Energy saving measures and their distributional effects – a study of households in Germany

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Abstract
We evaluate the distribution of selected energy saving potentials at the household level as identified in an ongoing project for the German Federal Environment Ministry , including measures related to behavioral change (e.g. reduction of hot water use) and lifestyle changes (e.g. less frequent air travel).

The core of our paper is a distribution analysis to assess how savings potentials both in physical and monetary terms are distributed across households or household characteristics. The final goal is to understand in how far financial incentives may play a role in triggering energy savings and which household groups (target groups) would be most promisingly and fairly targeted when designing policy measures.

The analysis is based on the German Income and Expenditure Survey, an administrative data source published by the German Statistical Office. It contains detailed information on income sources, expenditure patterns and on other household characteristics, such as social status and type of household.

The analysis reveals that for measures that affect all households uniformly (e.g. reduction of hot water use), absolute savings in kWh are often highest for high income households, while monetary savings relative to household income are higher in lower income households. This is due to the fact that low income households spend a relatively lager share of their income on energy. For some measures the picture looks different. Measures in the area of mobility, for example, concern mainly higher income households and both absolute energy savings and (relative) monetary savings are thus higher in this group.

For the average household, however, monetary savings turn out to be rather small in relation to household income. Moreover, physical and relative monetary savings can be negatively correlated – that is, those households with the highest energy saving potentials have the lowest (relative) monetary gain. Thus, the highest absolute reduction potentials may be most difficult to reach as they occur in households that are least likely to appreciate related financial savings. This underlines the general challenge associated with energy savings measures. For most households, we expect that monetary savings associated with the measures investigated in this paper do not provide sufficient incentives to change behavior and/or lifestyles. They will need to be complemented with policies and measures that specifically address barriers and provide additional motivation for specific target groups to implementing these potentials.

Introduction
The German "Energy Concept" (2010/2011) outlines ambitious goals for energy savings across the German economy: 20 % of primary energy are to be saved in 2020 as compared to 2008, rising to 50 % in 2050. Sub-goals for buildings, electricity and transport are also inscribed. Realizing that these goals will not be achieved without providing external incentives or stimulation, a number of policy measures and instruments have been identified by the German government in its National Energy Efficiency Action Plan and its Climate Action Programme 2020, which were publicly announced in December 2014. Both action plans tackle the time period until 2020 and measures are to be implemented in due time. With regards to energy consumption both action plans have in common that they primarily focus on energy efficiency improvement, addressing

technology improvement and better performance with lower specific energy use. It is envisaged that this implies cost savings, new markets for innovative efficient products, increased competitiveness, job creation, whilst guaranteeing current use and performance patterns. As an example, the national plans/programmes cover a vast range of measures to tackle savings potentials in the area of housing, focusing on energy efficiency improvements via insulation, better heating technology, and more efficient implementation of existing programs to stimulate these activities.

Little attention is given in these action plans to the potential of changes in individual behavior. Individual behavior seems to be understood as a rather "unbending" personal choice based on individual preferences, which are hard to alter and therefore could only contribute marginally to energy savings. However, as argued in this paper, individual behavior has the potential to play a much larger role and changing behavior could realize large potentials for reducing energy consumption. Reaping these potentials requires both a broader understanding of what individual behavior is and comprises, and a clearer picture of its dynamics and environment. To tackle this further, the Federal Environment Ministry has commissioned a research project that explores possibilities for reducing energy demand via behavior-related measures in individual households. The project applies a broad concept of individual behavior including investment behavior, usage behavior (e.g. reduction of hot water use, reduction of room temperature, more efficient use of appliances) and lifestyle changes (e.g. less frequent air travel, telemeeting, reduction of living space). The project tries to develop an understanding of the various ways in which this behavior is embedded and shaped. It takes a deeper look into which households (or groups) show the highest potentials for reducing energy consumption through individual changes, how physical and monetary savings are distributed across household groups and how these groups might be reached.

