High-income households emit more greenhouse gases, primarily due to transport behavior

By Sandra Bohmann, and Merve Kücük

- Study using 2023 SOEP data analyses the per capita carbon footprint in Germany in the areas of residential energy use, nutrition, and transport
- At 6.5 tons of carbon emissions per capita per year, emissions in these areas are twice as high as required to achieve the two-degree target
- High-income households cause twice as many emissions as low-income households
- Main drivers of emissions are meat consumption, the number of people living in a household, per capita living space, and particularly air travel
- In addition to individual efforts, politicians should set the course by introducing an animal welfare levy, a ban on short flights, and simplifying housing swaps

Regardless of income, the carbon footprint of private individuals is definitely too large

To reach the two-degree target, only three tons of CO₂ equivalents may be emitted per capita.

From the Authors

“Air travel in particular increases an individual’s carbon footprint and is one of the main reasons why higher-income households have a carbon footprint that is twice as high as lower-income households. A single long-haul flight causes more emissions per capita than housing and food-related emissions in an entire year combined.”

— Sandra Bohmann

Media

Audio Interview with Merve Kücük (in German)

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**ABSTRACT**

Greenhouse gas emissions must be reduced by 65 percent compared to 1990 by 2030 to achieve national climate targets. Nearly one third of greenhouse gas emissions in Germany are caused by private household consumption. Using Socio-Economic Panel (SOEP) data, this Weekly Report calculates the amount of CO2 equivalents emitted by households due to residential energy use, nutrition, and transport in Germany. Consumption in these three areas alone results in average emissions that exceed the emissions budget targeted for private individuals more than twofold, with transport and residential energy-related emissions accounting for the largest share of emissions. Emissions increase as income increases, especially in the area of transport, with air travel as the main driver. Meat consumption is the main contributor to nutrition-related emissions, and household size and building type contribute the most to residential energy-related emissions. By identifying the most significant driver of emissions in each of the three areas, targeted political instruments can be identified, such as simplifying housing swaps and the energy-efficient renovation of residential buildings, banning short-haul flights, and introducing an animal welfare levy.

Human emissions of greenhouse gases such as carbon dioxide (CO2), nitrous oxide, and methane are the main driver of climate change. According to the Federal Environment Agency (Umweltbundesamt, UBA), around 673 million tons of greenhouse gases were emitted in Germany in 2023, ten percent less than in 2022. However, the Federal Climate Change Act stipulates that emissions must be reduced by at least 65 percent compared to 1990 levels by 2030. However, as of 2022, only 40 percent of this reduction had been achieved.

To reduce greenhouse gas emissions more effectively, it is important to understand their primary driver. Policymakers should consider both the reduction potential in industry as well as in private households: After all, around one third of emissions in Germany can be attributed to private household consumption. This Weekly Report calculates and analyzes the average per capita residential energy consumption (housing), nutrition, and transport-related emissions in Germany using individual and household information.

The analyses are based on unpublished preliminary data from the 2023 Socio-Economic Panel (SOEP) survey. We calculate per capita residential energy, nutrition, and transport-related carbon footprint of private households based on respondents’ information on their consumption behavior (Box). First, the carbon footprint of the entire household is calculated. In a second step, the household’s total

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1. To be able to compare the effects of the various climate-active gases on the climate, they are converted into CO2 equivalents. For this purpose, emissions of greenhouse gases other than CO2 are converted into CO2 equivalents according to their global warming potential.
2. Umweltbundesamt, Treibhausgasemissionen sinken deutlich (2024) (in German; available online; accessed on June 11, 2024). This applies to all other online sources in this report.
3. Bundesregierung, Ein Plan fürs Klima (2024) (in German; available online), Umweltbundesamt, Treibhausgasemissionsziele Deutschlands (2023) (in German; available online).
6. Carbon footprints indicate how many tons of CO2 equivalents (tCO2e) one person generates per year. It is a measure of one individual’s impact on the climate, see the DIW Berlin Glossary on the carbon footprint (in German; available online).
emissions are divided by the number of household members, including children.

Greenhouse gas emissions of private households exceed climate thresholds twofold

According to the SOEP survey data, annual per capita emissions in the three areas (residential energy consumption, nutrition, and transport) are around 6.5 tons of CO2 equivalents (tCO2e). Each person in Germany emits an annual average of 0.7 tCO2e through the use of electricity in their home (Figure 1). A further 2.2 tCO2e are due to heating and hot water preparation. Nutrition has an average impact of 1.6 tCO2e, while 2.0 tCO2e can be attributed to transport. Calculations using SOEP data are thus very close to the UBA’s calculations, which are calculated using a different methodology. The values in both calculations are significantly higher than the one to three tons that are—depending on the specific calculation—climate-compatible according to climate experts and the UBA.

