



# Who should waste less?

## Food waste prevention and rebound effects in the context of the Sustainable Development Goals

*The issue of food waste prevention plays a role in global and national policies. Such prevention can reap economic and, in particular, environmental benefits. As our study shows, these environmental benefits are often lost due to indirect rebound effects. Income differences play a crucial role here.*

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#### Abstract

Addressing food waste prevention is one target of the *Sustainable Development Goals (SDGs)* and a major task for the *UN Environmental Programme* and the European Commission. It is promising in terms of its environmental saving potential. However, it also leads to consumers being able to save money, which they then are likely to spend, thus again causing a negative environmental impact. This dimension of the so-called indirect rebound effect, which prevents the desired ecological benefits from being achieved, is investigated in this paper. By using a single-region environmentally extended input-output model from a production perspective, the indirect rebound effects from food waste prevention in Germany are analysed. Any political action needs to consider not only a differentiation in income class, but also alternative concepts such as the principles of sufficiency in order to achieve all ecological benefits and specifically the third target of *SDG 12*.

#### Keywords

food waste prevention, rebound effect, sufficiency, sustainable consumption, Sustainable Development Goals, target SDG 12.3

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Within the framework of the *Sustainable Development Goals (SDGs)*, target *SDG 12.3* addresses one of the major sustainability challenges: food waste. The aim is to “halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses” (UN 2015, p. 22) by 2030. According to the Food and Agriculture Organization of the United Nations (FAO 2014), around one third of food produced each year gets lost or wasted. In total, that makes 1.3 billion tonnes of food waste each year. Food waste means not only an economic loss of 750 billion dollars but also huge environmental impact. 1.3 billion tonnes of food waste have generated emissions of 3.3 billion tonnes of greenhouse gases (GHG), consumed 250 cubic kilometres of water, and taken 1.4 billion hectares of land – these impacts could otherwise have been prevented. The amount of food wasted in developed and developing countries is about the same, though the reasons are different. In developing countries food is mostly wasted within production processes. In developed countries food is mostly wasted at the consumption stage.

Against this background, the *SDG* sets the objective of halving food waste and food losses by 2030. Only few specific *SDGs* have raised such a level of public awareness; inter alia the European Commission has initiated a policy *Platform on Food Losses and Food Waste*, and the *United Nations Environmental Programme* launched its *think.eat.save* initiative. Thus, the process of formulating an *SDG* on food waste prevention can be seen as one of the early key success stories. Nevertheless, it also highlights the specific risks of trade-offs and rebound effects: reducing food waste will lead to cost savings for households (WRAP 2013) and the environmental impacts depend on consumption patterns for this additional budget (Druckman et al. 2011); the risk of rebound effects and a potential backfire has been raised by several studies and its significance has been highlighted by various empirical analyses.

With regard to these rebound effects, our paper addresses a specific research gap and an issue of specific relevance for the integration of environmental and social development goals: does the significance of indirect rebound effects vary between income classes? Which of these effects would constitute new challenges for so-





cially just and environmentally efficient policies in order to achieve the SDGs? Taking the example of Germany and using an environmentally extended input-output model, the paper shows that food waste prevention policies are likely to miss their environmental objectives if the consequences of indirect income-dependent rebound effects are ignored. Against this background, the paper draws conclusions concerning the role of rebound effects as well as of the specific socioeconomic context necessary for the success of policy instruments linked to the SDGs.

## State of research

Generally, the rebound effect describes the relation of the potential ecological savings to the savings that are not realised (Chitnis and Sorrell 2015). Druckman et al. (2011) define the rebound effect with the following equation:

$$\text{rebound effect} = \frac{(\text{potential savings}) - (\text{actual savings})}{(\text{potential savings})} = \frac{\Delta H - (\Delta H - \Delta G)}{\Delta H} = \frac{\Delta G}{\Delta H}$$

The denominator ( $\Delta H$ ) represents the level of reduction of an environmental impact, that is, GHG emissions, which can be expected by a certain measure. These measures, such as avoiding food waste, can result in monetary savings. It is mostly assumed that consumers use the money saved in some other way, for instance, re-spending it on additional goods and services. These goods and services also have a certain environmental impact, which is related to the saved capital. This final reduction of the ecological savings in reference to the initial measure is the numerator ( $\Delta G$ ).

