivalent income (0.19**). Again, only in Scotland and Germany a relationship between income and emissions—in this case car emissions—is apparent (SCO: 0.19**; GER: 0.20***). It is quite astonishing that income has seemingly little influence on fuel consumption in a country with high fuel prices like the Czech Republic. The same pattern arises regarding flight emissions: while income does not explain flight emissions in the Czech case, in Scotland and Germany it explains flights moderately to very well (GER: 0.27**; SCO: 0.36***).

The respondent's age plays a rather different role in the three samples. In Germany older people use more heating energy (0.28***) and have considerably lower car emissions (−0.41**). This kind of "trade off" adds up to an average CO_2 footprint for older people (cf. Table 3). In Scotland, however, older respondents by trend have a higher CO_2 footprint, because they use noticeably more heating energy (0.31***) and electricity (0.14*).

The factor 'type of house' has an decisive influence on heating in Germany (−0.30***), less so on electricity (−0.16**), but also on car mobility (−0.14*). In Scotland it is not a significant factor—maybe an effect of the undifferentiated response categories "flat" and "house". In Czech Republic it has a strong effect on electricity (−0.41***), but—astonishingly—not on heating.

Summing up, equivalent income, household size and the urban or rural region are overall the strongest predictors: they have moderate effects on overall and sector-specific emissions, especially in Scotland. This also holds true for Germany, but here the type of house is more decisive for the CO_2 emissions than the rural location. In Scotland also education and age are important predictors for housing emissions. In the Czech case, on the other hand, equivalent income and education do not represent significant influences, while gender differences are quite important when it comes to food and car transportation. Lifestyle aspects in most cases do not help to explain the level of emissions. However, in Germany and Scotland they serve better to explain food choices than socio-demographic variables, and in Scotland they also help to understand flight emissions, electricity consumption and even the overall CO_2 footprint.

6 Conclusions

In this paper we focused on household emissions and managed to include direct, indirect, and even some embodied emissions (food). However, we had to set aside business travel, indirect emissions from the public sector, and emissions embodied in other consumer goods. Also regarding the little variance in food emissions, further research on product carbon footprints and more precise proxies on food consumption are necessary.

While the differences in carbon footprint across the case studies reveal an income gradient, the proximity of Czech emissions (6.1 t) to those of Germany (6.7 t) is surprising regarding the wide income gap. Conversely, the Scottish and German case study shows only slight differences in average income, but their mean carbon footprint diverges considerably. As shown there are other influencing factors on different levels—different contextual factors, such as the respective energy mix of a country, the availability of public transport, the urban form, household structure and socio-demographic characteristics and potentially also individual attitudes. Hence, in this paper we shed some light on on the overall relations between structural factors and private carbon footprints in different EU countries.

Using the lifestyle concept does in some instances increase the explanatory power of social science models analyzing energy use and carbon footprints of societies. However, we find the lifestyle concept even more important when it comes to explaining behavioral and wider social change. Change as an intentional project requires the involvement of the actors' values and social interactions. It thus is very helpful to choose a segmentation strategy that includes values. As a rule, people with higher incomes tend to have higher carbon footprints, pointing to the need of a de-coupling of growth and GHG emissions. Nevertheless, there are 'rich' households in Europe living on a carbon footprint of 3–5 tons. It is not a lack of income that shapes their behavior, but a range of factors, apparently some form of voluntary simplicity when it comes to energy use and climate protection.

These people might eventually serve as examples and multipliers of a low carbon lifestyle. They bear the potential for being positive role models for a wider social transformation to a low-carbon society, as they combine social status with relatively low carbon footprints. And it is not the need for de-coupling growth from emissions, but a deliberate stance or lifestyle that they actually exemplify.

Lifestyles include choices, but also contextual constraints. Energy systems, infrastructures, the urban form influence lifestyles, and lifestyles shape their built and technological environment. Our findings support the view that there is no choice between 'lifestyle politics' and 'infrastructure politics'. In fact, the two are closely interrelated. If Europe should become a green Economy, it will only be possible if we re-direct public and private investments in a way that carbon–neutral will emerge, but also by propagating and supporting greener lifestyles of these cities' dwellers. Without the support of the built environment and public institutions, individual households will find it hard to translate their pro-environmental preferences into real behavior, and without supporting attitudes and behaviors green cities will neither come about nor function.