Greenhouse gas emissions increase with income

Our calculations confirm that households’ carbon footprint increases as equalized income rises, primarily due to more transport-related emissions (Figure 2). In terms of nutrition and heating, higher-income households tend to have slightly lower per capita emissions. The following sections take a closer look at the composition of emissions in the areas of residential energy, nutrition, and transport, and explain the differences between the income groups using information on all households for which an area-specific carbon footprint was calculated.

Living with others reduces CO2 emissions

Emissions from residential use of electricity, heating, and hot water preparation are considered together below. On average, 2.9 tons of residential energy-related CO2e are emitted per person per year. As people who live together share the use of electricity and heat, the number of people living in a household is decisive for the emissions caused per person.
The type and age of residential buildings also plays a role: and space per person are taken into account. person has no significant effect when the factors of people half of the observed differences in residential energy-related emissions per person rise by 0.022 tCO₂e per year. These two factors alone explain nearly 4.0 tCO₂e per year (Figure 3).

In addition, the carbon footprint of people living in newer buildings is lower. Calculations also show that the use of solar energy decreases the per capita carbon footprint in a household by around 0.7 tCO₂e on average.

Using a linear regression model, we investigate the correlation between various household characteristics and residential energy-related emissions per person (Table). The decisive factor is therefore the number of people in the household. In addition, the living space available per person has a significant, albeit smaller, influence on emissions: For each additional square meter of space, emissions per person rise by 0.022 tCO₂e per year. These two factors alone explain nearly half of the observed differences in residential energy-related emissions per capita. In contrast, the income available per person has no significant effect when the factors of people and space per person are taken into account.

The type and age of residential buildings also plays a role: People living in multiple-family residential buildings with more than four housing units create around half a ton fewer emissions per person than people living in detached single or two-family homes or farming infrastructure (Figure 4). In addition, the carbon footprint of people living in newer buildings is lower. Calculations also show that the use of solar energy decreases the per capita carbon footprint in a household by around 0.7 tCO₂e on average.

Meat consumption affects nutrition-related emissions

Around one quarter of global greenhouse gas emissions can be attributed to food production, in particular from livestock farming, fisheries, and land use. Compared to livestock farming, fisheries, and land use, the carbon footprint of people living in newer buildings is lower. Calculations also show that the use of solar energy decreases the per capita carbon footprint in a household by around 0.7 tCO₂e on average.
Influence of household characteristics on housing-related greenhouse gas emissions

In tons of CO₂ equivalents

<table>
<thead>
<tr>
<th>Reference: Single-person household</th>
<th>Average</th>
<th>95-percent confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-person household</td>
<td>−0.82</td>
<td>−0.91 to −0.738</td>
</tr>
<tr>
<td>Three-person household</td>
<td>−1.15</td>
<td>−1.28 to −1.02</td>
</tr>
<tr>
<td>Four-person household</td>
<td>−1.33</td>
<td>−1.49 to −1.18</td>
</tr>
<tr>
<td>Five+ person household</td>
<td>−1.52</td>
<td>−1.76 to −1.28</td>
</tr>
</tbody>
</table>

Equivalent income (in thousands of euros)

| Constant | 0.01  | −0.004 to 0.02   |
| Square meter per person           | 0.022  | 0.021 to 0.023   |

Observations: 4,056

1 The constant shows the average emissions of a single-person household. Adding the estimated value of the other household sizes to the constant results in the average per capita emissions of each household size.

Note: Linear regression model. The 95 percent confidence interval means that the unknown actual value is within this interval in 95 percent of cases. Therefore, the probability of error is five percent. The narrower the interval, the more accurate the estimated average.

Legend: A two-person household emits 0.82 tons of CO₂ equivalents less than a single-person household. Each square meter of living space leads to 0.02 tons more CO₂ equivalents being emitted per year, and per capita.

Source: Authors’ calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

Based on the respondents’ information on their dietary preferences and weekly frequency of beef, pork, poultry, and fish consumption, nutrition-related emissions are calculated in combination with gender and age as indicators for the respondents’ necessary caloric intake. The diet profiles are assigned to five categories in accordance with the UBA’s CO₂ calculator: vegan, vegetarian, low-meat, a mix of meat and plant-based foods, and high-meat diet. A low-meat diet corresponds to average meat consumption of 50 grams per day, while a balanced meat and plant-based foods diet and a meat-heavy diet refer to daily meat consumption of 165 grams and 351 grams, respectively.


