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Analysis of the air pollution associated with household consumption in Belgium in 2014: the case of greenhouse gas emissions

Working paper for the SUSPENS research project funded by the Federal Science Policy Office

September 2019

Gertjan Cooreman, gc@plan.be
Jean-Maurice Frère, jmf@plan.be
Petra Zsuzsa Lévay
Josefine Vanhille
Gerlinde Verbist
Tim Goedemé

Avenue des Arts 47-49 – Kunstlaan 47-49
1000 Brussels

e-mail: contact@plan.be
http://www.plan.be

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Federal Planning Bureau
Avenue des Arts 47-49 – Kunstlaan 47-49, 1000 Brussels
phone: +32-2-5077311
fax: +32-2-5077373
e-mail: contact@plan.be
http://www.plan.be

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Abstract - This report examines which socioeconomic household characteristics determine greenhouse gas emissions in Belgium. The analysis is based on a new version of the PEACH2AIR database, which links the air pollution data with consumption expenditure of Belgian households as recorded in the 2014 Household Budget Survey. We find that food, transport fuel and household energy consumption account for more than 60% of greenhouse gas emissions, while they represent less than 30% of total expenditure. Total greenhouse gas emissions per household increase with income, but pollution intensity (grams of pollution per euro spent) decreases as income increases. After checking for the effect of other variables, it appears that the age, the level of education of the head of the household and the size of the dwelling lead to higher greenhouse gas emissions at the household level, while being unemployed, living in an apartment or renting a dwelling lead to lower greenhouse gas emissions.

Jel Classification - C67, C81, D12, Q53, Q56
Keywords - sustainable development, household consumption, environmental economic accounts

* Centre for Social Policy Herman Deleeck – University of Antwerp
** Institute for New Economic Thinking at the Oxford Martin School, Department of Social Policy and Intervention – University of Oxford; Nuffield College

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Executive summary

To combat the greenhouse effect and climate change, as stipulated by various international treaties, greenhouse gas emissions must be strongly reduced. For instance, Belgium has made a commitment to reduce greenhouse gas emissions in non-ETS sectors by 35% between 2005 and 2030. Households, businesses and the government have a shared responsibility. This report focuses on the household sector.

This report examines which socioeconomic household characteristics determine greenhouse gas emissions associated with consumption by households in Belgium. Taking into account a series of assumptions, the most important of which is that imported goods and services cause the same level of air pollution as those produced in Belgium, the PEACH2AIR database forms the basis for this research. PEACH2AIR links the air pollution data with consumption expenditure of Belgian households as recorded in the 2014 Household Budget Survey. It has been improved on several points compared to the 2018 version, such as the imputation of irregular expenditures and more precise air pollution data.

The analysis shows that food, transport fuel and household energy consumption account for more than 60% of greenhouse gas emissions, while they represent less than 30% of total expenditure. As a result, these categories have a high pollution intensity.

Total greenhouse gas emissions increase with income, but pollution intensity (grams of pollution per euro spent) decreases as income increases. This is because the higher the income, the lower the share of expenditure on energy for the home and food in total expenditure, and it is precisely this expenditure that is proportionately highly polluting. This relative decoupling between air pollution and income persists after controlling for the effect of other socioeconomic household characteristics. The same reasoning applies to greenhouse gas emissions and household size. As the household grows, the total greenhouse gases increase, but decrease per household member, which is due to economies of scale.

After controlling for the effect of other variables, it appears that the higher the age and education level of the head of the household as well as the size of the dwelling, the higher the greenhouse gas emissions at the household level. The opposite is true for households of which the head is unemployed, who live in an apartment (rather than in a house) or rent a dwelling. These results help to better understand the distribution of contribution to greenhouse gas emissions in Belgium, the potential redistributive effects of environmental policies, and the identification of households that may need more support for reducing their emissions.

This report is part of the SUSPENS research project funded by the Federal Public Service for Science Policy Programming. SUSPENS wants to support the policy preparation that accompanies the social transition to less polluting consumption patterns.

1. Introduction

Since 1992, when the United Nations Framework Convention on Climate Change was approved, the international community is increasingly aware of the necessity to reduce greenhouse gas emissions and thus to limit global warming. The internationally approved objective is to limit global warming to 1.5 or 2°C above pre-industrial levels. The Sustainable Development Goals approved by the General Assembly of the United Nations in 2015 unambiguously state in SDG 13 that urgent action is needed to combat climate change and its impact.

Since 2005, a market for emission allowances, the total of which is reduced every year, has progressively converged at the European level for heavy energy-using industries and the aviation sector. This market is called the EU Emissions Trading System (EU ETS). It is a cost-efficient way for these sectors to reduce their emissions. In line with the so-called Paris Agreement of 2015, the EU has also agreed to reduce greenhouse gas emissions for non-ETS sectors as a whole by 40% between 2005 and 2030. All key legislation for implementing this target had been adopted by the end of 2018. For Belgium, this target is equal to reducing greenhouse gas emissions by 35%. The non-ETS-sectors include agriculture, transport (excluding aviation and shipping), the residential sector, the commercial sector, the waste sector and other non-energy intensive industries.

This policy framework and these objectives set the scene for this report. In order to reduce greenhouse gas emissions and thus to limit global warming, it is necessary to change the consumption patterns of households towards low carbon patterns. Lower-carbon production and consumption patterns are not only a climatological concern. They are also a social issue because not all citizens contribute equally to greenhouse gas emissions when buying and using goods and services. It all depends on their consumption pattern. Furthermore, not all households have the same possibility to reduce their consumption-related greenhouse gas emissions.

This report describes the relation between the consumption patterns of the Belgian households, their income and other socioeconomic characteristics on the one hand and greenhouse gas emissions on the other hand. It is the tangible output of task 3.1. of the research project SUSPENS funded by the Federal Science Policy Office.

The analysis is based on the PEACH2AIR dataset (Frère, Vandille, Wolff: 2018), which is further developed here. This database links the expenditures on products and services included in the Belgian Household Budget Survey (HBS) of 2014 with air pollution data of these commodities using the following general principle:

$$total\ pollution\ (gram) = expenditure\ (€) * air\ pollution\ coefficient\ \left(\frac{gram}{€}\right) \tag{1}$$

We make a distinction between direct air pollution and indirect air pollution coefficients. The latter refer to emissions created during the production of goods and services, the former to emissions caused by the direct use of fuels by households. Note that in calculating the coefficients by product, we only take into account the Belgian air pollution as registered in national statistics: the air pollution generated by the production abroad of goods bought by Belgian households is assumed to be the same as if they were produced in Belgium. All in all, the consumption-based assessment of emissions as presented in this report contrasts with the more common production-based accounting framework that assigns emissions related to the production of goods and services to the place and location where they were produced.

Based on the above-stated general formula, the air pollution of each product included in the household budget survey can be calculated and then analyzed together with the socioeconomic characteristics of the households that purchased them. More precisely, the following research questions will be answered.

- How are GHG emissions distributed across households?
- Which household characteristics are associated with the level of GHG emissions of households?

The answer to these questions can help policy makers to finetune measures to reach the above-mentioned objectives related to global warming without disregarding social objectives, and vice versa.

This report is divided into the following chapters.

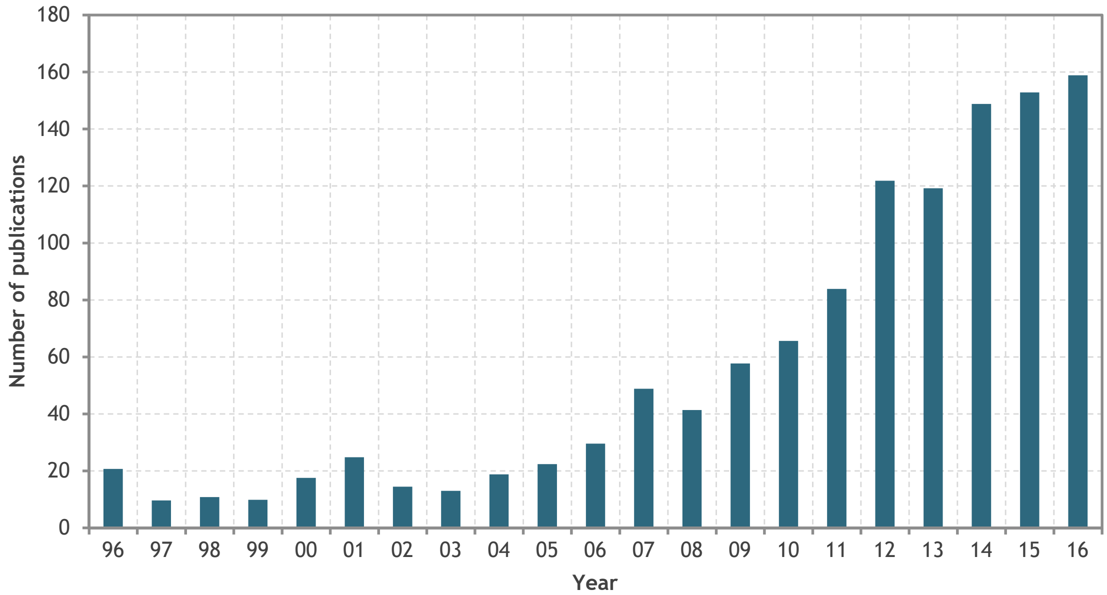
- Chapter 2 gives an overview of the literature that follows the same method as presented in this report and focuses in particular on the elasticity of the pollutants in relation to expenditure, one of the issues that will be discussed further in the report.
- Chapter 3 clarifies the method of linking household consumption expenditure to data on the pollution caused by that expenditure and explains the possibilities and limitations.
- Chapter 4 presents the research results and answers the research questions. First, the pollution related to household expenditure is described and related to different household characteristics separately. Next, a multivariate analysis of the relative impact of the different household characteristics on this pollution is carried out.
- Finally, chapter 5 summarizes the results and limitations of the research and formulates some conclusions.

Belgium's statistical office Statbel, the Commission for the Protection of Privacy, experts from the Environment administration of the Brussels Region and the experts invited to the seminar organized by the Federal Planning Bureau and Centre for Social Policy Herman Deleeck on the 6th of June 2019 and finally all those who have worked in the SUSPENS consortium contributed to this report. The authors would like to thank these organizations and take responsibility for all remaining mistakes and inconsistencies.

2. Context and literature review

Analysis of the environmental impact of households dates back to the 1970s. Bullard and Herendeen (1975) were the first to connect an input-output model with a consumer expenditure survey (CES) to calculate the energy impact of consumer decisions. Their work built on the environmentally extended input-output (EEIO) models developed by Leontief (1970). Later studies did not only focus on energy requirements, but also on CO_2 emissions, and other types of pollutants. Until the mid-2000s, however, the total number of studies carried out in this way remained rather limited. In his review about life cycle approaches to sustainable consumption, Hertwich (2005) cites 12 studies that combined EEIO with CES. After that, the number of studies on the (carbon) emissions of household consumption rose rapidly: Zhang, Luo, and Skitmore (2015) reviewed 69 papers, all of them published after 2000. Also, Geng et al. (2017)'s bibliometric review of 1 197 papers on emissions of household energy consumption shows this trend: while the yearly number of papers published on the subject was below 20 before the mid-2000s, it grew to almost 160 papers per year by 2016. The growth of papers might be attributed on the one hand to increasing global concerns about energy depletion, climate change (Geng et al., 2017) and their social impact, and on the other hand to the higher availability of more precise environmentally extended single-region and multi-region input-output models. The latter is due to increasing computational capabilities, a wider availability of economic accounts, environmental accounts and trade data (Wiedmann, 2009).

Graph 1 Number of academic publications about energy consumption and greenhouse gas emissions in the residential sector



Source: Geng et al., 2017

Of the papers that use the methodology connecting CES with macro-level EEIO, the majority aims – like in this paper – to provide a general overview of the distribution of consumption-related household emissions (Abdallah, Gough, Johnson, Ryan-Collins, & Smith, 2011; Büchs & Schnepf, 2013; Duarte, Mainar, & Sánchez-Chóliz, 2012; Lenzen, 1998; Pohlmann & Ohlendorf, 2014; Steen-Olsen, Wood, &

Hertwich, 2016; Weber & Matthews, 2008; Wier, Lenzen, Munksgaard, & Smed, 2001). Yet the methodology also allows for studies focusing on specific topics such as the effect of aging on consumption-based emissions (Shigetomi, Nansai, Kagawa, & Tohno, 2014), emission differences across generations (Chancel, 2014), across different pollutants (Roca & Serrano, 2007), relationship between urbanization and emissions (Ala-Mantila, Heinonen, & Junnila, 2014), effect of different lifestyles on emissions (Fan, Guo, Marinova, Wu, & Zhao, 2012), relationship between residential location and emissions (Poom & Ahas, 2016), the relationship between expenditures and emissions (Isaksen & Narbel, 2017), and studies that explain regional or country differences in household consumption-related emissions (Ivanova et al., 2016; Kerkhof, Benders, & Moll, 2009).

In the above-described literature, households' living standards (measured by income or expenditures) was found to be the most important influencing factor in explaining consumption-related emissions. Household size was also proven to be an essential determinant: larger households tend to emit more on an absolute basis. However, on a per capita basis, the trend reverses due to economies of scale. Other dimensions through which household emissions were found to vary greatly are employment status, urban/rural location, age, type of dwelling, and education.

Many studies that connect EEIO tables with CES discuss the expenditure (or income) elasticity of GHG or CO_2 emissions, estimating how household emissions respond to changes in their expenditure levels. The elasticity of emissions with respect to expenditures measures the percentage change in carbon emissions as a result of a 1 percent change in expenditures. This concept is essential in understanding whether growing income and emissions can decouple or not. The question whether income growth is possible without increased environmental degradation has been widely researched on a macro (i.e. country, regional) level, and the literature of household consumption footprints adds the micro perspective to this wider area of research. The micro-level analysis is crucial to understand the responsiveness of household emissions to changing income levels and the possible effects of demand-side climate policies. This is also discussed in this study, more specifically in the section on the determinants of household emissions.

Table 1 lists the estimates of the elasticity found in previous studies. The grouping of expenditure categories in the studies do not necessarily correspond to each other. However, the general conclusion arises that expenditure/income elasticities of emissions related to the consumption categories that satisfy basic needs, such as heating and food, is much lower than that of more luxurious product groups, such as recreation and transport. Elasticity of emissions from food consumption is the lowest, which is followed by energy and housing, transport, goods and services. Transport and goods are mostly found to have an elasticity higher than 1, meaning that for a one percentage increase in expenditures, emissions increase by more than one percentage.