The core of our current paper is a distribution analysis to assess how savings potentials both in physical and monetary terms are distributed across households or household characteristics. In order to determine which households are most affected by a specific savings measure, we use additional information on the target group of each of the measures and on the households within this target group that would be most affected. For the purpose of the distribution analysis, households are assigned to different groups according to net household income[1], social status of main income earner[2], number and age of household members (household type).

The final goal of our paper is to reveal insights about which measures might be given higher priority to efficiently tackle potentials and how policy instruments might be designed to reach specific target groups. We focus on two questions: In how far do financial incentives play a role in triggering energy savings? And which household groups (target groups) would be most promisingly and fairly tackled when designing policy measures?

The remainder of this paper is organized as follows: First, we provide some background information on the distribution of energy consumption across households in 2014. This is followed by a presentation of several reduction potentials that have been identified for the years 2020 and 2030. In the next section, we evaluate the distribution of these reduction potentials across households via the distribution analysis, followed by a discussion of the results and subsequent conclusions that we draw to inform policy makers and researchers.

Distribution of household energy consumption in 2014

Before we look into reduction potentials of specific measures, it is helpful to get an understanding of the state-of-the-art distribution of energy consumption at the household level. We use data from the German Income and Expenditure Survey (EVS) to show the current distribution of energy consumption. The EVS is an administrative data source and contains detailed information on income sources and expenditure patterns of households, as well as information on other household characteristics, such as social status and age of the household members. The survey is the largest of its kind in Germany covering about 60,000 households and is published every five years. Households are observed for one quarter reporting individual income and household level expenditures. The EVS is statistically representative for all of Germany.[3]

Table 1 shows energy consumption in 2014 by **income group**. Generally, we observe that absolute energy consumption increases with income (e.g. consumption of electricity, heating energy, motor fuels). Moreover, we observe that the relative difference in consumption between poor and rich households increases continuously from electricity use over heating fuels to the consumption of motor fuels. Households in the lowest income decile use about 70 % of average electricity consumption (2,327 kWh p.a. out of an average of 3,367 kWh p.a.) and only half of the amount that households in the highest income decile use (4,204 kWh p.a.) while for motor fuels lowest income households consume less than one quarter of average motor fuel consumption and only less than one seventh of the consumption in the highest income decile. This indicates that flexibility in consumption is low for electricity, as it provides more of a basic need, while flexibility of consumption is substantially more pronounced for motor fuels. In terms of policy implications, these flexibility and use patterns imply that financial incentives (e.g. taxes) might be effective for motor fuels while they would not be as effective for electricity. The extent depends on the actual responsiveness to price changes, i.e. the elasticity of demand. This distribution also implies that financial incentives that would increase the price of electricity are expected to put a relatively higher burden on lower income households and have a regressive effect, whilst the result for motor fuels may be different, since lower income households use relatively less (see also below). Taking a deeper look into household energy

1. We use net equivalent household income which corrects for different household settings. The main salary earner is weighted fully while other household members at the age of 14 and more receive a weight of 0.5 and children younger than 14 a weight of 0.3 (new OECD scale)

2. The head of household is usually considered the main income earner. Social status refers to employment status such as self-employed, civil servant, worker, employee, unemployed, retirees, student or non-working.

3. It should be noted that households with income of more than €18,000 per months are not included in the statistics, neither are people who live in homes or institutions. So the representation at the margins of the income distribution might be limited.

consumption by social status of the main income earner reveals that students, unemployed and non-working households have the lowest energy consumption[4]. Very high energy consumption can be detected for households whose main breadwinner is either self-employed or a civil servant. Noteworthy, retirees show a particular high consumption of heating energy compared to their total energy consumption (and independent of their income). This may have several underlying causes, including time spent at home, comfort temperature levels, but also the state of the dwelling in terms of insulation.