There are different types of rebound effects: the *direct rebound effect* describes a consumer spending the saved capital for the same good. As an example, a consumer can save money due to a technological improvement in his car, operated with fuel. Though, the capital is re-spent on fuel to drive more (Berkhout et al. 2000), an *indirect rebound effect* occurs, when the saved money is spent on other goods and services. Furthermore, there is an *economy-wide rebound effect*. This sums up both the direct and indirect rebound effects. It also includes broader developments such as changes in price (Chitnis and Sorrell 2015).

Recently, a high number of publications have been released concerning the rebound effect, especially regarding energy efficiency measures (Colmenares et al. 2018), though few cover the issue of food waste prevention in private households (Druckman et al. 2011, Bjelle et al. 2018, Salemdeeb et al. 2017). Other authors have focused instead on the effects of a change in diet, that is, consuming less meat, more organic and local food or a shift to vegetarianism (Alfredsson 2002, Grabs 2014). Those papers vary in their underlying assumptions in terms of, for example, methodology, change of consumption patterns, geographical change, and the focus of the respective research field.

For the following investigation, Druckman et al. (2011) is one of the relevant publications. It covers the rebound effects of food waste prevention in private households in Great Britain as one of three changes (food waste, heating, mobility) in consumer behav-

our. Other areas of consumption are considered to be unchanged. The consumer spends the monetary savings on other goods and services or investments. The distribution of expenditure is carried out according to current consumption patterns. The authors applied the *Surrey Environmental Lifestyle Mapping Framework (SELMA)*, a method that they have developed themselves. It embeds a quasi multi-regional, environmentally extended input-output model, which combines life cycle assessment indicators such as GHG emissions with monetary values and is applied through the consumption perspective. The result is the identification of a rebound effect of 51 percent. A scenario analysis shows that it might be even up to 515 percent, which would be a so-called backfire effect.

Another current publication is by Bjelle et al. (2018), who focus on private households in Norway and identify a possible change in lifestyle, that is, a combination of household actions, which aim to achieve a reduction in the carbon footprint. One of the 34 household actions among others like a reduction in business flights, washing at lower temperatures and reduced printing is the elimination of food waste in three scenarios: 1. average, 2. marginal, 3. green. According to the average scenario, the re-spending occurs in the same proportion as current household expenditure. The marginal scenario considers a change in income group and thus in spending pattern due to the additional budget as a result of the household's action. The green scenario takes into account a rise in environmental awareness, which is defined as avoiding categories of products with high emissions when re-spending the initial money. The rebound effects are calculated using the monetary savings and weighted multi-regional emissions-multipliers for Norway from the database *EXIOBASEv2*. The ecological saving potential is 1,020 kilogrammes of carbon dioxide equivalent per household and year. Considering the first scenario, the rebound effect is 78 percent, while the second scenario leads to a rebound effect of 100 percent. The highest ecological savings can be realised in the third scenario, as the rebound effect is 68 percent.

The investigations introduced here offer an impression of the scale of the rebound effects in the field of food waste prevention. However, the decisive characteristics for food waste prevention in private households such as gender, age and most of all income are left aside (Gaiani et al. 2018). These aspects are highly valuable in terms of the design of political actions. Accordingly, the rebound effect for food waste prevention in private households and its dependence on income is investigated within the current work, and was carried out with a focus on Germany.

## Methodology

Here the focus is upon the indirect rebound effect, as avoiding food waste in a private household is assumed to be a conscious change in behaviour. Therefore, the consumer is not expected to re-spend it on additional food. Accordingly, the direct rebound effect can be excluded. The economy-wide rebound effect is left aside, as this is a microeconomic rather than a macroeconomic investigation.



To determine the rebound effects differentiated by income regarding food waste prevention in private households, three components are needed: the savings resulting from food waste prevention, the consumption structure differentiated by income group, as well as the respective environmental impact. Here, the savings of food waste and the consumption structure are measured in monetary values. The environmental impacts are measured in GHG emissions, which are determined by using GHG intensities, which imply the emissions per monetary unit spent on a defined category (UN et al. 2014). Considering the first equation and the components that have been introduced, the calculation of the rebound effects differentiated by income group can be described using the following formula:

$$\text{rebound effect} = \frac{(\text{potential savings}) - (\text{actual savings})}{(\text{potential savings})} = \frac{\sum a_1 * \delta_1 + \dots + a_n * \delta_n}{S * \delta_{\text{food}}}$$