Table 1 Expenditure/income elasticity of GHG/CO_2 emissions in the literature

Paper	Country	All	Food	Energy and housing	Transport	Goods	Services
Ala-Mantila et al. (2014)	FI	0.790a	0.512	0.133		1.233	1.42
Büchs & Schnepf (2013)	UK	0.432		0.187[b]	0.598		
Duarte et al. (2012)	ES	0.84					
Girod & Haan, (2010)	CH	0.94c			1.21	1.3	
Isaksen & Narbel (2017)	NO	0.99	0.5	0.25[d]	1.01		
Kerkhof et al. (2009)	NL	0.84					
Lenzen (1998)	AU	0.7e					
Steen-Olsen et al. (2016)	NO	1.14	0.98	1.02	1.48	1.26-1.29	0.57-1.05
Weber & Matthews (2008)	US	0.6-0.7f					
Wier et al. (2001)	DK	0.9g					

a: Expenditure elasticity: 0.790. Income elasticity: 0.577.

b: Home energy emissions

c: Expenditure elasticity when emissions are calculated on the monetary base: 0.94. Elasticity when emissions are calculated based on units: 0.53

d: Only energy. not housing. Expenditure elasticity of emissions from clothing: 1.3

e: Elasticity of energy expenditure with respect to monetary expenditure/income. Expenditure elasticities: Netherlands: 0.63. Australia: 0.59. Income elasticities: USA: 0.73. Netherlands: 0.83. Australia: 0.74

f: Expenditure elasticities vary between 0.6 and 0.7. Income elasticities vary between 0.35 and 0.52

g: Expenditure elasticity: 0.9. Income elasticity: 0.48

3. Data and methodology

Our analysis requires two types of information: consumption and pollution data. The PEACH2AIR database combines these two types of information into a single dataset, which is the basis of our calculations. The database was created by the Federal Planning Bureau of Belgium and the Herman Deleeck Centre for Social Policy – University of Antwerp. It concatenates a single region environmentally extended input-output model with the 2014 Belgian Household Budget Survey (HBS).

The PEACH2AIR dataset is constructed using the following formula:

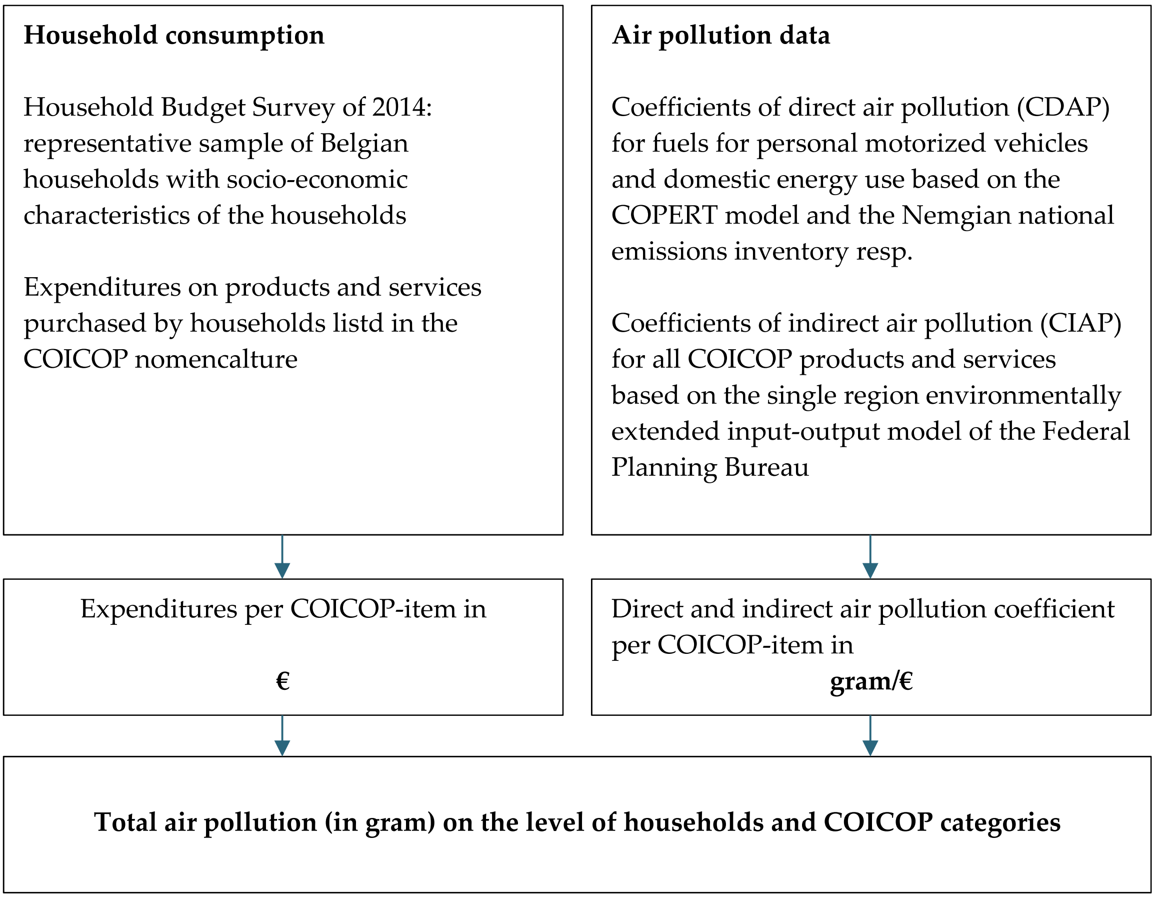
$$TAP_{h,p,c} = EXP_{h,c} \times \left(CDAP_{p,c} + CIAP_{p,c}\right) \quad (2)$$

The formula indicates that the total air pollution (TAP) in grams of pollutant p by household h caused by consuming product c is equal to the sum of the coefficient of direct air pollution (CDAP) and the coefficient of indirect air pollution (CIAP) of pollutant p and product c, multiplied by the amount spent (EXP) on product c of the COICOP classification by household h. The CDAP and CIAP of a given product-pollutant combination is expressed in grams of pollution per euro spent while the expenditures are expressed in euros. We distinguish 13 pollutants (CO_2, N_2O, CH_4, NO_x, SO_x, NH_3, NMVOC, CO, $PM_{2.5}$, PM_{10}, HFCs, PFCs and SF_6) and 3 indices: Greenhouse gas index (GHG), tropospheric ozone forming potential (TOFP), and acidification (ACID).

Households pollute directly (CDAP) or indirectly (CIAP). Direct pollution refers to the pollution caused when households burn fuels directly. In our model, these are all fuels for heating or transport. The indirect pollution of a product refers to the emissions released during the full production process of goods and services. The CIAP and CDAP were calculated using a different methodology.

The data linking method of expenditures on goods and services and their direct and indirect air pollution can be presented schematically as follows.

Box 1 Schematic structure of PEACH2AIR



In this section we briefly describe the data sources. In section 3.1., 3.2., and 3.3. we describe the consumption, direct, and indirect air pollution data, respectively. In section 3.4. we describe data limitations.

3.1. Consumption data

The basis of our analysis is the 2014 Belgian HBS, which contains detailed information on socioeconomic characteristics and consumption patterns and levels of a representative sample of Belgian households. It consists of 6 135 households and 16 093 individuals. The HBS is a biannual survey, which builds on the BelgianLabour Force Survey (LFS)[1]. The LFS sample is a two-stage stratified sample from which the HBS is drawn in the third stage. Sampling variables were taken into account throughout the analysis for this report. The HBS micro-data was provided by Statbel, Belgium's statistical office.

During the HBS, each participating household was provided a logbook which they filled out for the duration of a month. In this logbook, they recorded all their expenditures (type of expenditure, price, quantity, unit of measurement, private part of purchase, place of purchase). At the end of the month, an interviewer visited the household, and recorded answers to a questionnaire that collects information

1 Before 2012 the survey was annual and separate from the LFS.

about the composition and socioeconomic characteristics of the household (income, age, region, education, etc.), details about the dwelling of the household (year of building, heating type, etc.), periodical expenses (e.g. television subscription) and possession of large devices (e.g. car, laptop, washing machine). There are also questions about the purchase of durable goods during the previous four months.

The reference period of our research is the year 2014: expenditures and emissions of households are expressed for the whole of the year 2014. The registration period for expenses in the logbook is one month (and different households fill out the logbook in different months). These expenditures were then annualized for the year 2014.

In the HBS, expenditures are categorized according to Classification Of Individual COnsumption by Purpose (COICOP). The COICOP classification is the international reference classification for household expenditures, maintained by the United Nations Department of Economic and Social Affairs. It consists of 12 1st level groups, which is broken down further into more and more detailed 2nd, 3rd, and 4th level subgroups. For Belgium, there is a 5th level, which results in a total of 1 154 consumption categories. To present the results, we created the following 5 big consumption categories: Food and drinks, Energy and Housing, Transport, Goods, Services (see annex 6.1 for further details).

We carried out some data manipulation in the HBS to make it better suited for our analysis. There are two issues that pose a problem to accurately account for the emissions of each household. Firstly, non-frequent expenditures, and secondly the underreporting of fuel expenses of company car-using households. In the next two paragraphs, we briefly describe how we treated these issues. The reader can find further details in annexes 6.2 and 6.3.

– Non-frequent expenditures, such as expenditures on durable goods or holidays, are problematic, because we observe large amount of expenditures (and subsequent emissions) on these goods and services for a small number of households, and zero expenses for the rest of the households. However, the rest of the households also spend on and use these goods and services, but at times that fall outside the timespan of the survey. There is a discrepancy between the lifetime (or purchase frequency) of these goods and services and the timeframe of the survey (one month for the logbook and a four-month timespan before the questionnaire regarding questions about durable purchases). We treated this problem by creating household clusters and distributing non-frequent expenditures among the households within each cluster.

– Company cars are a type of benefit in kind provided by the employer to the employee. Both commuting-related and private fuel expenses of the employee are paid partly or totally by the employer. Consequently, company car-using households report less expenses on fuel in the HBS than the other households. However, this does not mean that company car-using households travel and emit less than the other households. Given that (1) in this report we aim to analyse the distribution of emissions among households, and that (2) company car-using households are positioned in the middle and upper part of the income distribution, leaving this topic unaddressed would result in distorted results. We treated this issue by imputing fuel expenses for company car-using households based on the observed fuel expenses of the rest of the households.

3.2. Coefficients of direct air pollution

The direct pollution coefficient of pollutant p created by consuming 1 euro of a certain fuel c used for transport, is the result of the formula below. A detailed description of all components of these formulas can be found in the annex 6.4.

$$CDAP_{p,c} = \frac{Total\ direct\ pollution_{p,c}\ (g)}{Total\ consumption_c\ (g)\ *\ specific\ volume_c\ \ (l/g) *\ \ price_c\ (euro/l)} \quad (3)$$

$$where\ c\ \in\ \{diesel, gasoline, LPG, two - stroke\ oil, other\ fuels\ \}$$

Data on the total direct pollution and total consumption of fuels used for transport was sourced from the COPERT model. COPERT is a European road transport emission inventory model. We used total pollution and consumption data from COPERT for 2014 based on the 2019 submission and selected only vehicle types typically used by consumers such as passenger cars. The specific volume of the fuels was found in the Energy Statistics Manual of the International Energy Agency. The price per litre is based on disaggregated FPB data used to calculate the consumer price index.

To calculate the coefficients of direct air pollution of fuels used for domestic energy use, we used two different formulas, because the price of liquid fuels is expressed per litre and had to be transformed.

$$CDAP_{p,c} = \frac{Emission\ factor_{p,c}\ \ * Energy\ conversion\ factor_c\ *\ \frac{Net\ Calorific\ Value}{Gross\ Calorific\ Value}_c}{Price_{(h),c}}$$

$$if\ c\ \in \left\{ \begin{matrix} natural\ gas, natural\ gas\ second\ home, \\ butane, propane, coal, firewood, other\ solid\ fuels \end{matrix} \right\}$$

$$CDAP_{p,c} = \frac{Emission\ factor_{p,c} * Energy\ conversion\ factor_c\ *\frac{Net\ Calorific\ Value}{Gross\ Calorific\ Value}_c}{specific\ volume_c * Price_{(h),c}} \quad (4)$$

$$if\ c\ \in \{fuel\ oil, other\ liquid\ fuels\}$$

We used emission factors, which are expressed in gram of pollution per Joule, from the Belgian national emissions inventory of 2017 for the year 2014 and emission factor data of the Flemish and Walloon region. The energy conversion factors and the specific volume of certain fuels can be found in the Energy Statistics Manual. We based the values of the share of net calorific value in the gross calorific value of a fuel on the IPCC background paper titled 'Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories' (IPCC, 2001).

For natural gas and fuel oil, the price per unit of fuel depends on the amount a household bought, as indicated by the (h) suffix. This is mainly due to different levels of taxes (natural gas) or because the price per unit is significantly lower for large orders (fuel oil). For all other fuels and other products, we assume uniform prices.

3.3. Coefficients of indirect air pollution

The majority of household-level air pollution is indirect and is embodied in the supply chain of goods and services purchased by households. Indirect emissions were calculated using an environmentally extended single-region input-output model of the Federal Planning Bureau. The methodology is discussed in detail in Frère et al., 2018. In our database, each household is assigned the amount of emissions related to their reported consumption.

Input-output (IO) analysis is a methodology that uses industry-level data to map supply chains in the economy. When extended with industry-level air pollution data, it becomes possible to quantify how much air pollution is embedded in the production process of goods and services on the industry level. These industry-level data (according to the Belgian SUT classification) were connected with the COICOP classification of the HBS in order to quantify the air pollution embedded in the consumption of goods and services by the households. Further details on the SUT-COICOP linkage can be found in Frère, Vandille and Wolff (2018).

We do take account of emissions related to imported goods, albeit assuming their production technology is the same as the production technology of the same product produced in Belgium. This type of input-output model is called a single region input-output model (as opposed to multi-region input-output models, which use supply and use tables for the IO model from several countries).

3.4. Data limitations

Our model's data are subject to different limitations. First, as mentioned in the previous section, our input-output model belongs to the single-region category, which comes with an important disadvantage. In contrast to multi-regional models, single-region models assume that the production technology in foreign countries is the same as in Belgium. When assigning environmental coefficients to goods such as apples or solar panels, we assume the production technology is identical to the one used in Belgium. In other words, we use the mix of inputs (for raw materials, transport and production) that is used in the Belgian industry for this product. This implies that we make abstraction of the fact that products that were purchased in Belgium but produced in another country (e.g. foreign steel) were probably produced with different material and energy inputs than products produced in Belgium. The main advantage of using the single-region input-output model is that it is the most detailed input-output model of Belgium currently available. The SUT classification consists of 354 industries, while (to the best of our knowledge) the most detailed MRIO model – Exiobase – which uses data of 2007 consists of 162 industries.

Second, we relate emissions to each euro spent on the consumption categories in the HBS. However, in reality, emissions occur during the production of units of goods for many product categories. As our pollution coefficients are on a gram of pollution per euro basis, we have to assume a sufficient homogeneity of the price of the goods belonging to the same category (e.g. peaches or cars).

Third, there is a risk that some consumption categories are underreported in the household budget survey. People might be inclined to report lower expenditures than in reality for products with stigma such as drugs, alcohol or tobacco (and possibly other consumption categories). However, given that comparable external statistics are difficult to obtain or construct, it is hard to assess the bias that results from this. As the categories we assume to be most prone to underreporting are not the ones generating big environmental impacts, we believe the bias from underreporting has a rather minimal impact upon our overall results in terms of emissions.

Fourth, as discussed in section 3.1, non-frequent purchases by households as reported in the HBS as well as the underreporting of fuel expenses by households using a company car pose a problem for accurately estimating the level and distribution of household emissions. The details of how we treated these problems can be found in annex 6.3. Another HBS-related issue is the pollution caused by the construction of houses and entire home renovations. These are not included in our model, because these expenditures happen too infrequently to reliably appear in the HBS. Moreover, the data on the stock of houses in HBS is not detailed enough to be able to impute a certain amount of pollution for housing. The consequence of this is that expenditures related to rent or mortgages are not considered in PEACH2AIR and consequently no pollution is attributed to theses expenditures.