Energy consumption in 2014 by **household type** is shown in Table 2. As would be expected larger households with many members use more energy than smaller households. However, significant scale effects can be observed once a household exceeds two members, meaning that the energy consumption increases less than proportional for any third or additional household member. The reason for this is that basic household equipment can be shared by all household members without increasing energy consumption (e.g. refrigerators are large enough to store food for all household members, room temperature keeps everybody warm). The scale effect applies to households with children (here the increase per child is even lower) as well as other households with three adults and more. Interestingly, the scale effect is quite limited between one and two person households, and for those can only be detected for electricity consumption. This implies that small households (1–2 persons) use relatively more energy. Considering current demographic development towards smaller households in larger homes, this fact highlights a potentially challenging development that may make it harder to realize energy savings in the future. Specific appliances or settings to meet the needs of small size households or, alternatively, incentives to live in larger size households (e.g. senior citizen home/flat shares) will be needed. Another insight from the distribution by household type is that male singles show considerably higher demand for motor fuels than female singles while female singles consume more energy for space heating. This already indicates that a careful distinction of target groups may be needed for specific measures.

Identified reduction potentials for 2020 and 2030

Information on reduction activities/measures and their potentials used within this analysis stems from the above mentioned ongoing research project on national energy savings measures. Within the research project possible behavioral energy saving measures were screened based on a literature review and expert judgment. Subsequently a short-list of 18 measures was arrived at which were investigated in more detail in terms of savings potential, induced behavioral change, economics, political feasibility and attention previously given by energy policies and measures. Only savings potentials were considered that were supposed to be additional to those already envisaged in other scenarios, namely the study “Politikszenarien für den Klimaschutz” (Matthes et al. 2013). Savings potentials were calculated for the years 2020 and 2030.The assessment led to a clustering into four profiles: measures which show high potential, are easy to implement and have not been given much attention in the past (priority measures); measures with high potential, challenges in implementation and little attention so far (perspective measures); measures with high potential, but which have already been well addressed by policies already (implemented measures); and measures with low potential (low priority measures). Consequently, we selected twelve measures of the first two profiles (priority measures and perspective measures) for the economic analysis, which consisted of an assessment of GHG abatement costs and the distributional analysis[5]. Most of the selected measures were sufficiency measures because it turned out that efficiency measures had already been considered in existing scenarios and did therefore not have additional potential. In that sense, our study provides an exploratory analysis of potentials not considered to date. For our distributional analysis only those measure could be considered that distinguish savings by energy carrier. This information is important, since it allows us to take into account the differences in the usage of energy carriers between households. Furthermore, when calculating monetary savings, we have to take account of the fact that (projections of) prices vary significantly by energy carries. This means that no measures regarding changes in diet could be considered for the distribution analysis. The twelve measures are described below.

Measures in the area of housing:

- Reduction of living space: Baseline projections reveal that per capita living space will increase from 38.8 m^2 in 2008 to 45.1 m^2 in 2030 (Matthes et al. 2013). In our analysis, we assess a policy induced change of a limited increase in per capita living space to 42 m^2 until 2020 and a reduction to 40 m^2 thereafter until 2030.
- Reduction of hot water use: We assess a reduction of average hot water use by 10 % (from 45 l/d per capita to 41 l/d) induced by behavioral change, such as taking showers instead of hot baths, taking shorter showers etc., and a reduction of the average hot water temperature by 2 K[6] (while at the same time initiating a program to protect from legionnaire’s disease).
- Reduction of room temperature: We assess an average reduction of room temperature by 1 K. The potentials are derived by differentiating between energy-refurbished buildings and unrefurbished buildings (the latter are assumed to use 90 % of final energy for heating in 2020 and 75 % in 2030).
- Insulation of heat distribution: We assess an average savings potential of 3 % of final energy use for heating in buildings in 2020 and 1.5 % in 2030.
- Investment in automation: Referring to measures which control, monitor, optimize and help using central heating and cooling devices and lighting, we assess an average energy savings potential through automation of about 4 % for heating and hot water use in residential buildings.

4. The results table is not shown here due to space limitations and to not overload the presentation.

5. More information on the identification and selection process of measures is available from the authors and will be discussed in the forthcoming research report.