Beginning with the denominator,  $S$  defines the total monetary savings resulting from food waste prevention per household and income group.  $\delta$  describes the identified GHG intensity related to product categories.  $\delta_{\text{food}}$  represents the relative ecological impact of food and nonalcoholic beverages measured in kilogramme of carbon dioxide equivalent per euro. Multiplied by the monetary savings of the prevented food waste, this results in a potential reduction of the total environmental impact. The numerator opposes the ecological impact caused by spending the monetary savings. Therefore, the spending per category ( $a$ ) is multiplied by the respective GHG intensities ( $\delta$ ). In the case of food waste prevention, it must be considered that the numerator categories do not include food and nonalcoholic beverages. This is based on the assumption of a conscious change in behaviour, whereby, due to the assumption of a conscious prevention of food waste, the consumer does not use the monetary savings for food and beverages. Therefore, the related GHG intensity is only used in the denominator. Beverages are defined only as nonalcoholic, because alcohol is not necessary for nutrition and is considered a luxury good. It thus belongs in one category with, for example, tobacco. The result of the equation is a percentage figure, which implies how much of the potential reduction of environmental impact cannot be realised. If the figure is above 100 percent, it constitutes a so-called backfire effect: in total, the corresponding measure leads to a higher degree of environmental impact (Santarius 2015, p. 49).

The focus is on the absolute monetary savings as the subsequent calculations are based on data on absolute income and expenditure. The total monetary savings in Germany are estimated to be between 19 and 25 billion euros (Hafner et al. 2012, p. 18, Cofresco 2011, p. 6). On average, the monetary savings is 530 euros per year and household. It was assigned to the fifth of the eight income groups, because the fifth income group includes the median household income. The median was considered, as there is no uniform distribution of household income. It was calculated using the distribution of the number of German households differentiated by income group as published by Destatis (2015, p. 32, line 2). The data do not allow a more accurate determination without breaking up the intervals and thus assuming a distribution of

**TABLE 1:** Assumed monetary savings from food waste prevention per household and year differentiated by income group. In the light of the potential absolute monetary savings in Germany (19 to 25 billion euros), the average monetary savings per year and household is 530 euros. It was assigned to the fifth income group, which includes the median household income, and equals 17 percent of the entire expenses for food per year. Accordingly, the monetary savings of the other income groups are determined by multiplying 17 percent with the specific annual expenses for food. Data source income group and expenses: Destatis (2015, p. 32, lines 2 and 4).

INCOME GROUP: NET INCOME/MONTH [EUR]	EXPENSES FOR FOOD/ NONALCOHOLIC BEVERAGES [EUR/YEAR]	MONETARY SAVINGS [EUR/YEAR]
1 <900	1,668	279
2 900–1,300	2,016	338
3 1,300–1,500	2,316	388
4 1,500–2,000	2,652	444
5 2,000–2,600	3,168	530
6 2,600–3,600	3,816	639
7 3,600–5,000	4,584	767
8 5,000–18,000	5,592	936

income within each income group. The relative monetary savings of 17 percent of the fifth income group form the basis for the calculation of the monetary savings of the other income groups, which is shown in table 1. The 17 percent were multiplied with the yearly expenses for food and nonalcoholic beverages per income group (expense data taken from Destatis 2015, p. 32, line 4). By using the relative instead of the absolute monetary savings of the fifth income group, higher income groups have higher absolute monetary savings than lower income groups. This distribution across the income groups is verified by further studies, which prove that high-income groups waste more than low-income groups (Gaiani et al. 2018). Taking the monetary savings and number of households per income group, the total monetary savings in Germany according to the assumed distribution is 23.4 billion euros, which is in the range of the results from Hafner et al. (2012) and Cofresco (2011). In comparison, the assignment of average savings according to average income, that is, to the sixth income group would result in relative savings of 14 percent. The total monetary savings for Germany (19.4 billion euros) would be lower, but also within the earlier named interval.

In the next step, the consumption structure was prepared for further calculation. The data, taken again from Destatis (2015, pp. 32 f.), include the consumption structure of German households differentiated by 70 COICOP (Classification of Individual Consumption by Purpose) product categories which are used to estimate the spending per category ( $a$ ). The relative distribution is used based on the assumption that the consumption structure does not change, excluding the category of food and nonalcoholic beverages. The assumption is based on the potential monthly savings in relation to the monthly expenditures (Destatis 2015, p. 33, line 71). Food waste prevention saves one to three percent of monthly expenditures, which may even go unnoticed by those



households. However, this point of the discussion will be covered later on.