Fifth, the expenses in HBS related to domestic energy use rely on a sizeable amount of imputation. As is noted in the methodological note of HBS 2014, the respondents could use so-called combined invoices for which there is only one amount for two or more types of energy expenditures. There are, for example, 4 522 mixed invoices for electricity and natural gas on a total of 6 135 households. A regression predicting the expenditure on electricity based on household size, region, possession of a washing machine and possession of solar panels was used to split these mixed invoices. For these 4 522 cases, the residual amount was attributed to natural gas. By consequence, all potential leftover variation in the use of electricity between households will appear in the expenditures on natural gas. A specific analysis of the energy-related expenditures or pollution should therefore be interpreted with care[2].

Finally, there are also emissions related to (voluntary or involuntary) consumption of publicly provided services, such as the education, health, social services and urban planning. Although the indirect pollution coefficients take the pollution by government individual consumption into account for certain consumption types (education, health and social services), such pollution will only appear in our model if these expenditures are represented in the HBS. This might in our methodology bias the attribution of pollution caused by the consumption of public goods to the households.

2 See the methodological note on HBS 2014 for a full overview of all imputations of energy-related expenditures.

4. Description of the air pollution patterns of household consumption

The PEACH2AIR dataset makes it possible to analyse household pollution by characteristics of individual households and the different types of products they consume. In this chapter, section 4.1 and 4.2 answer the research questions of this study.

4.1. How are GHG emissions distributed across households?

To answer this research question, a bivariate analysis will be performed. First, we will calculate and discuss the share of certain types of products in the total pollution. After this, we analyse how certain household characteristics are associated with the level of pollution. Greenhouse gas emissions are the main focus of our analysis but results for other types of pollutants will be shown occasionally.

4.1.1. Share of different product categories in total pollution

Table 2 describes the share of emissions generated from different types of consumption categories in total GHG emissions generated by household consumption. The distribution of expenses is also listed. The third column shows the pollution intensity of each type of product. The pollution intensity is the average amount of greenhouse gases that are emitted by consuming 1 euro of the consumption category.

Table 2 Share of different product categories in total pollution and total expenditure
Expenditure and GHG in percent, GHG/EURO in grams per euro

	COICOP group	Expenditure	GHG	GHG/EURO
1	Food and non-alcoholic beverages	15.7%	18.0%	769
2	Alcoholic beverages and tobacco	2.5%	1.1%	305
3	Clothing and footwear	5.8%	1.7%	202
4.a	Housing: rental. water supply	3.3%	1.9%	385
4.b	Electricity	3.0%	8.2%	1851
4.c	Gas from the natural gas network	2.0%	11.6%	3967
4.d	Butane or propane in bottles	0.0%	0.1%	1789
4.e	Fuel oil	1.6%	9.3%	3814
4.f	Other solid or liquid fuels	0.2%	2.6%	9117
5	Furnishings. household equipment and maintenance	7.4%	3.0%	276
6	Health	5.8%	6.2%	716
7.a	Ppt*: non-motorised vehicles. parts and services	0.3%	0.1%	177
7.b	Ppt*: motorised vehicles. parts and services	10.7%	2.4%	148
7.c	Ppt*: diesel	2.1%	7.9%	2466
7.d	Ppt*: gasoline	1.5%	3.8%	1698
7.e	Ppt*: other fuels	0.0%	0.2%	2980
7.f	Public transport	1.2%	2.9%	1609
8	Communication	3.8%	0.8%	141
9	Recreation and culture	10.4%	7.8%	499
10	Education	0.6%	4.0%	4233
11	Restaurants and hotels	8.2%	3.8%	311
12	Miscellaneous goods and services	13.8%	2.6%	129
	Total (in billion euros. in grams and in grams per euro)	136.66	9.16E+13	670

* Ppt: personal private transport

Based on our calculations, Belgian households spent 136.7 billion on goods and services in 2014. This total expenditure generated 9.16 billion grams of greenhouse gases expressed in CO_2 equivalents. In other words, every euro spent by households in 2014 was, on average, responsible for 670 grams of greenhouse gases. These gases were emitted during the production of purchased goods and services (indirect emissions) and during the use of fuels for transport and domestic use (both direct emissions). These 670 grams per euro correspond to the average pollution intensity of greenhouse gases of Belgian household expenditure.

The distribution of these expenditures and greenhouse gases among the various expenditure items shows that certain categories of expenditures are associated with proportionally more greenhouse gas emissions. In other words, the pollution intensity of these categories of expenditure is bigger. Three expenditure categories stand out. Food and non-alcoholic beverages (18% of GHG), domestic energy use (4.b-4.f, 31.8%) and fuels used for transport (7.c-7.e, 11.9%) are responsible for 62.8% of the total greenhouse gas emissions. Those three categories alone account for 26.1% of the total expenditures and can thus be characterised as pollution intensive on a per euro basis.

One remark has to be made. The high pollution intensity of education is due to our methodology. Households spent proportionally little on education because it is a public good provided by the state. During the calculation of the coefficients of indirect air pollution, the pollution linked to government individual consumption for education, for human health and for social services was added to the corresponding coefficients of direct air pollution linked to household consumption directly (Frère et al., 2018: 22). By doing so, at least part of the pollution caused by consuming public goods at reduced prices is taken into account in our model via higher indirect pollution coefficients.

The HBS contains a wide range of household characteristics such as age, size of the household, income, main way of heating the house, region or number of cars. In the following figures and tables, we will analyse if certain household characteristics are associated with a higher or lower level of pollution per household. With formula (2) (see p. 7) in mind, the origin of a certain level of pollution can be split up into two parts: the level of expenditures and the average pollution intensity, defined as the quotient of total pollution and total expenditure. Each element is important, as they can necessitate different types of policy action.

Box 2 Reading aid for graphs

A series of graphs are presented below with on the horizontal axis the number of households in Belgium that belong to a specific category. The vertical axis represents the average greenhouse gas emissions or the average expenditure per household of each category in question. In order to present average expenditures and GHG emissions per household on the same vertical scale, these averages are expressed as a percentage of the average of the total population, i.e. 100% or the dotted line indicated in the graph. It is thus possible to determine whether the average expenditure or emissions per household for a given household category are above or below the average for the total population.

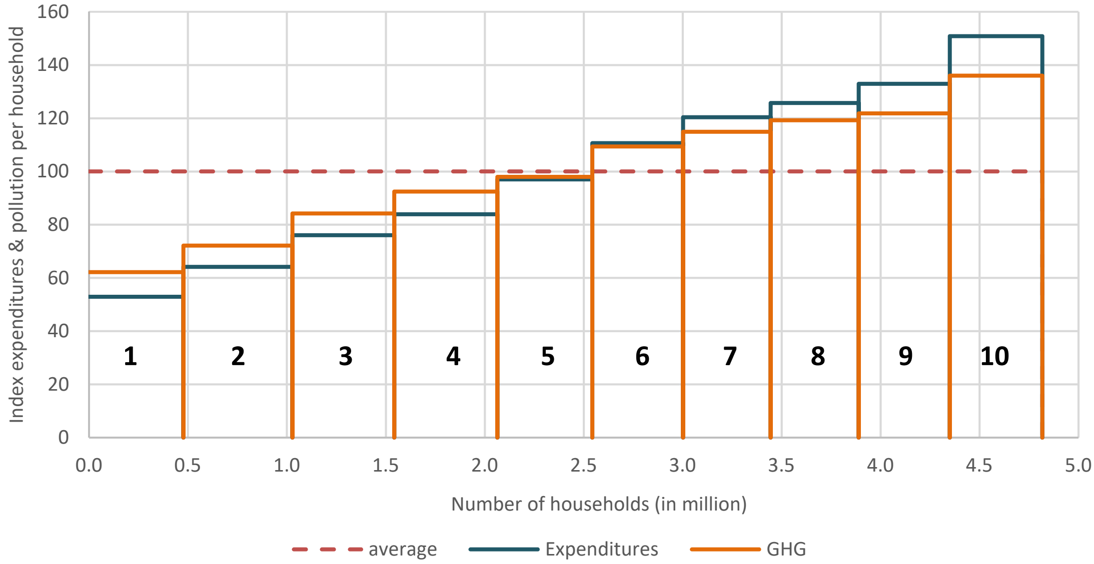
In this method of representation, the area of the columns is the total greenhouse gas emissions of different household categories. Indeed, the total greenhouse gas emissions of a specific category equal the product of the average greenhouse gas emissions per household of that category (i.e. the pollution intensity) and the number of households of that category (of course, the same reasoning applies to the expenditures). It is consequently possible to assess the influence of both factors on the total pollution of different household categories.

4.1.2. Equivalised income deciles

In graph 2, each household is assigned to an income decile based on their equivalised net disposable income[3]. The width of each bar represents the number of households that are in each group. Both the level of expenditures and the level of greenhouse gas emissions are expressed as a percentage of the average household expenditure and pollution of the entire population. We can clearly see that the pollution per household increases considerably with income. Households in the first decile pollute 62% of the average pollution per household by spending 53% of the average expenditure. Households in the last decile pollute 136% of the average by spending 151% of the average level of expenditures. Pollution intensity, which is the average pollution per euro spent, is generally higher than average if the share of pollution is higher than the share of expenditures. In graph 2, we can observe that pollution intensity is higher than average in the first income decile, and lower than average in the last income decile. So, although richer households pollute more on an absolute basis, the pollution intensity per euro spent decreases with increasing income. This relation between income and pollution is also observed by other authors such as Christis et al. (2019) and Sommer and Kratena (2017). Kerkhof, Benders and Moll (2009) find that the emissions intensity of household consumption falls with income in the UK and in the Netherlands and increases with income in Sweden and Norway.

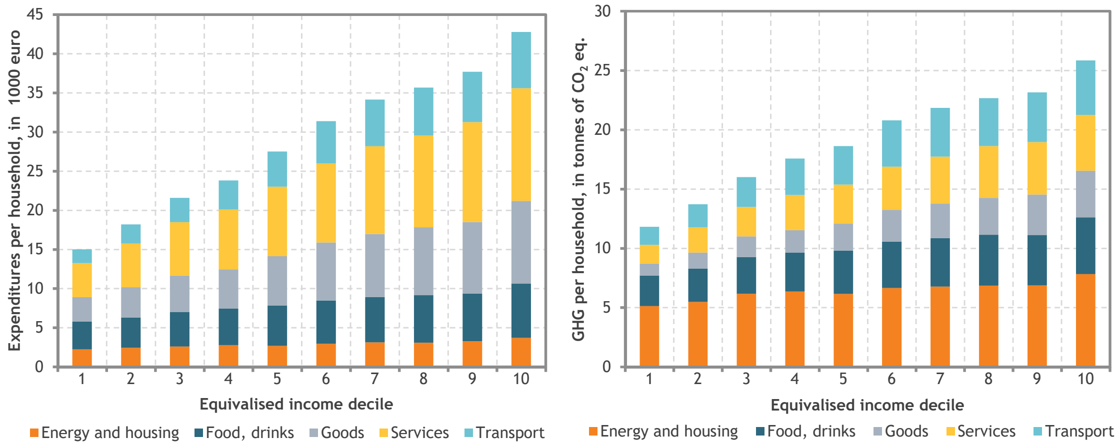
3 The OECD-equivalence scale was used to do this. Each decile contains a tenth of the total population. Due to differences in average household size, the number of households in each decile varies slightly.

Graph 2 Pollution of greenhouse gases and expenditure per household by equivalised income deciles
Expressed as a % of the average pollution and expenditure per household



Graph 3 shows the total expenditure and total pollution by type of product: energy and housing, food and drinks, goods, services and transport. It offers a possible explanation for the decreasing pollution intensity. As income grows, households tend to consume more goods and services. Compared to energy and housing, which remains rather constant across the income distribution, goods and services have a low pollution intensity. Both effects, partially compensated by the increasing expenditures on the pollution-intensive transport category, result in a decreasing pollution intensity.

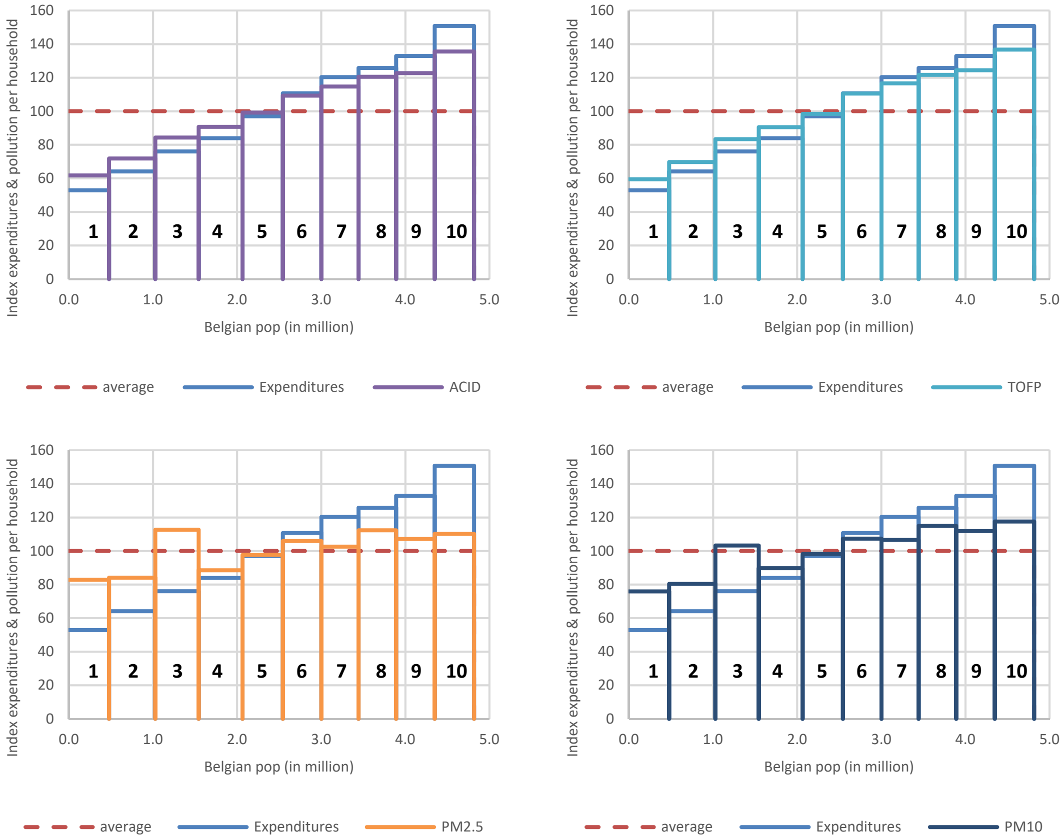
Graph 3 Expenditures and greenhouse gas emissions per household per type of product for each equivalised income decile
Expressed as a % of the average pollution and expenditure per household



* Housing refers to housing-related costs such as general upkeep, water and waste collection. Rent, imputed rent and mortgages are not included.