12 Age and gender-specific average weights are used to estimate the calorie requirements of the household members, cf. Statista, Mitteilever von Körpergröße, gewicht und BMI bei Frauen in Deutschland nach Altersgruppe im Jahr 2021 (2022) (in German; available online); Statista, Mitteilever von Körpergröße, gewicht und BMI bei Männern in Deutschland nach Altersgruppe im Jahr 2021 (2022) (in German; available online); Robert Koch Institut, Körpermaße bei Kindern und Jugendlichen in Deutschland (2007) (in German; available online).

People living alone cause more than twice as many greenhouse gas emissions as people in three-person households.

Greenhouse gas emissions from residential energy consumption per person by household size

In tons of CO₂ equivalents, annual average

<table>
<thead>
<tr>
<th>People per household</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.03</td>
<td>2.6</td>
<td>1.9</td>
<td>1.5</td>
<td>1.3</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The height of the columns corresponds to the average per capita emissions due to heating, electricity consumption, and hot water preparation. The vertical black lines show the confidence intervals. This means that the unknown actual value is within this interval in 95 percent of cases. Therefore, the probability of error is five percent. The narrower the interval, the more accurate the estimated average.

Source: Authors’ calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

People living in detached or semi-detached homes have a larger housing-related carbon footprint than people living in buildings with multiple residential units.

Greenhouse gas emissions per person due to heating and electricity consumption by building type

In tons of CO₂ equivalents, annual average

<table>
<thead>
<tr>
<th>Building type</th>
<th>0</th>
<th>15</th>
<th>30</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detached and single-family homes, agricultural buildings</td>
<td>3.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single or two-family row house</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apartment building with 3 to 4 units</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apartment building with 5 to 8 units</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apartment building with 9+ units</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-rise buildings</td>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The horizontal black lines show the confidence intervals. This means that the unknown actual value is within this interval in 95 percent of cases. Therefore, the probability of error is five percent. The narrower the interval, the more accurate the estimated average.

Source: Authors’ calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).
Vegans and vegetarians have the smallest food-related carbon footprint.

and 290 grams, respectively. According to the statistics by the Federal Office for Agriculture and Food (Bundesanstalt für Landwirtschaft und Ernährung, BLE), a declining trend in average meat consumption has been observed in recent years. In 2023, the largest decline was observed in beef consumption, which is particularly harmful to the climate. One percent of SOEP respondents indicate they follow a vegan diet, while 12 percent report following a vegetarian diet. A high number of the latter nonetheless report eating meat or fish occasionally (less than once a month and less than two to three times a week, respectively). The large majority of the German population follows a low-meat diet (47 percent) or a diet with a mix of meat and plant-based foods (42 percent). Around one in ten respondents reports to eating meat products several times a day.

Per capita (including children), the average nutrition-related emissions in Germany are 1.6 tCO$_2$e. A vegetarian diet results in an average of only 1.2 tCO$_2$e per year (Figure 5). People who eat meat less than once a week emit around 1.5 tCO$_2$e on average per year, while people who eat meat multiple times a day emit around 2.1 tCO$_2$e per year.

**One intercontinental flight emits more CO$_2$ than one year of residential energy and nutrition-related emissions**

Transport-related emissions are calculated using household information on car ownership, the fuel type used, use of public transport (short-distance commuting with all public transport types as well as long-distance commuting with trains and buses) as well as the number of domestic, European, and intercontinental flights and cruises taken.

On average, the per capita transport-related emissions are around 2.0 tCO$_2$e per year, about half of which come from car trips. The greatest share of transport-related emissions is due to flights. Emissions from car trips average 1.0 tCO$_2$e per capita. An average round-trip flight within Germany causes 0.24 tCO$_2$e; for the same amount, a person could travel 8,000 kilometers by train.

According to the UBA, a domestic or European round-trip flight emits 0.2 or 0.5 tCO$_2$e, respectively, while an intercontinental round-trip flight emits 4.7 tCO$_2$e. Therefore, there are major differences in transport-related emissions per person depending on if and where they fly. While each person in Germany only flies once a year on average, frequent fliers fly ten or more times per year. People who do not fly at all have a transport-related carbon footprint of around 1.0 tCO$_2$e per capita. An average round-trip flight within Germany causes 0.24 tCO$_2$e; for the same amount, a person could travel 8,000 kilometers by train.

People in the highest income decile (the ten percent with the highest household incomes) emit seven times as much CO$_2$e as people in the lowest income decile in the area of transport (Figure 7). Emissions from car trips vary between 0.3 tCO$_2$e for people in the lowest income decile and 1.4 tCO$_2$e for people in the higher income deciles. At 4.1 tCO$_2$e, flight-related emissions in the highest income decile are around ten times higher than in the lowest income decile at 0.4 tCO$_2$e. The frequency at which individuals in the highest income decile fly intercontinentally results in their emissions being 40 percent higher than the emissions of the ninth income decile.