The GHG intensities are calculated by setting a monetary input-output table in relation to a table of GHG emissions of the German economy in 2013 (Destatis 2018). A single-region environmentally extended input-output model from a production perspective is then applied. One of the main assumptions resulting from the concept is that Germany is considered a closed economy. Therefore, imports and exports are left out. The following equation describes the approach (UN et al. 2017):

$$\delta = r * \hat{q}^{-1}$$

As already mentioned above,  $\delta$  describes the intensity of environmental impact per production segment, that is, GHG intensities measured in kilogramme of carbon dioxide equivalent per euro. It is the result of multiplying the vector of GHG emissions per production segment ( $r$ ) and  $(\hat{q})^{-1}$ . The latter is attained by diagonalising  $q$  – the vector of output per production segment and forming its inverse.

The data sets used for the final calculation were modified, as they are categorised according to two different classification schemes. The GHG and monetary input-output tables are structured according to CPA (Classification of Products), while the consumption structure is classified according to COICOP. The CPA is rather industry focused and is not compatible with the consumption focused COICOP. As there is no standardised procedure for transferring, an allocation matrix was developed using approaches of, for example, the Office for National Statistics (2013). Further information about the market structure of industries such as the construction and oil industry were taken from the annual reports of sector associations (ZDB 2017, MWV 2017). The matrix implies to what extent for example the textile industry (CAP) is distributed to the clothing, home textile and furniture categories (COICOP). The final data were categorised according to the COICOP classification with a differentiation of 48 categories as some subcategories had to be set aside. In addition, the monetary unit of the input-output table was changed from production price to purchase price.

The chosen methodological approach has limitations due to its so-called production perspective. Germany is considered a closed economy as the impacts are assigned to the producers and the related territory, that is, Germany. Therefore, imports and exports are ignored. By contrast, a consumption perspective allocates the environmental impacts of the entire production process of a product or service to its consumer. In this way the complete upstream chain and interdependencies between countries are included and the impacts are fully calculated (Druckman et al. 2011). Due to the production perspective, the assumptions in our study result in lower absolute impacts. However, the production perspective is more suitable for evaluating national measures due to a lower complexity. When choosing the production perspective, it must be considered that the impacts are based on the national technological and sector-specific circumstances. In terms of food, it means that the characteristics of German agriculture – shaped by the climate damaging production of meat and dairy products with an export sur-

plus (Hirschfeld et al. 2008), predominate the indicators. At the same time, imported goods are left aside, such as feedstuff. Nevertheless, the production perspective is effective for displaying changes achieved by policy measures on a national level.

In addition, including a more precise differentiation regarding, for example, the ecological assessment of food waste by income is impossible due to a lack of primary data. For instance, the composition of food waste and the relation between food buying behaviour and income in Germany should be investigated. The former influences the GHG intensity of food waste and the latter its quantity. Both aspects influence the environmental saving potential.

Lastly, the research gap in the field of changes in consumption pattern should be mentioned. Here, the subsequent consumption structure is considered as unchanged. That the monthly monetary savings is unnoticed might be true for high-income groups, but is unlikely for low-income groups as they still focus on the necessities. The prevention of food waste might correlate with green consumption patterns as mentioned by Bjelle et al. (2018). It might lead to the savings being spent on more expensive food and goods, thus lowering the rebound effect. In addition, the consumer might even spend the monetary savings on GHG-intensive products due to the “psychological rebound”, which further increases the rebound effect (Santarius 2015, pp. 115 f.). Moreover, the change in consumption pattern might also be related to income resulting in various changes. In conclusion, a deeper understanding of change in consumption regarding sustainability is required.

## Results and interpretation: the relation between indirect rebound effects and income groups

Our investigation shows: in Germany, less than half of the potential reduction of environmental impact can be realised. Considering the German-wide effect of food waste prevention, the environmental impact of food could be reduced by around 7.3 million tonnes of carbon dioxide equivalent per year. However, according to our estimates the re-spending of the monetary savings is related to an impact of 4.2 million tonnes of carbon dioxide equivalent per year. Therefore, an impact of only 3.1 million tonnes of carbon dioxide equivalent per year could be prevented. This results into an average rebound effect of 56.9 percent. The average value is used to show the plausibility of the investigation, which has the same scale as the results of Druckman et al. (2011) and Bjelle et al. (2018).