As stated before, PEACH2AIR also contains data on other pollutants than the greenhouse gas index. In graph 4, the ACID and TOFP index and two measures for particulate matter were added to graph 2. The observation of increasing pollution with income and decreasing pollution intensity holds true for almost all variables. The pollution intensity of particulate matter is especially high for the first three income deciles. This can be explained by the fact that burning coal and wood generates a large part of total particulate matter emissions and about 70% of households who indicated in the HBS that burning coal is their main way of heating, are in the first three income deciles.

Graph 4 Pollution of multiple pollutants and expenditure per household by equivalised income deciles
Expressed as a % of the average pollution and expenditure per household

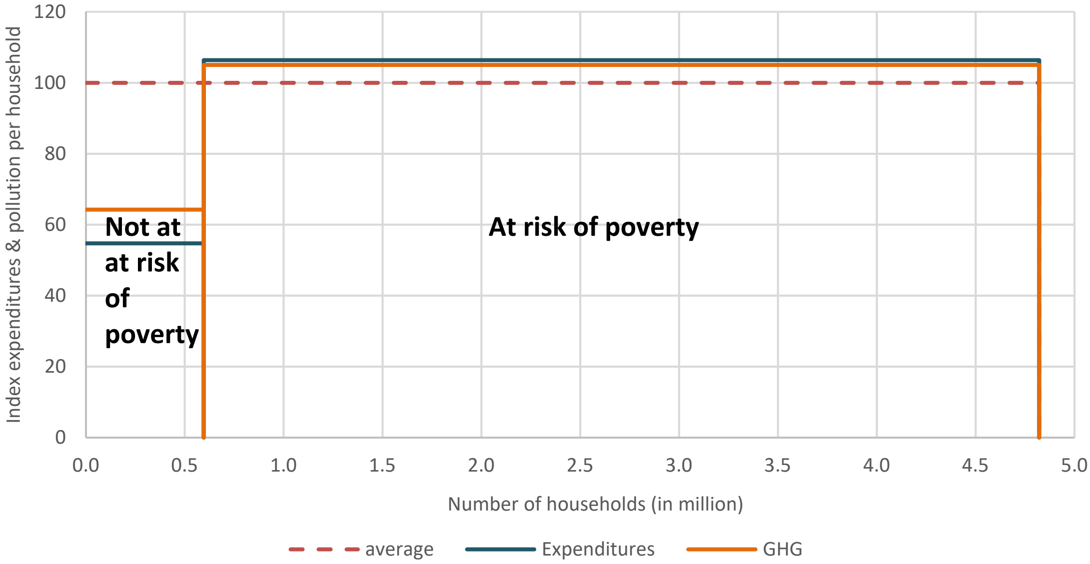


4.1.3. Poverty risk

The previous point dealt with the distribution of greenhouse gases and other gases among the different income deciles. Here the equivalent income was used to rank the households from low to high income. The same income concept is used to calculate the population at risk of poverty. A household has a poverty risk if the equivalised income is less than 60% of the median equivalised income. Based on the HBS, 12.3% of the population in Belgium was at risk of poverty. Note that the official poverty statistics based on the Statistics on Income and Living Conditions (SILC) report for that same year 15.5%.

In graph 5, one can observe that households with a poverty risk have lower expenses and greenhouse gas emissions than average. But more importantly, as noticed in the previous section, their pollution intensity is higher. Their expenditures account for about 55% of the mean expenditures while their pollution is at 64% of the mean. So, persons with a risk of poverty, globally pollute less than persons not living in poverty. But their pollution intensity, the pollution generated by each euro, is higher.

Graph 5 **Expenditures and greenhouse gas emissions by households at risk of poverty or not**
Expressed as a % of the average pollution and expenditure per household



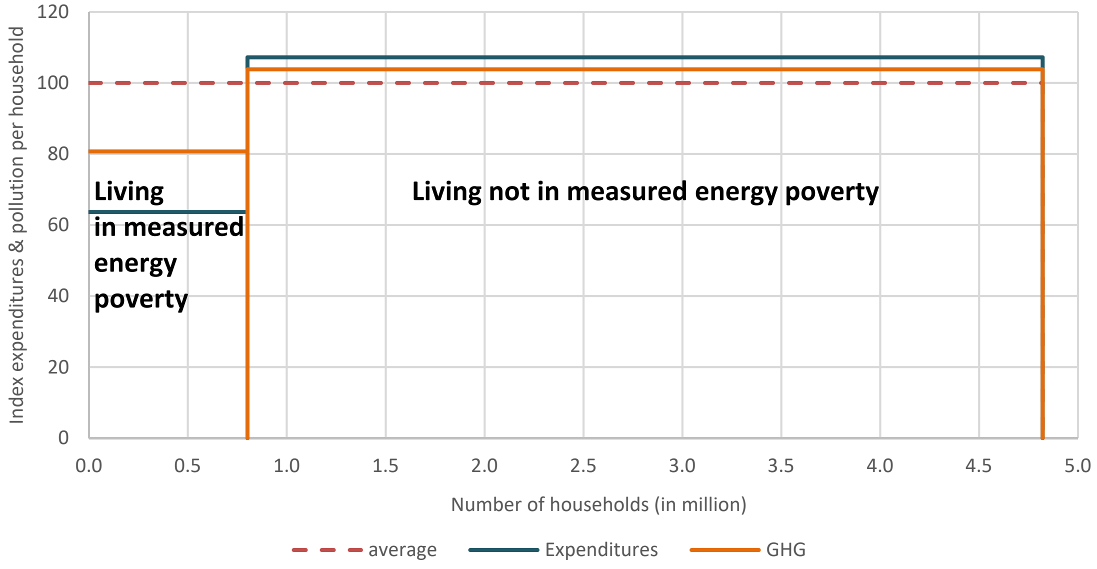
4.1.4. Measured energy poverty

We calculated which households live in measured energy poverty according to a methodology by Coene and Delbeke (2014). Contrary to these authors, we used HBS data in the PEACH2AIR dataset rather than SILC data. A household is considered to live in measured energy poverty if the ratio of energy expenses to income excluding costs related to the dwelling[4] is higher than two times the mean ratio of the two. These households have to be in the first five (equivalised) income deciles too. Using HBS data, 12.8 percent of the population lives in measured energy poverty compared to 14.6% measured using SILC data by Coene and Delbeke.

Graph 6 shows that households living in energy poverty pollute less than the average household but have a high pollution intensity. Note, however, that if the graph would be on a per capita base, pollution per capita of household in energy poverty would be 15% above the average per capita pollution while expenditures would be at 90% of the expenditure per capita. This indicates that households living in energy poverty are smaller than average.

[4] These costs are rental or repayment of a mortgage loan, property tax, maintenance costs for common areas and the use of lifts and maintenance costs and small repair costs.

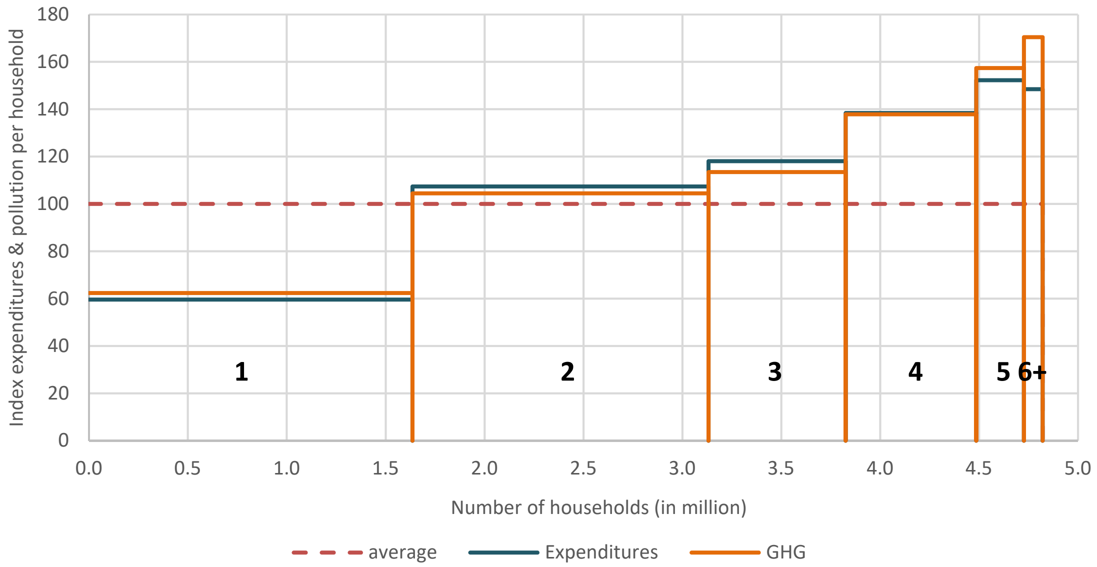
Graph 6 **Expenditures and greenhouse gas emissions by households living in measured energy poverty or not**
Expressed as a % of the average pollution and expenditure per household



4.1.5. Household size

Total pollution increases less than proportionally with household size (graph 7). This effect, which can be interpreted as a kind of scale effect, appears both on the expenditure as on the total pollution side. Pollution intensity is higher than average for one person households and very large households. Two and three person households have a lower than average pollution intensity.

Graph 7 **Expenditures and greenhouse gas emissions by households per household size**
Expressed as a % of the average pollution and expenditure per household



4.1.6. Household type

In table 3, ten different types of households were identified based on the number of adults, number of children and the age of the reference person of the household. In the HBS, the reference person is the person with the highest individual income. Expenditures and greenhouse gas emissions per household, expressed as a percentage of the average pollution and expenditure is shown, as is the pollution intensity. For a comparable household size, older households emit more greenhouse gases and have a higher pollution intensity than households with a reference person who is younger than 65. Possible explanations for this are a less energy efficient housing and more hours spent in the house by individuals above 65. Households with children tend to emit more, spend more and have higher pollution intensity than households without or with less children.

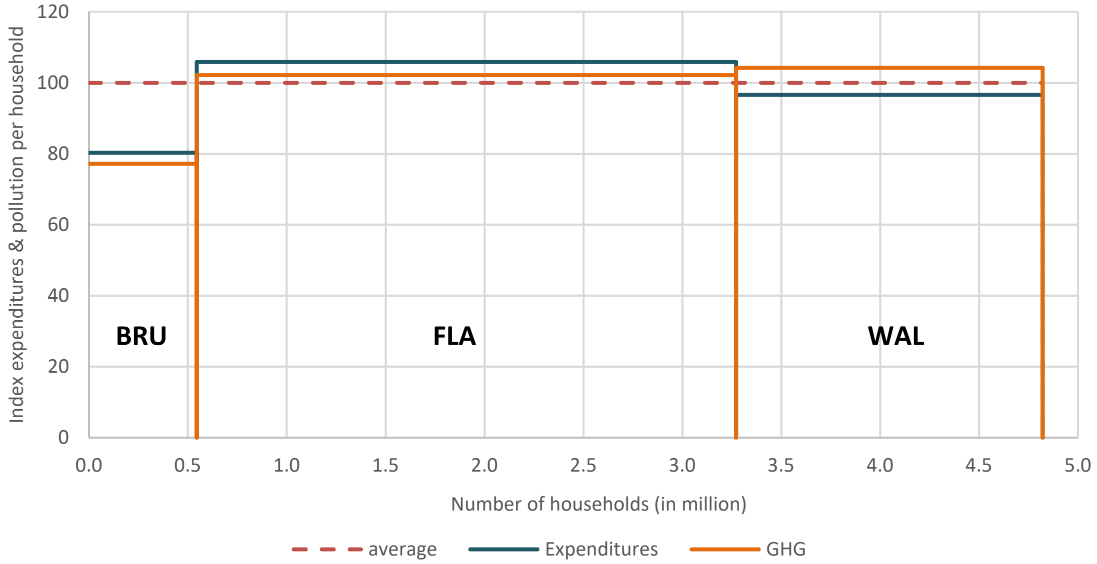
Table 3 Expenditure and greenhouse gas emissions per type of household

Household type	Number of households	Expenditures per households	GHG per households	Pollution intensity
	In million	As % of mean	As % of mean	Gram/euro
1 adult <65	1.20	58.79	60.88	693.97
1 adult+dependent children	0.32	83.17	91.51	737.32
1 adult, 65+	0.44	61.78	66.55	721.85
2 adults with 1 dependent child	0.43	123.35	115.64	628.15
2 adults with 2 dependent children	0.52	140.65	139.45	664.34
2 adults with >=3 dependent children	0.25	156.05	168.28	722.58
2 adults, <65, no children	0.77	111.58	104.82	629.48
2 adults, >65, no children	0.57	109.69	109.49	668.86
More than 2 adults with children	0.14	143.14	142.53	667.17
More than 2 adults, no dep children	0.20	129.94	124.70	643.06

4.1.7. Region

The pollution per household is slightly higher in the Walloon region than in the Flemish region (graph 8) while the level of expenditures is higher in the Flemish region. This means that pollution intensity is higher in the Walloon region too. The level of pollution and expenditures is considerably lower in Brussels than in the other two regions. Results are similar on a per capita basis. It is unlikely that the difference in emissions of greenhouse gases is purely due to the region a household belongs to. The regional variable is probably a proxy for regional variations such as population density, differences in the stock of houses, types of heating and possible regional differences in environmental policy, which are not covered in this analysis.

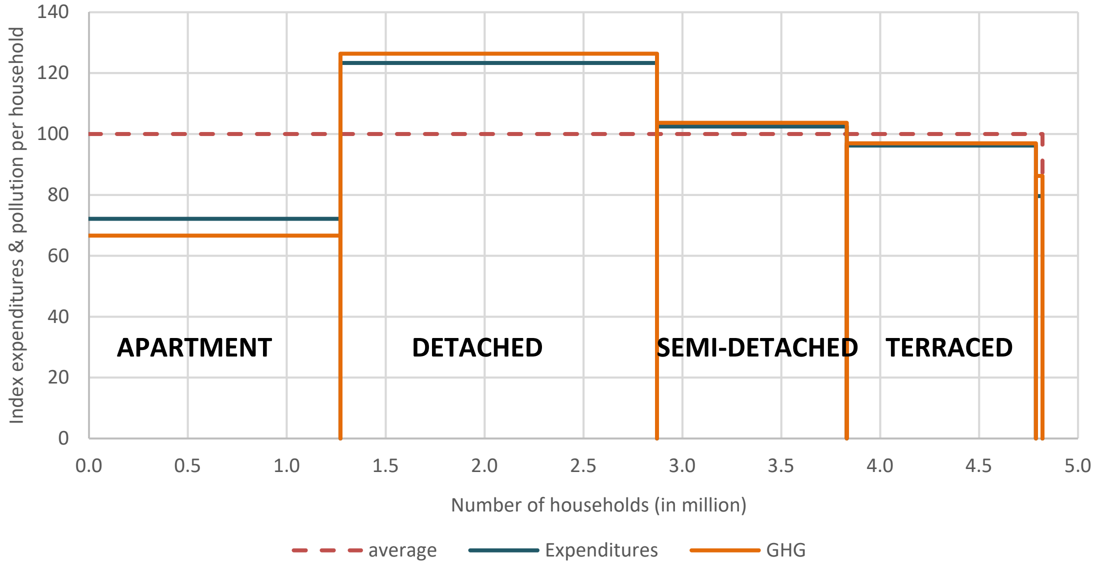
Graph 8 **Expenditures and greenhouse gas emissions by households per region**
Expressed as a % of the average pollution and expenditure per household



4.1.8. Type of housing

The type of housing affects the level of pollution and the pollution intensity of a household (graph 9). Households living in a detached house emit 26% more greenhouse gases than average, which is more than any other type of house. Detached houses also have a higher than average pollution intensity. The denser a type of housing is (semi-detached,terraced, apartment), the less a household pollutes. Households living in an apartment not only pollute the least, their total pollution is a little more than half of that of a detached house, but they also have the lowest pollution intensity. One could argue that this difference in pollution per household is due to a higher average household size living in detached houses. This is, however, only partially true. Even pollution per capita is more than 10% higher than average for individuals living in a detached house and pollution intensity is still higher than average.