**Conclusion: Greatest emissions inequality is in transport**

Calculating the greenhouse gas emissions of German households that can be attributed to residential energy consumption, nutrition, and transport showed that there are clear main drivers in each area: For residential energy, it is
CARBON FOOTPRINT

primarily the number of people living in a household that is crucial for the individual carbon footprint. Frequent meat consumption is the main driver of nutrition-related greenhouse gas emissions and flying is the main contributor to transport-related emissions. While the income-related differences are small and higher income groups tend to have lower per capita emissions in the areas of residential energy consumption and nutrition, people from higher-income households cause significantly more emissions than people from lower-income households in the area of transport.

To achieve the goal of carbon neutrality by 2045 as laid out in the Federal Climate Change Act, massive individual as well as political efforts are required: Policymakers must implement and support measures that increase energy efficiency in residential energy consumption, promote environmentally-friendly eating habits, and expand sustainable transport options while reducing the emissions-intensive options. In addition to promoting climate-friendly technologies, their research, and piloting, as well as the economic incentives and accompanying social compensation measures, regulation-based policy instruments also are needed in the transition to a low-carbon economy.

The analyses in this Weekly Report point to a number of policy measures that foster the ecological transition while taking social justice into account. For example, a thermal insulation strategy for the most inefficient buildings could result in the most emissions savings and make low-income households less vulnerable from energy price fluctuations. In addition, using existing housing more efficiently could create major savings in the building sector. One instrument to achieve this would be to simplify housing swaps, as was discussed in the Bundestag in 2023 and as has been enshrined in Austrian tenancy law since 1982. This would not only combat the housing shortage, but also reduce greenhouse gas emissions due to residential energy consumption.

Reducing the number of flights offers the greatest potential for reducing transport-related emissions. The air traffic tax increase effective May 1, 2024, which, if passed on in full to customers, will increase the price of short-haul flight tickets by 15 euros and long-haul tickets by 70 euros, is likely to only have a minor impact on flight demand, especially among the higher income groups that fly more frequently. The French ban on domestic flights over distances that can be reached in 2.5 hours by train, which was implemented at the beginning of 2023 using an environmental protection

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19 Sophie Behr et al., “Thermal retrofitting of worst performing buildings mitigates risk of high heating costs,” DIW Weekly Report, no. 19/20 (2024) (available online).

20 Jusline, Gesamte Rechtsvorschriften MRG (2012) (in German; available online).
clause in European law,\(^{21}\) goes much further in this respect and also provides positive incentives for the expansion of rail transport.\(^{22}\) Although short-haul flights only make up a small share of flight-related emissions, they are particularly damaging, as the most greenhouse gases are emitted during takeoff and landing.\(^{23}\) From a climate policy perspective, it would be even more important to limit the number of long-haul flights via international agreements.

Policy measures aimed at changing eating habits can be viewed skeptically by the public, as cultural habits play an important role in dietary choices. However, according to studies, reducing heavy meat consumption is beneficial to the both climate and our health.\(^ {24}\) The animal welfare levy that was endorsed by the Bundesrat as well as farmers’ associations at the beginning of 2024 would be a step in the right direction.\(^ {25}\) Studies show that quite high approval rates (50 to 70 percent) can be achieved with lower price increases of around 19 cents per kilogram of meat, especially when the increases are linked to animal welfare.\(^ {26}\) Possible slight regressive effects could at least be mitigated by lowering the value-added tax on plant-based foods.\(^ {27}\) Overall, a variety of different measures will be required to reduce the amount of greenhouse gases produced by private households.

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\(^{21}\) Cf. Article 20 of EU Regulation no. 1008/2008 (available online).

\(^{22}\) Zentrum für Europäischen Verbraucherschutz e.V., Frankreich verbietet kurze Inlandsflüge (2023) (in German; available online). Studies show that emissions can be reduced by 95 percent without sacrificing travel time by replacing short-haul flights of up to 400 km with rail travel. The introduction of bans on short-haul flight also reduces the time that a newly built high-speed rail line has to be operated before the greenhouse gas emissions generated during construction are amortized from sixty to ten years. Cf. Anne de Bortoli and Adélaïde Féraille, “Banning short-haul flights and investing in high-speed railways for a sustainable future?” Transportation Research Part D: Transport and Environment, vol. 128, (2024) (available online).


\(^{25}\) Bundesrat, Drucksache 105/21 (2021) (in German; available online).


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