Focusing on the household level, the rebound effect varies depending on the income group. The reasons are differences in the consumption structure per income group and in the GHG intensities of the 48 COICOP product categories defined in our study. The consumption structure of the low-income group is related to a higher GHG intensity compared to the high-income groups. Considering the first income group, 30 percent of the income is spent



**TABLE 2:** Rebound effects and ecological savings per household and income group per year. With a growing income, the potential environmental savings increase, the environmental impact of re-spending rises, and the rebound effects decrease. The values of the potential ecological savings, the impact of re-spending, the actual savings and the rebound effect are based on the above-calculated greenhouse gas intensities, the monetary savings and relative consumption patterns. Data source: consumption patterns (Destatis 2015, pp. 32 f.), greenhouse gas intensities (Destatis 2018), own calculations as described in the text above.

INCOME GROUP: NET INCOME/MONTH [EUR]	MONETARY SAVINGS [EUR/YEAR]	POTENTIAL SAVINGS [KG CO <sub>2</sub> EQ/YEAR]	IMPACT OF RE-SPENDING [KG CO <sub>2</sub> EQ/YEAR]	ACTUAL SAVINGS [KG CO <sub>2</sub> EQ/YEAR]	REBOUND EFFECT [%]
1 <900	279	87	66	21	76
2 900–1,300	338	105	73	32	70
3 1,300–1,500	388	120	79	41	66
4 1,500–2,000	444	138	86	52	63
5 2,000–2,600	530	165	101	64	61
6 2,600–3,600	639	198	115	83	58
7 3,600–5,000	767	238	130	108	54
8 5,000–18,000	936	290	136	154	47

for the five product categories with the highest GHG intensity, which include, for example, energy used for heating, transportation services, food and beverages as well as fuel (figure 1). Households of the highest income group spend only 22 percent on those categories. Regarding the five product categories with the lowest GHG intensity, low-income households spend five percent on them compared to the highest income group, which spends twelve percent. The product categories with the lowest GHG intensities are services for education, culture and leisure time, housekeeping and healthcare. Generally, the spending pattern results in a higher GHG intensity of the re-spending for the low-income groups and thus in a higher rebound effect (table 2).

The rebound effects per income groups are between 47 percent and 76 percent. The highest income group has the lowest

rebound effect and realises most of the potential environmental saving. Generally, the total environmental impact of re-spending rises with the income. However, this increase is lower than the rise of the potential environmental savings. Thereby, the rebound effects decrease with a growing income.

In addition, the findings in terms of the consumption pattern and its related GHG intensity confirms Chitnis et al. (2014): low-income groups spend more on GHG intensive “necessities” such as food, drink and domestic energy. Spending a higher share on necessities generally increases the indirect rebound effects of low-income groups as it effects the re-spending in the same way. While thinking about the distribution of environmental impact of the respective consumption structure, the higher absolute impact of the higher income groups must be considered.

**FIGURE 1:** Fuel has one of the highest greenhouse gas intensity and hence leading to a high indirect rebound effect, when it comes to spending monetary savings from food waste prevention.



These aspects are also represented by figure 2 (p. 124). The dark and light green area together demonstrates the increasing environmental saving potential per household and income group, which could be realised by food waste prevention. The light green area shows the environmental impact caused by the re-spending of the monetary savings. The dark green area illustrates the actual environmental savings a household could achieve in the respective income group. The exponential increase also implies the decrease in rebound effect. Figure 2 illustrates that the higher income groups have the higher potential to contribute to the reduction of environmental impacts through food waste prevention.

A general specificity of eliminating food waste in households is the characteristic of sufficiency measures (Chitnis et al. 2014): it doesn't go along with any costs for households to take such actions. This means that





the monetary savings for re-spending is not reduced by an investment and the indirect rebound effect is higher. For comparison, striving for an energy-efficient home is related to investing in, for instance, light bulbs and insulation. Thus fewer savings can be spent on other goods and services, while eliminating food waste causes only indirect rebound effects, as no savings are re-spent on food. However, considering a higher environmental awareness in terms of food could reduce the rebound effect. If consumers eliminated food waste and bought organic food that cost more, the monetary savings would be reduced and thus in turn the rebound effect.

## Conclusions

Currently the European member states have been obliged to develop national waste prevention programmes, while the effect of food waste prevention on consumption levels should be focused on, as it is one of the *SDGs*. The German government addresses food waste on the consumer level through a communication campaign to support waste-free shopping. Our investigation of rebound effects in relation to the income groups shows that solely addressing food consumption patterns lacks the possibility of realising the potential GHG emissions reduction resulting from food waste prevention. To achieve the highest reduction through the German government campaign, the target group should be the high-income classes. As shown above, the potential environmental savings are higher, and the rebound effect is lower than those of the low-income groups due to the different share of expenditure on necessities. Looking at the potential environmental savings and the number of households per income group, 77 percent of the German-wide environmental saving potential is related to the four highest income groups.