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References

Ackerman F, DeCanio S; Howarth R, Sheeran K (2010) The need for a fresh approach to climate change economics. In: Gulledge J et al. (ed) Assessing the benefits of avoided climate change: cost benefit analysis and beyond. Proceedings of workshop on assessing the benefits of avoided climate change, 2009. Arlington, VA, pp 159–174

Beckmann K, Hesse M, Holz-Rau C, Hunecke M (2006) StadtLeben-Wohnen, Mobilität und Lebensstil: neue Perspektiven für Raum-und Verkehrsentwicklung. VS Verlag, Wiesbaden

Bohunovsky L, Grünberger S, Frühmann J, Hinterberger F (2011) Energieverbrauchsstile. Publizierbarer Endbericht. http://seri.at/wp-content/uploads/2011/09/BohunovskyGruenbergerFruehmann2010_Energieverbrauchsstile_Endbericht.pdf, retrieved on 25th April 2012. (Accessed Sep 2012)

Bourdieu P (1976) Distinction: a social critique of the judgment of taste. Harvard University Press, Cambridge

Ciscar J-C et al (2011) Physical and economic consequences of climate change in Europe. PNAS 108(7):2678–2683

Earl PE (1986) Lifestyle economics: consumer behaviour in a turbulent world. Palgrave Macmillan, Hampshire

European Comission (2011a) Europe 2020 Targets. http://ec.europa.eu/europe2020/pdf/targets_en.pdf (Accessed Sep 2012)

European Commission (2011b) Energy roadmap 2050. Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions. http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf (Accessed Sep 2012)

Jardine CN (2009) Calculating the carbon dioxide emissions of flights. Final Report, Environmental Change Institute Oxford. http://www.eci.ox.ac.uk/research/energy/downloads/jardine09-carboninflights.pdf (Accessed Sep 2012)

Klimaktiv (n.d.) CO_2-Calculator Klimaktiv 2.0, retrieved from http://klimaktiv.klimaktiv-CO_2-rechner.de. (Accessed Sep 2012)

Minx J et al (2009) Input-output analysis and carbon footprinting: an overview of application. Econ Syst Res 21(3):187–216

Müller H-P (1992) Sozialstruktur und Lebensstile: der neuere theoretische Diskurs über soziale Ungleichheit. Suhrkamp, Frankfurt am Main

Öko-Institut (n.d.), GEMIS 4.5 (Globales emissions-modell integrierter systeme), internet release on www.gemis.de

Otte G (2004) Sozialstrukturanalysen mit Lebensstilen: eine Studie zur theoretischen und methodischen Neuorientierung der Lebensstilforschung, (Social structure analysis with lifestyles) VS Verlag, Wiesbaden

Reusswig F (2010) Sustainability transitions through the lens of lifestyle dynamics. In: Lebel L, Lorek, S, Daniel, R (eds) Sustainable production and consumption systems. Knowledge, engagement and practice. Springer, Berlin, pp 39–60

Rifkin J (2011) The third industrial revolution: how lateral power is transforming energy, the economy, and the world. Palgrave Macmillan, New York

Satterthwaite D (2008) Cities' contribution to global warming: notes on the allocation of greenhouse gas emissions. Environment and Urbanization 20(2):539–549

Schächtele K, Hertle H (2007) Die CO_2 Bilanz des Bürgers: Recherche für ein internetbasiertes Tool zur Erstellung persönlicher CO_2 Bilanzen. (CO_2-Calculations for Citizens: Research for an online-based tool for personal CO_2-calculations). http://www.umweltdaten.de/publikationen/fpdf-l/3327.pdf (Accessed Sep 2012)

Schneider N, Spellerberg A (1999) Lebensstile, Wohnbedürfnisse und räumliche Mobilität. Leske + Budrich, Opladen

Schulze G (1992) Die Erlebnisgesellschaft: Kultursoziologie der Gegenwart (Thrill-seeking society: cultural sociology of today)

SINUS Markt und Sozialforschung (n.d.) The sinus-milieus in Germany 2011. http://www.sinus-institut.de/en/ (accessed April 2012)

Stern NH (2006) The economics of climate change: the stern review Cambridge. Cambridge University Press, Cambridge

Van den Bergh JCJM (2010) Safe climate policy is afford-able—12 reasons. Clim Change 101:339–354

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