Graph 9 **Expenditures and greenhouse gas emissions by households per type of housing**
Expressed as a % of the average pollution and expenditure per household



4.1.9. Type of heating

The average pollution per household varies widely across different types of heating (table 4). Pollution per household is the highest for the small group of households using a heat pump while their pollution intensity is the lowest. This is greatly affected by a larger than average household size of this group because pollution per capita is the lowest of all ways of heating considered. Households who use fuel oil as their main way of heating, emit more than average and have a very high pollution intensity. Only households who use coal have an even higher emission intensity but pollute less than the average household. Natural gas, which is the most common way of heating, is associated with a lower than average pollution and pollution intensity.

Table 4 Expenditure and greenhouse gas emissions per household by type of heating

CD_Heatingmean	Number of hh In million	Expenditures per hh As % of mean	GHG per hh As % of mean	Pollution intensity Gram/euro
Butane_Propane	0.05	95.74	82.60	578.22
Coal	0.05	70.41	94.05	895.18
Electricity	0.34	91.13	79.08	581.60
Heat_pump	0.04	150.63	121.70	541.46
Heating_oil	1.26	110.42	120.67	732.38
Natural_gas	2.85	96.71	92.62	641.84
Other_energy_source	0.00	83.18	63.27	509.78
Wood	0.11	97.05	108.49	749.16
Wood_pellets	0.11	93.94	112.33	801.33

hh = household

4.1.10. Conclusion

Taking into account a number of methodological limitations, our analysis has shown that the majority of greenhouse gas emissions caused by the consumption of households can be allocated to three categories of expenditure: food, fuel for transport and energy expenditure for the home. Together, these categories account for three fifths of total emissions, while they represent only a quarter of total expenditure.

The analysis shows that total pollution increases with income. This is logical in view of the fact that expenditure increases with income and that expenditure is one of the determining parameters of total emissions, as mentioned in formula (2). In other words, lower incomes, including households living with an income below the at-risk-of-poverty threshold or households with a measured energy poverty, emit less than higher incomes. However, the intensity of the pollution, i.e. the emission per euro spent, follows an opposite pattern: it decreases as the income increases.

Although the previous sections indicate that the total greenhouse gases emitted by a household vary across many different household characteristics, one should be careful when attributing the (size of) these differences to specific household characteristics. They can be a proxy for other variables not used in this analysis. For example, regional differences in pollution might be due to differences in population density or the type of housing. Moreover, households with higher income and expenditures tend to be bigger, or they are more likely to have higher educational attainment. A regression analysis in which the different characteristics are considered at the same time, is needed to establish insight into the influence each characteristic has on the total pollution of a household.

4.2. Which household characteristics are associated with the level of GHG emissions of households?

The previous bivariate analysis provided insight into how household emissions are related to different household characteristics. In this section, we will turn to multivariate analysis to disentangle the individual effects of these characteristics.

The next section describes this multivariate analysis. The section thereafter drafts some conclusions.

4.2.1. Multivariate analysis

Following the papers described in the literature review, we run multiple regressions where we explain household GHG emissions with socioeconomic and house-related characteristics.

Our regression model takes the following form:

$$\ln(GHG_i) = \alpha + \beta \ln(inc_i) + \delta_i \boldsymbol{x}_i + \gamma_i \boldsymbol{z}_i + u_i \tag{5}$$

where GHG_i is the yearly household GHG emissions of household i, inc_i is the yearly household net disposable income of household i, $\boldsymbol{x}_i$ is a vector of socioeconomic variables of household i (number of adults, number of children, age of the household head, professional status of the household head, highest education in the household, and the region of the household), $\boldsymbol{z}_i$ is a vector of house-related variables (tenure status, number of rooms, dwelling type). α, β, δ_i, and γ_i are parameters and parameter vectors to be estimated. We estimated the model by ordinary least squares method with the statistical software Stata and used the 'svy' prefix to take into account survey design to estimate correct point estimates and standard errors.

In order to better understand how emissions from different consumption categories are associated with the explanatory variables, we estimated the regression model (5) separately with emissions from five consumption categories (food, energy and housing, transport, goods, and services) at the left-hand side. Details about how these categories were constructed can be found in the Annex.

As we took the logarithm of both household emissions and household income, the β coefficient can be interpreted as the elasticity of emissions with respect to income.

The tables in annex 6.5 present summary statistics of the continuous and categorical variables included in the regression model.

Table 5 Results of multivariate analysis

	(1) Ln(GHG_all)	(2) ln(GHG_Food)	(3) ln(GHG_Energy_ housing)	(4) ln(GHG_Transport)	(5) ln(GHG_Goods)	(6) ln(GHG_Services)
Income	0.323***	0.235***	0.114***	0.589***	0.693***	0.582***
	(0.019)	(0.019)	(0.025)	(0.040)	(0.030)	(0.046)
Number of adults						
1	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
2	0.199***	0.437***	0.103***	0.360***	0.203***	0.175***
	(0.017)	(0.019)	(0.025)	(0.036)	(0.023)	(0.049)
3	0.264***	0.573***	0.149***	0.300***	0.126***	0.236***
	(0.023)	(0.027)	(0.032)	(0.065)	(0.030)	(0.062)
>=4	0.354***	0.738***	0.192***	0.284***	0.140***	0.387***
	(0.029)	(0.026)	(0.043)	(0.056)	(0.032)	(0.086)
Number of children						
0	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
1	0.095***	0.123***	0.070**	-0.038	-0.018	0.269***
	(0.015)	(0.023)	(0.024)	(0.040)	(0.018)	(0.039)
2	0.122***	0.225***	-0.009	-0.088*	-0.066**	0.444***
	(0.015)	(0.022)	(0.025)	(0.039)	(0.020)	(0.050)
3	0.190***	0.316***	0.052	-0.105	-0.084*	0.636***
	(0.034)	(0.032)	(0.054)	(0.075)	(0.033)	(0.087)
>=4	0.292***	0.428***	0.122	0.093	0.051	0.730***
	(0.055)	(0.069)	(0.118)	(0.151)	(0.053)	(0.185)
Age of reference person	0.005***	0.010***	0.005***	-0.001	0.001	0.008***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
Prof.stat.refpers.						
working	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
unemployed	-0.085**	-0.084	0.018	-0.404***	-0.198***	-0.246***
	(0.030)	(0.045)	(0.048)	(0.072)	(0.040)	(0.069)
student	-0.067	-0.120	-0.034	-0.360**	-0.104	0.090
	(0.098)	(0.096)	(0.187)	(0.136)	(0.115)	(0.178)
housewife	-0.046	-0.127*	0.051	-0.235	-0.096	-0.199
	(0.064)	(0.061)	(0.133)	(0.204)	(0.061)	(0.179)
incapacitated	-0.046	0.009	0.047	-0.406***	-0.067	-0.062
	(0.034)	(0.037)	(0.059)	(0.074)	(0.039)	(0.075)
pension	-0.049*	-0.030	-0.007	-0.149**	0.003	-0.053
	(0.025)	(0.024)	(0.037)	(0.056)	(0.033)	(0.060)
Education refperson						
primary or less	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
lower secondary	0.025	-0.023	0.060	0.055	0.017	0.083
	(0.031)	(0.044)	(0.065)	(0.091)	(0.045)	(0.074)
upper secondary	0.092**	0.044	0.074	0.262**	0.110**	0.301***
	(0.030)	(0.040)	(0.051)	(0.081)	(0.040)	(0.077)
tertiary	0.173***	0.147***	0.092	0.323***	0.236***	0.515***
	(0.032)	(0.040)	(0.055)	(0.077)	(0.040)	(0.078)
Region						
BXL	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
VL	0.019	-0.034	-0.021	0.170*	0.035	0.080
	(0.028)	(0.025)	(0.038)	(0.073)	(0.022)	(0.061)
WA	0.100***	-0.016	0.200***	0.314***	0.017	-0.108
	(0.029)	(0.024)	(0.038)	(0.075)	(0.023)	(0.063)
Number of rooms						
1	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
2	0.185***	0.168*	0.119	0.184	0.126	0.348***
	(0.052)	(0.065)	(0.084)	(0.156)	(0.066)	(0.091)
3	0.248***	0.095	0.218*	0.342*	0.177*	0.462***
	(0.049)	(0.064)	(0.087)	(0.154)	(0.071)	(0.092)
4	0.323***	0.139*	0.330***	0.473**	0.186**	0.465***
	(0.047)	(0.068)	(0.083)	(0.153)	(0.071)	(0.092)
5	0.356***	0.196**	0.405***	0.473**	0.203**	0.466***
	(0.048)	(0.069)	(0.088)	(0.158)	(0.071)	(0.092)
>=6	0.398***	0.230***	0.471***	0.429**	0.236***	0.516***
	(0.049)	(0.067)	(0.088)	(0.165)	(0.069)	(0.097)
House type						
Detached	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
Semi-detached	-0.083***	-0.008	-0.134***	-0.175***	-0.012	-0.010
	(0.012)	(0.016)	(0.021)	(0.030)	(0.020)	(0.030)

	(1) Ln(GHG_all)	(2) ln(GHG_Food)	(3) ln(GHG_Energy_ housing)	(4) ln(GHG_Transport)	(5) ln(GHG_Goods)	(6) ln(GHG_Services)
Apartment	-0.162***	-0.061*	-0.371***	-0.254***	-0.066*	0.137**
	(0.019)	(0.025)	(0.035)	(0.050)	(0.028)	(0.052)
Other	-0.015	-0.046	-0.118	-0.155	0.156	0.170
	(0.082)	(0.135)	(0.171)	(0.188)	(0.126)	(0.191)
Tenure status						
Owner	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
Tenant	-0.109***	-0.050*	-0.060*	-0.242***	-0.113***	-0.315***
	(0.016)	(0.024)	(0.026)	(0.045)	(0.018)	(0.043)
Constant	-1.342***	-2.389***	-0.171	-6.080***	-7.021***	-6.931***
	(0.218)	(0.221)	(0.298)	(0.470)	(0.295)	(0.483)
Observations	6124	6124	6124	6124	6124	6124
R^2	0.581	0.486	0.265	0.411	0.620	0.354

Standard errors in parentheses: * p < 0.05. ** p < 0.01. *** p < 0.001

The income coefficient in the 'Total' model is 0.323, which means that a one percent increase in household income is associated with a 0.323 percent increase in household GHG emissions. The elasticity is lower than unity – a finding consequent with existing literature. Similarly, to our results, the majority of the studies on the field find that there is no absolute decoupling between income and emissions, but that a relative decoupling can be observed. As income increases, the level of emissions increases, but in a less than proportionate way. Estimated income or expenditure elasticities in other studies vary between 0 and 1; i.e. a 1 percent increase in income is associated with a 0-1 percent increase in emissions. For an overview of elasticities in other studies, see table 1 (p. 6).

We find that income elasticities of emissions from categories that satisfy consumption associated with basic needs ('Energy and housing' and 'Food') are lower than those of other product groups. Demand and subsequent emissions of these product categories are less responsive to changes in overall income levels. The income elasticity of emissions related to consumption of products in the 'Energy and housing' category is the lowest (0.114), while that of 'Goods' is the highest (0.693). This means that a 10% increase in the overall income levels of households is associated with a 1.1 percentage increase in GHG emissions from 'Energy and housing', and a 6.9 percentage increase in GHG emissions from 'Goods'. These findings are in line with results on other papers presented in table 1. The elasticity of household emissions with respect to expenditures are higher than with respect to income. Authors who calculated category-specific elasticities used expenditures instead of income in their regressions (Steen-Olsen et al. (2016), Isaksen & Narbel (2017), Girod & Hann (2010), Ala-Mantila et. Al. (2014)). Thus, our results are directly comparable only with the results of Büchs and Schnepf (2013). For the UK, they found that the overall emission elasticity with respect to income was 0.432, which is somewhat higher than our 0.323 estimate. They found that the elasticity of emissions from 'Energy and housing' and 'Transport' with respect to income are 0.187 and 0.594. respectively. These estimates are close to our respective estimates of 0.114 and 0.589.

Household size has a positive effect on household emissions. According to our estimates in the 'Total' model, a household with two (three) persons emit 20 (26) percent more than a single household. This means that as we double (triple) household size, emissions grow, but do not double (triple). On a per capita basis, emissions fall with growing household size. This finding reflects the presence of economies of scale. In bigger households, resources, such as living place, heating, or vehicle fuels are shared and this results in less per capita emissions. In the commodity-specific models, we see that the effect of household size differs greatly. The estimated coefficients for the adult and children variables are the smallest in the 'Energy and housing' model, thus the economies of scale effect are the strongest in case of this consumption category. An additional household member adds little or nothing to heating and other housing-related expenses and subsequent emissions. The estimated coefficients for the adult and children variables are the highest in the 'Food' model, thus the economies of scale effect are the weakest for this category. An additional household member requires considerable amount of extra expenses on and subsequent emissions from food and drinks. Our findings about the presence of economies of scale in household GHG emissions suggests that shrinking average household size in the society puts an upward pressure on GHG emissions.

The coefficients of the children variable are smaller than those of the adult variable. The presence of children does not add as much to overall emission levels of households than the presence of adults. The category-specific regression results show that the positive effect of children on overall household emissions comes mainly from emissions from 'Food' and 'Services'. The estimated coefficients of children in the 'Energy and housing', 'Goods', and 'Transport' regressions are small and insignificant.

Age has a small and significant positive effect on total emissions. The age variable captures the age of the household head. In the 'Total' model, one extra year is associated with 0.5 percent higher emissions, ceteris paribus. Or, in other words, 10 more years are associated with 5 percent higher emissions. This might reflect the fact that values and lifestyles change with age, and they translate into different consumption and emission patterns. Other authors also found a small, but significant effect of age on emissions. Büchs and Schnepf (2013) estimated a 0.02 coefficient for age on UK data, Golley and Meng (2012) estimated a 0.001 coefficient on Chinese data. The coefficient of age is not significant in the 'Transport' and 'Goods' models, and it has the largest estimated value in the 'Food' model: an additional year of age of the household head is associated with 1 percent higher emissions from food and drinks.