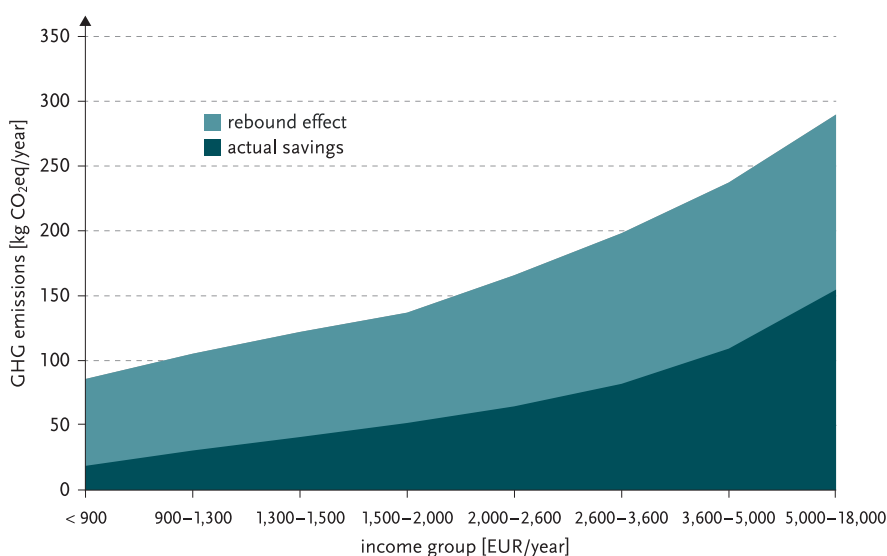
To realise a growing reduction of environmental impact through food waste prevention, the rebound effect must be lowered. This

can be achieved by accomplishing a change in the consumption structure. Therefore, it needs a shift from product categories with high GHG intensities to those with low GHG intensities as shown by Bjelle et al. (2018). The GHG intensity must be the decisive criterion for purchases. It also requires knowledge and a conscious change in behaviour by the consumer. Even if a shift in consumption to product categories with low GHG intensities is achieved, the potential environmental reduction would not be realised. The rebound effect cannot be lowered to zero as all product categories have some GHG intensity, that is, cause some environmental impact. Against this background, the results also underline the need for stringent policy instruments that internalise these impacts into market prices for environmental goods, for example, a carbon tax or an even more comprehensive resource taxation (Bahn-Walkowiak et al. 2007).

A solution for benefits to be felt from the entire environmental saving potential through food waste prevention in households is its alignment with the concept of sufficiency. This contains the idea of “having enough” and understanding the fulfilment of one’s own needs (Schneidewind et al. 2013, Sachs 1993). Specifically with regard to the necessary transformation of our food system, successful policy mixes should steer consumption towards more ecological products of a higher quality such as regional and organic food instead of additional goods and services.

Halving food waste is indisputably a crucial target but it raises specific challenges. Only a combination of improved efficiency alongside the food value chain, dietary changes towards less meat-based and at the same organic food in combination with institutional frameworks that internalise environmental costs into the price of food will lead to actual progress towards sustainability. Only such a comprehensive strategy will allow the realisation of a targeted reduction of environmental impact from food waste prevention and this should be communicated to consumers.

Such an approach would not only support target *SDG 12.3* but further *SDGs* would also benefit from a more comprehensive con-



**FIGURE 2:** Potential environmental savings resulting from food waste prevention per household and year differentiated by income group. Actual environmental savings (dark green) and rebound effect (light green) together represent the potential environmental savings. The rebound effect decreases with increasing income. The higher income groups realise the highest ecological savings. The graph shows exponential increases rather than linear ones.



sideration of indirect rebound effects. Food waste prevention can be seen as an example that the consistency of sustainable policy mixes and thus their impact will depend on an in-depth understanding of consumption patterns that goes beyond the “average consumer”. An increased effectiveness of policy instruments aiming at reduced food waste generation and resulting environmental burdens seems to depend on considering behavioural aspects that differ between income classes. Against this background it will require taking into account the specific socioeconomic context of consumption behaviour in order to avoid rebound effects and to design policy instruments that actually enable and support the fundamental transformation towards sustainable consumption patterns – additional research will be necessary, especially for the SDGs related to waste generation that so far often focus on technological or industry-driven approaches.

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