The professional status variable captures the professional status of the household head, and its reference category is 'working'. The estimated coefficients of the other categories are negative in all the models (except the 'Energy and housing' model), meaning that households where the household head is unemployed, student, incapacitated, housewife or in pension emit less compared to households where the household head is working. The only model where the estimated coefficients of professional status categories are positive is the 'Energy and housing' model. A plausible explanation for this is that non-working people spend more time at home, which translates into higher heating requirements, and thus higher emissions from 'Energy and housing' consumption. The largest estimated professional status coefficient is that of the incapacitated category in the 'Transport' regression. The emission from transport is 41 percent less for households with an incapacitated household head, than for households with a working household head. Also, in the 'Transport' regression, the coefficient of unemployed is -0.404, meaning that a household with an unemployed household head emits 40 percent less than a household with a working household head, ceteris paribus. This finding is likely to reflect that unemployed people commute less, or that they have less means to travel for leisure.

The higher the educational attainment in the household, the higher its emissions. The reference category of the education variable is 'primary or less'. Compared to this category, households with lower secondary, upper secondary and tertiary education emit 3, 9, and 17 percent more, respectively in the 'Total' model. Only the coefficient of tertiary education is significant on the 1 percent significance level.

We found the strongest association between education and emissions in the ‘Services’ model, where a household with tertiary education is associated with 52 percent higher emissions than a household where the highest educational attainment is primary or less. A possible driver behind the positive education-emissions relationship might be that people with higher educational attainment have different preferences, norms and values related to how to spend their free time than people with lower educational attainment. These different preferences might translate into more emission-intensive consumption patterns. However, it is important to note, that our model cannot capture the exact driving forces behind the positive education-emissions relationship. Mixed results have been found in the literature about the association between household carbon footprints and education. Some authors found that educational attainment and emissions are positively associated even after controlling for other factors (Büchs & Schnepf, 2013; Poom & Ahas, 2016), while others found negative ceteris paribus associations (Lenzen et al., 2006).

The Region variable has three categories: Brussels-Capital Region (reference category), Wallonia and Flanders. Households in Wallonia and Flanders emit more than households in Brussels. The coefficient of Wallonia is significant in the ‘Total’ model: households in Wallonia emit 10 percent more than households in Brussels. The category-specific regressions show that the big positive effect comes from emissions in the ‘Energy and housing’ and ‘Transport’ regressions. Table 7 shows that houses in Wallonia are older. The pollution-intensive types of heating coal, fuel oil and wood, are also more prevalent in Wallonia (table 6). This might be a driving force behind the positive significant coefficient that we found in the ‘Energy and housing’ model. In case of the ‘Transport’ model, we assume that travel, commute, and driving distances are longer in Wallonia than in Brussels, and that is why the region has a large and significant effect. We do not have data on driving distances, urban/rural distinction, or the quality and density of the public transport system. Ideally, we would include these variables in the transport regression. We assume that the region variable picks up the effects of these factors.

Table 6 Percentage of households using a type of heating broken down by region

Heating type	FLA	WAL	BRU	Total	Share heating type[a]
Natural gas	64.4%	19.7%	15.9%	100%	59.3%
Butane	59.2%	34.3%	6.5%	100%	0.2%
Propane	30.2%	69.8%	0.0%	100%	0.8%
Electricity	61.9%	32.5%	5.7%	100%	7.1%
Fuel oil	43.9%	50.8%	5.2%	100%	26.3%
Coal	29.7%	68.5%	1.8%	100%	1.0%
Wood	40.6%	58.4%	1.0%	100%	2.3%
Wood pellets	25.3%	74.7%	0.0%	100%	2.3%
Heat pump	52.2%	46.3%	1.4%	100%	0.8%
Other energy source	0.0%	63.7%	36.3%	100%	0.0%

a: Share of the heating type (row) in the total number of households

Table 7 Percentage of households broken down by building year of the house

	Building year	BXL	VL	WA
1.	Before 1946	38.67	19.43	41.04
2.	1946-1960	22.7	14.78	16.69
3.	1961-1970	15.5	12.98	9.05
4.	1971-1980	6.22	17.77	11.21
5.	1981-1990	2.6	10.74	5.92
6.	1991-2000	1.63	10.47	6.29
	Total	100	100	100

The number of rooms has a positive effect on emissions, and it has the highest coefficients in the 'Services' model.

Households that live in semi-detached houses or in apartments, emit less than households that live in detached houses. The effect is significant in the 'Energy and housing' model, which is likely to be driven by the fact that detached houses tend to have higher heating requirements: the area surface of the house tends to be higher while the energy performance of an (average) detached house is typically lower than an (average) apartment. Tenants emit less than owners, and this effect is the strongest in the 'Services' model. This might be partially due to the way our model was constructed. Tenants spend a higher percentage of their income on housing related costs compared to owners while our model excludes expenditure on rent and mortgage payments.

4.2.2. Conclusion

Results of the multiple regression analysis in section 4.2.1 are in line with results of the bivariate analysis. The added value of the multivariate analysis was that we could disentangle and quantify the effects of individual variables. We find that income, household size, age, education and the size of the house have positive effects on household GHG emissions. Unemployment, living in an apartment (rather than living in a house), and being a tenant are associated negatively with household emissions. We found regional differences in household emissions, which mainly stem from higher emissions related to transport, energy and housing in Wallonia and Flanders than in the Brussels-Capital Region.

We found a very strong economies of scale effect: households with more members emit more in absolute terms, but not on the per capita basis. This stems from the fact that the most polluting consumption category (Energy and housing) is shared to the highest extent among household members. For example, emissions from heating the house do not increase when an additional member is added to the household. On the other hand, emissions from food consumption do grow significantly when household size increases. In other words, the sharing of consumption expenditure among household members has a negative effect on total household emissions. As a result, the statistical trend towards smaller households that we observe in demographic statistics puts an upward pressure on emissions.

The main variable of our interest was income. We found that there is relative decoupling between income and emissions, i.e. emissions grow with income, but in a less than proportionate way. The elasticity of emissions with respect to income is 0.323, i.e. a 10% increase in income is associated with a 3.23% increase in emissions. An important driving force behind the relative decoupling is the fact that the share of the most polluting consumption categories ('Energy and housing' and 'Food') in total expenditures is higher at the bottom part of the income distribution than at the top. This has been demonstrated in graph 3, and controlling for other socio-economic factors in the multiple regression analysis supported the findings of the graph.

5. Conclusion

In this report, we examined the relationship between greenhouse gas emissions due to the consumption of goods and services by households and the socioeconomic status of Belgian households. The PEACH2AIR database, which links the 2014 household budget survey with air pollution data, forms the basis for this study. Compared to the first analysis (Frère, Vandille, Wolff: 2018), PEACH2AIR has been improved. Improvements pertain in particular to imputations related to fuel expenses for transport and more precise direct pollution coefficients.

Two research questions were of interest to us. The answer to these questions can help to clarify the context in which policies that aim at reducing consumption-related greenhouse gas emissions have to operate.

- How are GHG emissions distributed across households?
- Which household characteristics are associated with the level of GHG emissions of households?

With regard to the first question, the bivariate analyses indicated that food, fuel used for transport and domestic energy use, account for more than 60% of greenhouse gas emissions while they represent less than 30% of the total expenditure. Not surprisingly, these are categories with a high pollution intensity. We also observed that pollution increases with income, but pollution intensity (gram of pollution per euro spent) decreases as income increases. In other words, the higher the income, the lower the share of emission-intensive consumption, such as heating. In general, different household characteristics such as region, type of heating, type of house or household size tend to be associated with different levels of pollution. These characteristics are, however, interdependent.

The second research question was answered using a multiple regression analysis. This analysis was done for all household expenditure together and then separately for expenditure related to food, energy consumption for the home, transport, goods and finally services. Income, household size, age, education and the size of the dwelling have positive effects on household GHG emissions. It appears that households with more members emit more in absolute terms, but not on a per capita basis. Also, after controlling for other socioeconomic factors, it appears that there is a relative decoupling between income and emissions. Greenhouse gas emissions increase less than proportional with income because the share of the most polluting consumption categories, i.e. 'Energy and housing' and 'Food' in total expenditures decreases with income, confirming the bivariate analysis.

6. Annex

6.1. Aggregation of COICOP categories

To make interpretation easier, we aggregated the 1 154 6-digit COICOP categories into 5 big categories: Food and drinks, Energy and housing, Transport, Goods, Services. The table below summarizes this aggregation (some aggregate codes were subdivided into 'goods' and 'services'):

Table 8 Summary of COICOP categories into 5 aggregate categories

1-digit COICOP category	Aggregate category
01 Food and non-alcoholic beverages	'Food and drinks'
02 Alcoholic beverages, tobacco	'Food and drinks'
03 Clothing and footwear	'Goods'
04 Housing, water, electricity, gas and other fuels	'Energy and housing'
05 Furnishings, household equipment and routine maintenance of the house	'Goods' or 'Services'*
06 Health	'Goods' or 'Services'*
07 Transport	'Transport'
08 Communication	'Goods' or 'Services'*
09 Recreation and culture	'Goods' or 'Services'*
10 Education	'Services'
11 Restaurants and hotels	'Services'

* Subclasses of the 1-digit COICOP category include both goods and services. In order to distinguish them, we use a variable which categorizes the 3-digit COICOP nomenclature into durable goods, semi-durable goods, non-durable goods, and services. This variable was downloaded from the website of the Statistical Division of the United Nations.

6.2. Treatment of non-frequent expenses

Non-frequent expenditures pose a difficulty for our analysis. Expenditures that do not occur on a regular basis are recorded only for a small fraction of all the households in the data. Such expenditures include, for example, durable goods (e.g. fridge), maintenance services, or holiday expenses. Even though only a small number of households report expenditures on these goods and services, we know that all the other households also purchase them at times that fall outside the survey period. Consequently, we observe a few households with large, and many households with zero expenditures on these products.

We dealt with this problem by smoothing non-frequent expenditures among households. We used a slightly modified version of the mean-imputation method proposed by Beznoska and Ochmann (2013)[5]. We created 14 household clusters based on net yearly household income quartiles and a categorical

[5] Amendola and Vecci (2014) describe that in poverty assessment reports durables are either left out from the welfare aggregate, or one of the following approaches are used: the 'acquisition approach' (i.e. using the purchase price of the goods), 'rental equivalent approach' (i.e. using market rental prices to estimate consumption flows), 'user cost approach' (i.e. calculating the cost of purchasing the durable at the beginning of the reference period and selling it at the end). Both Amendola and Vecci (2014) and Deaton and Zaidi (2002) describe clearly why the 'user cost approach' is superior to the other approaches both from a theoretical and a practical point of view. While this approach would be our preferred one when dealing with durable expenditures, we cannot use it, because there is no information in the survey about the market value and age of the durable goods, which is indispensable for the estimate.

household size variable (1,2,3 or higher)[6]. Then, for each durable product and each cluster, we calculated total expenditures and allocated a fraction of total expenditures to every household. This way, a small amount of durable expenditures is allocated to each household, instead of observing a little number of households consuming large amounts and the majority of the households consuming zero.

Non-frequent purchases were identified with two variables. Firstly, households were asked during the personal interview about their durable and non-frequent purchases during the four-month period preceding the interview. The price of these purchases is stored in a separate variable than the price of all other purchases. The second variable is a categorical variable of the COICOP categorization with the following categories: non-durables, semi-durables, durables, services and was retrieved from the website of the United Nations (United Nations, 2017). The two variables do not coincide perfectly. On the one hand, there are categories, which are labelled as durable in the COICOP categorization, but appear in the monthly logbook and not in the questionnaire. On the other hand, there are categories in the questionnaire, which are not labelled as durables in the COICOP categorization (e.g. holidays, flights). We took the union of the two variables, i.e. we smoothed the expenditures of all categories that were included in the personal questionnaire or fell in the durable category in the COICOP categorization.

The smoothing was done differently for two consumption categories. The first category consists of 12 durable goods about which ownership information was collected during the survey. During the personal interview, the interviewer asked how many of each of the following 12 goods the household possesses: cell phone, landline phone, motor, scooter, desktop, laptop, tablet, television, washing machine, dishwasher, fridge and cars. The second category consists of 141 products and services whose ownership information we do not have. For example: furniture, household appliances and tools, smaller electronic products, some maintenance and repair services, holiday expenses.

In case of the first group (i.e. where we have ownership information about the number of possessed items for each household), we smoothed durable expenditures by carrying out the following steps.

In the first step, we calculated a cluster-specific unit price by dividing total expenditures by the total number of items possessed within each cluster:

$$UP_{kc} = \sum_{i=1}^{n_c} p_{ik} \Big/ \sum_{i=1}^{n_c} q_{ik} \tag{6}$$

UP_{kc} stands for the unit price of durable good k in cluster c, p_{ik} stands for expenditures of household i on durable good k, q_{ik} stands for number of k possessed by household i, and n_c is the number of households in cluster c where household i belongs to.

[6] The initial number of clusters was 16 (4 income groups times 4 household size groups). However, due to their small sizes, the third and fourth household size groups within the first income quarter, and the first and second household size groups in the fourth income quarter were concatenated.

In the second step, we allocated a smoothed expenditure amount to each household by multiplying the cluster-specific unit price with the number of items possessed by the household:

$$p_{ikSM} = UP_{kc} * q_{ik} \tag{7}$$

p_{ikSM} stands for smoothed expenditures of household i on durable good k, UP_{kc} was calculated in the first step and stands for the unit price of good k in cluster c where household i belongs to, and q_{ik} stands for the number of k possessed by household i. Note, that if a household does not possess durable good k, zero smoothed expenditures on k are allocated to that household. If a household possesses two k's, the allocated smoothed expenditures on k are two times as large as in case of a household that possesses only one k.

In case of the second category of non-frequently purchased goods and services (i.e. where we do not have ownership information), we allocated total cluster-level expenditures equally to the households in the cluster:

$$p_{ikSM} = \sum_{i=1}^{n_c} p_{ik} \Big/ n_c \tag{8}$$

Again, p_{ikSM} stands for smoothed expenditures of household i on good k, p_{ik} stands for expenditures of household i on durable good k, and n_c is the number of households in cluster c where household i belongs to. Note, that p_{ikSM} is the same for each household within a cluster but varies between different clusters.

6.3. Correcting underreported fuel expenses of households using company cars

6.3.1. Introduction

We face a problem when estimating emissions of households that use a company car. Part of the fuel expenses of these households are paid by the employer and do not appear among the expenditures of the households in the HBS. A Wald test showed that the mean monthly fuel expenses of households with a company car (M = 78.31, se = 5.67) is significantly lower than that of households without a company car (M = 104.98, se = 1.64), F(1 337) = 19.10, p = 0.000. Moreover, the proportion of households that reports zero expenditures on fuel is higher for households that use company cars (table 9). Due to the fact that we calculate household emissions based on reported expenditures in the HBS, our estimate for the emissions of these households is biased downwards. Thus, we impute fuel expenses for households using company cars.

Table 9 Percentage of households reporting zero expenditures on fuel broken down by car ownership

Private car	Company car	
	No	Yes
No	90.3	64.8
Yes	12.8	22.5

When imputing fuel expenses for households using company cars, four issues needed to be resolved. Firstly, we found that the proportion of company cars is slightly underestimated in the HBS when compared to official statistics. Thus, we corrected the data and identified some company cars that were previously labelled as private cars. Secondly, when households own both cars and motorcycles, it is not possible to identify the share of fuel bought for the car. Thirdly, we observe that fuel expenditures do not grow linearly with the number of cars in the household, thus we had to account for the order of vehicles during the imputation. Lastly, we needed to make assumptions about the imputed fuel mix.

6.3.2. Number of company cars in Belgium

When trying to validate the proportion of company cars in the HBS using external sources, we found that it is not possible to know the exact number of company cars in Belgium from official statistics. We explain the reason for this in the next paragraphs, which are the summary of May's (2017) article.

There are two methods to calculate the number of company cars in Belgium. The first method uses tax-related information. In Belgium, there are two types of beneficiaries of company cars: employees and company directors. Company cars are subject to two legal obligations. (1) Employers must pay a so-called CO_2 solidarity contribution. However, it does not have to be paid for company directors, only for employees. According to the CO_2 solidarity contributions paid by employers, there were 425 000 cars made available to employed workers. (2) Employees and company directors must declare benefit in kind in their income tax. In case of company directors, company cars can be identified via the corresponding code of the text sheet. However, in the case of employees, it is not possible to extract this information because the corresponding code in their case is a broader category and includes benefit of any kind. For the company directors, 41.5% mentioned the usage of company cars in their income tax declaration, which equals 125 000 cars in 2015. Based on the above two pieces of information, there were 550 000 company cars in Belgium in 2015. However, the estimated number of 550 000 is likely to be a lower bound of the estimate, because there might be underreporting in the tax declarations of company directors.

Another method to calculate the number of company cars in Belgium is to take the 831 000 cars that are owned by legal persons and subtract all vehicles that are not company cars (short-term hire cars, replacement cars, car sharing, and service cars). This gives an upper-bound estimate of 670 000 company cars. The steps that were taken to arrive from 831 000 to 670 000, are listed in table 10.

Table 10 Estimates about the total number of company cars in Belgium

	2015[a] - official	2014[b] - official	2014 - HBS	2014 – HBS corrected
Passenger cars		5527074	5455932	5455932
Cars owned by private persons		4698910		
Company cars in HBS			455598	579825
Cars owned by legal persons	831000*	828164		
- Short-term hire cars	17000			
- Replacement cars	52000			
- Cambio and Zencar	670			
- Service cars	91200			
Upper-bound estimate	670000			
Lower-bound estimate	550000			
+Cars made available to employees	425000			
+Cars for company directors	125000			

a: Source: May (2017).
b: Source: Denys (2016).
* The total number of cars owned by legal persons is 859 350 in Denys (2016).

In conclusion, in 2015 there were at least 550 000 (425 000 for employees and 125 000 for company directors) and at most 670 000 company cars in Belgium. The final cautious estimate of May (2017) is 626 000 company cars for 2015, which represents 11% of all cars. For 2014, another source (Denys, 2016) gives only the number of cars that were owned by legal persons. This was 828 164.

6.3.3. Number of company cars in the HBS

There are three car-related variables in the HBS:

– ms_cars: The number of cars in the household

– ms_carsemployer: Out of the total number of cars, how many were made available by the employer

– cd_mainvehicle: Categorical variable about the ownership of main car of the household. It has five values:

  – Property of the household

  – Made available for free of charge by the employer

  – Made available for free of charge by other than employer

  – In leasing

  – Other

The total weighted number of cars (5 455 932) based on the ms_cars variable corresponds with the official statistics (5 527 074) in magnitude. Based on the ms_carsemployer variable, the number of company cars was 455 598 in 2014, which is only 8.4% of the total number of cars. This does not reach the lower bound of the estimate (11%) of May (2017). 11% in the HBS would mean 600 153 company cars. This is 32% higher than the current estimate of 455 598.

However, when we tabulate the ms_carsemployer and cd_mainvehicle variables (table 11), we see that there are 121 households that do not have any company car based on the ms_carsemployer variable, but report that the main vehicle was made available by free from the employer in the cd_mainvehicle variable. The mean fuel expenditures of these 121 households are lower than the mean fuel expenditures in the whole population. Thus, we assume that in these 121 cases, the cd_mainvehicle variable is correct, while the ms_carsemployer is not, and we recoded the ms_carsemployer from zero to one. After this correction, the weighted number of company cars based on the ms_carsemployer variable is 579 825. This is 10.6% of the total number of cars, which is an estimate closer to the 11% of May (2017).

Table 11 Number of households broken down by number of company cars in the household and ownership of main vehicle of the household

Number of company cars in the household	Main vehicle of the household						
	Property of household	Free - from employer	Free - other	In leasing	Other	NA	Total
0	4590	121	25	16	9	847	5608
1	218	178	1	8	3	0	408
2	35	59	3	13	2	0	112
3	4	3	0	0	0	0	7
Total	4847	361	29	37	14	847	6135

Note: Number of households in cells

Table 12 Percentage of households using private and company cars

Number of private cars in household	Number of company cars in household				
	0	1	2	3	**Total**
0	17.0	2.5	1.5	0.1	**21.1**
1	54.2	4.7	0.2	0.1	**59.2**
2	17.1	0.6	0.0	0.0	**17.7**
3	1.6	0.2	0.0	0.0	**1.7**
4	0.3	0.0	0.0	0.0	**0.3**
5	0.0	0.0	0.0	0.0	**0.0**
6	0.0	0.0	0.0	0.0	**0.0**
Total	90.0	8.0	1.8	0.1	100.0

Note: Percentage of households in cells

6.3.4. Motorcycle ownership

The HBS contains information about both car and motorcycle ownership. There are 544 households that have both car(s) and motorcycle(s), representing 7.7 percent of all the households (table 13). In case of these households, it is not clear if fuel was bought for the car, for the motorcycle, or for both. To not blur the picture of fuel purchases, it is reasonable to exclude these households from the imputation. However, they represent 10.3 percent of car-using households. Given that this is a high share, we reduce the number of excluded households based on the observation that motorcycle engines run on gasoline and not on diesel. Thus, we can always be sure that diesel was purchased for cars and not for motorcycles. If a household owns car(s) and motorcycle(s), there are three possible fuel expenditure cases:

1. The household buys gasoline and does not buy diesel. In this case, we cannot know how much share of this gasoline was used for the motorcycle. These households (147 in total) were excluded from the imputation exercise.
2. The household buys diesel and does not buy gasoline. We can safely assume that the diesel was purchased for the car and not for the motorcycle. These households (183 in total) were included in the imputation exercise.
3. The household buys both gasoline and diesel. In this case, if the household has one car, we can assume that the diesel was bought for the car, and the gasoline was purchased for the motorcycle. If

there are more cars, we cannot know the share of gasoline purchased for the car and for the motorcycle. Thus, we excluded these households (92 in total) from the imputation exercise

Table 13 Percentage of households broken down by car and motorcycle ownership

Car	Motorcycle		Total
	No	Yes	
No	16.1	0.9	**17.0**
Yes	75.3	7.7	**83.0**
Total	91.4	8.6	100.0

6.3.5. Fuel expenditures and order of vehicles in the households

Table 14 and table 15 show the mean monthly fuel expenditures of households broken down by the number of company and private cars possessed by the household. Columns 'a' and 'b' in table 14 represent means estimated with and without zero expenditures, respectively. We highlight two observations based on these tables.

Our first observation is that for the same number of cars, the mean monthly fuel expenses is always lower when at least one of the cars are company cars. In case of households with one car, the mean monthly fuel expenditure is 88 euros when the car is private and 47 euros when the car is provided by the company. In case of households with two cars, the mean monthly fuel expenses of households that own two private cars is 151 euros, while that of households that own one private and one company car is 93. Households with two company cars spend 68 euros on fuel on average.

Our second observation is that monthly fuel expenditures do not grow proportionally with the number of cars used by the household, i.e. fuel expenditures do not double when the number of cars double. The mean expenditures of households that own two, three and four private cars are 72. 116. and 149 percent higher than households that own only one private car (and do not own company cars). Thus, it would be incorrect to impute double the amount of the fuel expenditures of a one-car household for a two-car household. Based on this observation, we took into account the order of the car in the household and followed the above-mentioned percentages during the imputation.

There are 849 households in the survey that do not have a car. Out of these, 108 report expenditures on fuels. There can be several reasons why households without car ownership spend on fuel: motorcycle ownership (24 out of the 108 own motorcycles), participating in a car sharing program, or renting a car.

Table 14 Mean monthly fuel expenses (euro) broken down by number of private and company cars used by the household

Nr. of private cars	Number of company cars							
	zero		one		two		three	
	a	b	A	b	a	b	a	b
0	9	73	44	178	67	121	100	166
1	88	103	92	118	38	108	0	
2	151	163	105	129	33	33		
3	188	205	174	174				
4	213	219	146	146	139	139		
5	140	140						

Note: a: zero expenditures calculated in mean.
b: zero expenditures excluded from calculation of mean. Households that own any motorcycle and buy gasoline are excluded.

Table 15 More information about the distribution of fuel expenses (euro) in the most populated cells

	Mean	Linearized std. err.	[95% Conf. Interval]		Min	Max	Median
no cars	8.70	0.98	6.53	10.41	0	419.8	0
1 private, 0 company	87.67	1.60	84.52	90.81	0	729.9	80
0 private, 1 company	44.04	14.78	14.41	73.66	0	693.9	0
2 private, 0 company	150.60	3.11	144.48	156.73	0	592	145.8
1 private, 1 company	91.91	6.36	79.34	104.49	0	664.7	74.6
0 private, 2 company	66.70	8.14	50.37	83.03	0	343.6	40

Note: households that own any motorcycle and buy gasoline are excluded.

6.3.6. Fuel mix

Table 16 presents how this fuel mix changes with the number and type (private/company) cars the household uses. The table shows the mean share of household expenditures in all fuel expenses. The mean share of diesel expenditures in total fuel expenses is higher for households that use one company car (0.66) than for households that own a private car (0.51). The difference in the fuel mix of households using company vs. private car can be explained by the fact that the percentage of diesel cars in the Belgian company car fleet is higher than in the private car fleet. According to Denys, Beckx, and Vanhulsel (2016) 86 percent of company cars were diesel in 2014. The share of diesel cars was much lower in the private fleet; only 57 percent of private cars were diesel. Based on these numbers, we suspect that underreporting of fuel expenditures in households using company cars mainly affects diesel and the mean share of diesel expenditures in these households is higher than 66 percent. Thus, we only impute diesel, except for households that own a company car and report gasoline expenses.

Table 16 Mean share of different fuels in household total expenditures on fuels (gasoline, diesel, other)

Number and type of cars in households	% of households	Gasoline			Diesel			Other		
		Mean share	95% LCL	95% UCL	Mean share	95% LCL	95% UCL	Mean share	95% LCL	95% UCL
No car	16.98	0.59	0.48	0.7	0.36	0.26	0.46	0.05	0.01	0.08
1 priv	54.18	0.48	0.45	0.5	0.51	0.48	0.53	0.01	0.01	0.02
2 priv	17.05	0.36	0.33	0.39	0.63	0.6	0.66	0.01	0.01	0.02
3 priv	1.57	0.34	0.27	0.41	0.63	0.56	0.71	0.02	0	0.05
1 comp	2.53	0.34	0.16	0.51	0.66	0.49	0.84	0		
2 comp	1.53	0.46	0.31	0.61	0.51	0.36	0.66	0.03	-0.01	0.06
1 priv, 1 comp	4.7	0.38	0.32	0.44	0.61	0.55	0.67	0.01	0	0.03
Other	1.47	0.45	0.35	0.54	0.55	0.46	0.64	0.01	0	0.01
Total	100	0.45	0.43	0.46	0.54	0.52	0.56	0.01	0.01	0.02

Note: LCL = lower confidence limit UCL = upper confidence limit

6.3.7. Imputation

Our aim is to impute fuel expenditures for households that use company car(s). We do so because the fuel expenditures of these households are often reimbursed by the employer, thus their reported expenditures in the HBS is lower than that of households without a company car.

We carried out the mean imputation according to the following procedure. If the fuel expenses of a household that uses a company car were smaller than the threshold presented in table 17, we imputed additional fuel expenses so that the total fuel expenses reach the threshold. The threshold is based on the mean fuel expenditures of households that own only private cars (see table 14). For example, if a household with one company car and one private car spends 100 euros on fuels in a month, we added

51 euros to its fuel expenditures to reach the threshold of 151 euros. It is likely that this is still underestimating the real costs, because company car owners tend to drive more kilometres per year than private car owners (Laine and Van Steenbergen, 2016).

Regarding the imputed fuels, we only imputed diesel expenses[7], because we expect that company cars are diesel vehicles as explained in the previous section. We disregarded expenditures on other fuels, because they represent only a small percentage of total fuel expenditures (table 16).

Table 17 Thresholds for mean imputation of fuel expenses

Cars in household		Threshold (euros)
Nr of company cars	Nr of private cars	
1	0	88
2	0	151
3	0	188
1	1	151
2	1	188
3	1	213
1	2	188
1	3	213

Note: LCL = lower confidence limit UCL = upper confidence limit

Total fuel expenses in the sample grew by 6.7 percent after the imputation.

There are two implicit assumptions in our imputation method. Firstly, the threshold for imputation is based on total fuel expenses of households, which includes diesel, gasoline and other fuel expenses. The share of the latter is so small, that we disregarded it. We only impute diesel, because 86 percent of company cars were diesel in 2014 according to Denys, Beckx, and Vanhulsel (2016), implying that underreporting of fuel expenses is likely to be related to diesel. However, there is a small percentage of company cars that run on gasoline. If gasoline is more expensive than diesel, we implicitly assume that these households consume more fuel. Secondly, the thresholds for the imputation is based on households using private cars. Thus, we implicitly assume that the private car fleet has similar characteristics to the company car fleet. However, company cars are bigger and newer than private cars. Bigger cars tend to consume more, newer cars tend to be more fuel efficient, thus consuming less. The total effect of the two factors are not known to us, because we do not have information on average fuel consumption of company cars and private cars.

Another way to deal with the problem of underreporting of fuel expenses in case of households using company cars is to explain fuel expenses in a regression framework. We tried this method, but the model performed poorly, thus we decided to stick to the above-described method.

[7] Except the case when a household uses one company car and reported gasoline expenses. In this case we can be sure that the household has a company car that runs on gasoline.

6.4. The calculation of coefficients of direct air pollution

6.4.1. Coefficients of direct air pollution: transport

A coefficient of direct air pollution (CDAP) reflects the amount of direct air pollution per euro spent on a certain product. For a given fuel c, the CDAP of a pollutant p is calculated using the following formula:

$$CDAP_{p,c} = \frac{Total\ direct\ pollution_{p,c}\ (g)}{Total\ consumption_c\ (g)\ *\ specific\ volume_c\ \ (l/g) * price_c\ (euro/l)} \qquad (9)$$

$$where\ c\ \in\ \{diesel, gasoline, LPG, two - stroke\ oil, other\ fuels\}$$

Due to a lack of disaggregated data, we assumed that the CDAP of COICOP 07223C 'Other Fuels' is equal to the CDAP of gasoline. The relative importance of this residual category is rather low.

The resulting values of the coefficients of direct air pollution are listed in the table below. The data sources we used, and the precise definition of each variable used in the formula above are described thereafter.

Table 18 Values of the coefficients of direct air pollution of fuels used for transport for different pollutants
Pollution in gram per euro spent

Pollutant (a) / COICOP	Diesel 07221A	Petrol 07222A	LPG 07223A	Two-stroke engine oil 07223B	Other fuels 07223C
CO_2	2220.6980	1453.1221	2856.0772	1513.0833	1453.1221
CH_4	0.0070	0.1370	0.3221	0.5607	0.1370
N_2O	0.0880	0.0141	0.0662	0.0240	0.0141
NO_X	8.9816	1.0180	3.2748	3.8788	1.0180
CO_2	0.7974	11.7406	31.1659	51.2302	11.7406
NMVOC	0.1208	1.6976	2.7277	62.7387	1.6976
SO_X	0.0118	0.0040	0.0000	0.0040	0.0040
NH_3	0.0218	0.2579	0.7022	0.0240	0.2579
$PM_{2.5}$	0.4031	0.1040	0.2070	0.6592	0.1040
PM_{10}	0.5402	0.1833	0.3654	0.7647	0.1833

a: Values for HFC, PFC and SF6 are all 0.

a. Total direct pollution$_{p,c}$ (gram)

The total direct pollution for each of the 13 different pollutants (p) studied, is based on data from the COPERT model. The COPERT model is a European road transport emission inventory model. Belgian COPERT data for 2014 based on the 2019 submission is used and was supplied by Bruxelles Environnement with the consent of the other Belgian regions. The COPERT model distinguishes pollution caused by both *fuel used* and *fuel sold*[8]. We used data expressed on a *fuel used* basis. For diesel, gasoline and LPG, we summed all pollution of the LRTAP-class 'Passenger Cars'[9], except CO_2 Biomass emissions, which are assumed to be CO_2 neutral. The pollution caused by two-stroke oil, was calculated using LRTAP-class 'Mopeds and Motorcycles' of which only the subsectors '2-stroke < 50 cm^3' and '2-stroke > 50 cm^3' were retained. CO_2 biomass emissions were again excluded.

8 The difference between fuel used and fuel sold can be due to a change in inventory stocks or purchases for foreign consumption.

9 The other classes are 'Heavy duty vehicles', 'Light duty vehicles' and 'Mopeds & Motorcycles'.

b. Total consumption$_c$ (gram)

The total consumption of each individual type of fuel *c* was calculated by aggregating the COPERT data in the same manner as was done for total direct pollution. The total consumption is expressed on a fuel used basis, as is the case for the pollution described above.

c. Specific volume$_c$ (litre/gram)

The specific volume of each fuel type in litre per gram was sourced from the Energy Statistics Manual of the International Energy agency[10]. For two-stroke oil, we assumed that 97% of it consists of gasoline, and 3% consists of synthetic oil for two-stroke gasoline engines.

d. Price$_c$ (euro/litre)

The price per litre for gasoline, diesel and LPG are based on disaggregated FPB data used to calculate the CPI. The prices used are the average prices (including VAT and duties) of these fuels in 2014. For gasoline, we constructed a weighted average of 98ron and 95ron, based on their respective weight in the calculations of the CPI. We assumed that the price per litre of two-stroke oil was the same as that of gasoline.

6.4.2. Coefficients of direct air pollution: domestic energy

The coefficients of direct air pollution for domestic energy were calculated using two different formulas. We applied the first formula to all fuel types except 'fuel oil' and 'other liquid fuels', for which the second formula was used.

$$CDAP_{p,c} = \frac{Emission\ factor_{p,c} * Energy\ conversion\ factor_c * \frac{NCV}{GCV}_c}{Price_{(h),c}}$$

$$if\ c \in \left\{\begin{matrix} natural\ gas, natural\ gas\ second\ home, \\ butane, propane, coal, firewood, other\ solid\ fuels \end{matrix}\right\}$$

$$CDAP_{p,c} = \frac{Emission\ factor_{p,c} * Energy\ conversion\ factor_c * \frac{NCV}{GCV}_c}{specific\ volume_c * Price_{(h),c}} \qquad (10)$$

$$if\ c \in \{heating\ oil, other\ liquid\ fuels\}$$

The resulting values of the coefficients of direct air pollution are listed in the table below. The data sources used and the precise definition of each variable used in the formulas above are described thereafter.

[10] International Energy Agency (2005). Energy Statistics Manual, 181.

Table 19 Values of the coefficients of direct air pollution of fuels used for domestic heating for different pollutants
Pollution in gram per euro spent

Pollutant (a) /COICOP	Natural gas (b) 04521A 04521B	Butane gas (excluding deposit) 04522A	Propane gas (excluding deposit) 04522B	fuel oil (c) 04530A	Other liquid combustibles (d) 04530B	Coal 04541A	Firewood 04549A	Other combustibles (e) 04549B
CO_2	2932.87	1299.72	1330.17	3564.10	3464.46	6109.26	9915.98	6862.76
CH_4	0.2614	0.1158	0.1185	0.4743	0.4610	19.3739	26.5607	18.3824
N_2O	0.0052	0.0023	0.0024	0.0281	0.0273	0.0969	0.3541	0.2451
NO_X	1.3155	1.0404	1.0648	1.8982	1.8451	6.4580	4.4268	4.9020
CO_2	1.2224	0.5396	0.5523	0.7584	0.7372	129.1598	354.1420	18.3824
NMVOC	0.0959	0.0424	0.0434	0.0138	0.0134	19.3740	53.1213	0.6127
SO_X	0.0000	0.0000	0.0000	2.3223	2.2574	38.7479	0.9739	0.6740
$PM_{2.5}$	0.0285	0.0121	0.0124	0.0764	0.0742	29.0609	65.5163	3.6765
PM_{10}	0.0285	0.0121	0.0124	0.0764	0.0742	29.0609	67.2870	3.6765
NH_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0194	6.1975	0.7353

(a): Values for HFC, PFC and SF6 are all 0.
(b): The price depends on the amount bought by each household. The cdap for a household consuming 23 260 kWh per year is shown here.
(c): The price depends on the amount bought by each household. The cdap for a household consuming more than 2 000 litres is shown here.
(d): e.g. kerosene
(e): e.g. charcoal, wood pellets

a. Emission factor of CO_2, CH_4 and N_2O (g/J)

For CO_2, CH_4 and N_2O, we used data from the Belgian national emissions inventory of 2017 for the year 2014[11]. Table 20 summarises which implied emissions factor from the national inventory was used for each COICOP code.

Table 20 Overview links between COICOP and emission factor category

	COICOP	COICOP name	Fuel National Inventory
1.	04521A	Natural Gas	gaseous fuels
2.	04521B	Natural gas 2nd home	gaseous fuels
3.	04522A	Butane	gaseous fuels
4.	04522B	Propane	gaseous fuels
5.	04530A	Fuel oil	liquid fuels
6.	04530B	Other liquid fuels	liquid fuels
7.	04541A	Coal	solid fuels
8.	04549A	Firewood	biomass
9.	04549B	Other solid fuels, e.g. pellets	solid fuels

b. Emission factor of NOx, SOx, NH_3, NMVOC, CO, $PM_{2.5}$ and PM_{10}

The emission factors of NOx, SOx, NH_3, NMVOC, CO, $PM_{2,5}$ and PM_{10} are based on data supplied to us by the Flemish and Walloon regions. In a previous version of the PEACH2AIR model[12], we used data from the EMEP/ EEA air pollutant emission inventory guidebook of 2016. The new data of Flanders uses the so-called tier 2 methodology which, for a given fuel, differentiates between multiple types of heaters/boilers. By dividing the total pollution of each fuel type by the total energy use of each fuel type, we get the weighted average emission factors. We specifically used the Flemish data because the tier 2 methodology, which is more precise than other methodologies currently in use, has not been implemented by each region yet. A single exception is made for wood and pellets, which are aggregated

11 Table 1.A(a) sheet 4
12 Frère, J.-M., Vandille, G., & Wolff, S. (2018). The PEACH2AIR database of air pollution associated with household consumption in Belgium in 2014 (Working Paper No. 3–18).

in the Flemish data and for which we used the more detailed and disaggregated data from Wallonia. An overview of which in the regional source has been linked to which COICOP code is shown in table 21.

Table 21 Overview of the links between COICOP and the emission factor category

	COICOP	COICOP name	Region	Name of emission factor category in regional source
1.	04521A	Natural Gas	Flanders	Aardgas
2.	04521B	Natural gas 2nd home	Flanders	Aardgas
3.	04522A	Butane	Flanders	propaan-butaan-LPG
4.	04522B	Propane	Flanders	propaan-butaan-LPG
5.	04530A	Fuel oil	Flanders	Stookolie
6.	04530B	Other liquid fuels	Flanders	Stookolie
7.	04541A	Coal	Flanders	Kolen
8.	04549A	Firewood	Wallonia	Poêle bois
9.	04549B	Other solid fuels, e.g. pellets	Wallonia	pellets

c. Energy conversion factors ($\frac{J}{KWH}$, $\frac{J}{g}$) and Specific volume ($\frac{l}{g}$)

The energy conversion factor to convert Joule to kWh is by definition 3.6 million J/kWh and is used to calculate the CDAP of natural gas, firewood and other solid fuels. The other conversion factors in J/gram can be found in the Energy Statistics Manual of the International Energy Agency[13]. In the second formula, used to calculate the CDAP of fuel oil and other liquid fuels, a specific volume is applied to convert gram to litre. This step is necessary because these fuels are bought and priced per litre and not per gram. The specific volume is also sourced from the Energy Statistics Manual.

d. The share of the net calorific value in the gross calorific value $\left(\frac{NCV}{GCV}\right)$

The emissions factors described above, are expressed and bought in terms of net calorific value. The prices, for example for natural gas, are expressed in gross calorific values. A correction is needed to align both concepts. We based the values of these shares (0.9 for gasses, 0.95 for all other fuels) on the IPCC background paper titled "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories".

e. $\mathbf{Price}_{(\mathbf{h}),\mathbf{c}}$ $\left(\frac{EUR}{KWH}\right)$ of natural gas

The average price of natural gas depends on the amount a household consumes. The disaggregated CPI data of the FPB with average prices for natural gas differentiates between four types of consumers[14]. Each type has its own average price at a certain consumption of kWh (e.g. 23 260 kWh). The average price includes distribution costs and levies. All profiles assume a fixed price per kWh of gas excluding distribution costs and levies. The average prices are averages of the year 2014. Using the so-called 'boordtabel'[15] from the Belgian energy and gas regulator CREG, we found that the CPI data of the FPB

13 International Energy Agency (2005). Energy Statistics Manual, 181.

14 Profile D1: 2 326 kWh), D2 (4 652 kWh), D3 (23 260 kWh) and D3b (34 890 kWh) are distinguished.

15 Creg (2014). Maandelijkse boordtabel elektriciteit en aardgas. Retrieved from http://www.creg.info/Tarifs/Boordtabel-Tableaudebord/Francais/

underestimates the average cost per kWh for the D3 profile (23 260 kWh) by about 3.5 . By consequence, we have chosen to adjust the average price per kWh for all four profiles by 3.5%.

Given the amount of kWh and the average price, we calculated the total expenditure of each profile in the CPI data. For each household, the expenditure in the HBS on natural gas is aggregated at the COICOP level of natural gas (COICOP 04521A and 04521B). Hereafter, we compared the total expenditure of each household with the total price of the 4 profiles in the CPI data and we interpolated the average price of the two profiles which are above and below the total expenditure of a household. By consequence, (almost) each household has its own unique average price per kWh. This is indicated in the formula above by the (h) in the formula. For profiles below 2 326 kWh and above 34 890 kWh, interpolation is not possible. By consequence, we assumed that the average price is equal to the average price of profile D1 and D3b respectively.

f. $Price_{(h),c}$ of fuel oil, butane, propane, other liquid fuels and coal

The price of butane, propane, other liquid fuels and coal is based on disaggregated CPI data from which we calculated the average price in 2014. For 'other liquid fuels' (COICOP 04530B) we assume that the price is equal to that of fuel oil for orders lower than 2 000 litres.

The price of fuel oil depends on the amount a household orders. Based on the total amount spent on fuel oil and assuming rational behaviour, we applied a lower average price per litre if more than 2 000 litres was ordered. Both prices were sourced from disaggregated CPI data.

g. $Price_{(h),c}$ of wood and other solid fuels (pellets)

For wood, the average price of 2014 as published by APERe, a Belgian non-profit organisation was used. The price of 'other solid fuels' like pellets and charcoal is based in the APERe prices for wood pellets. The prices are the result of a market study by Valbiom asbl. These prices, which are expressed in stère, map or kg, are converted by APERe to kWh using the following hypotheses[16]:

Table 22 Conversion to kWh of wood and pellets

	Type of product	Conversion hypothesis
1.	Logs	1800 kWh/stère
2.	Wood chips	800 kWh/map
3.	Wood Pellets	5 kWh/kg

Map: mètre cube apparent de plaquettes, a unit to measure m³ of wood chips.

[16] Apere (2018. March 6). Hypothèses et Méthodologie. Retrieved from: http://www.apere.org/sites/default/files/OBS_Hypoth%C3%A8ses_Methodologie_0.pdf

6.5. Summary statistics of variables included in the regression models

Table 23 Summary statistics of the continuous variables included in the regression models

Variable	Nr of obs.	Mean	Std. Dev.	Min	Max
Household income	6135	40422.82	25050.42	0.00	514080.00
Nr of adults	6136	2.06	0.88	1.00	4.00
Nr of children	6136	0.53	0.90	0.00	4.00
Age of reference person	6135	49.59	14.14	16.65	93.94
Nr of rooms	6128	4.32	1.24	1.00	6.00
GHG total*	6136	20.65	11.32	0.00	182.66
GHG food*	6135	3.94	2.21	0.01	18.44
GHG energy and housing*	6135	6.87	4.36	0.05	74.14
GHG transport*	6135	3.71	2.95	0.01	21.42
GHG goods*	6135	2.58	1.73	0.25	34.82
GHG services*	6135	3.57	6.31	0.03	157.69

* Household GHG emissions resulting from the consumption of the category

Table 24 Summary statistics professional status

Professional status of the reference person	Freq.	Percent	Cum.
Working	3894	63.47	63.47
Unemployed	437	7.12	70.59
Student	42	0.68	71.28
Housewife	49	0.80	72.08
Incapacitated	327	5.33	77.41
Pension	1386	22.59	100.00
Total	6135	100.00	

Table 25 Summary statistics highest educational attainment in the household

Highest educational attainment in the household	Freq.	Percent	Cum.
primary or less	297	4.84	4.84
lower secondary	593	9.67	14.51
upper secondary	2106	34.33	48.83
Tertiary	3139	51.17	100.00
Total	6135	100.00	

Table 26 Summary statistics highest region

Region	Freq.	Percent	Cum.
Brussels-Capital Region	633	10.32	10.32
Flanders	2893	47.16	57.47
Wallonia	2609	42.53	100.00
Total	6135	100.00	

Table 27 Summary statistics type of house

Type of house	Freq.	Percent	Cum.
Detached	2269	36.99	36.99
Semi-detached	2465	40.19	77.18
Apartment	1368	22.30	99.48
Other	32	0.52	100.00
Total	6134	100.00	

Table 28 Summary statistics tenure status

Tenure status	Freq.	Percent	Cum.
Owner	4424	72.11	72.11
Tenant	1711	27.89	100.00
Total	6135	100.00	

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