6. A reduction of 2 K is equivalent to a reduction of 2 °C.

Table 1. Household energy consumption 2014 by income group.

Decile net Equivalent household income1)	Net equivalent household income		Electricity use			Heating energy					Motor fuels			
	Average	highest income (percentile)	Electricity	Elec. for night-storage heating	Total	Nat. gas	Heating oil	Coal	District heat	Total	Gasoline	Diesel	Aviation fuel	Total
	Euros per month		kWh p.a.			kWh p.a.					kWh p.a.			
Below 5%	686	855	2 087	241	2 327	2 810	1 576	270	1 653	6 309	1 866	148	218	2 232
1st decile	812	1 043	2 130	213	2 343	3 171	1 576	208	1 816	6 771	2 194	159	269	2 622
2nd decile	1 193	1 329	2 559	315	2 874	4 654	2 509	282	1 761	9 207	4 084	554	483	5 121
3rd decile	1 441	1 552	2 778	291	3 069	5 469	3 154	318	1 627	10 568	4 978	871	960	6 810
4th decile	1 659	1 771	2 944	268	3 212	5 726	4 315	342	1 411	11 795	5 517	1 404	1 083	8 004
5th decile	1 883	1 994	3 038	313	3 351	6 551	4 796	306	1 204	12 857	5 781	1 917	1 302	9 000
6th decile	2 116	2 244	3 218	355	3 573	7 042	5 050	398	1 113	13 603	6 217	2 454	1 723	10 394
7th decile	2 396	2 564	3 276	395	3 671	7 520	5 186	409	858	13 973	5 791	3 559	1 880	11 230
8th decile	2 773	3 021	3 501	290	3 791	7 963	6 544	445	872	15 823	5 830	4 349	2 145	12 324
9th decile	3 386	3 854	3 629	366	3 995	8 899	6 558	448	798	16 704	5 484	5 362	2 834	13 679
10th decile	5 385	.	3 805	399	4 204	9 690	6 665	392	990	17 737	5 857	5 760	4 427	16 044
Average	2 252	.	3 051	317	3 367	6 532	4 506	349	1 272	12 660	5 063	2 531	1 657	9 252

[1] *Equivalence weighted with new OECD scale for population in private households. Source: Micro simulation analysis based on German Income and Expenditure Survey (EVS) 2008 (80 % scientific use file by the research data centers of the German Federal and Länder Statistical Offices). Extrapolated to 2014.*

Table 2. Household energy consumption 2014 by household type.

Household type	Number of households	Electricity use			Heating energy					Motor fuels			
		Electricity	Elec. for night-storage heating	Total	Nat. gas	Heating oil	Coal	District heat	Total	Gasoline	Diesel	Aviation fuel	Total
	in 1000	kWh p.a.			kWh p.a.					kWh p.a.			
Singles (female)	10 191	1 925	262	2 187	4 027	2 625	122	1 629	8 403	3 224	141	1 050	4 415
Singles (male)	6 213	1 959	270	2 229	3 812	2 295	197	1 153	7 457	4 657	627	1 114	6 399
Single parents	1 350	2 871	393	3 263	5 254	2 468	274	1 469	9 465	4 761	856	767	6 384
Couples without children	12 090	3 402	384	3 786	7 737	6 123	406	1 270	15 535	6 231	2 600	2 438	11 269
Couples with one child	2 501	3 797	238	4 035	7 429	4 354	504	934	13 221	6 980	4 720	1 304	13 004
Couples with two and more children	3 252	4 513	282	4 795	10 366	5 560	623	849	17 399	3 754	9 429	1 658	14 840
Other	4 810	4 636	369	5 005	9 627	7 224	637	1 083	18 572	6 524	4 552	2 117	13 193
Total/average	40 406	3 051	317	3 367	6 532	4 506	349	1 272	12 660	5 063	2 531	1 657	9 252

Source: Micro simulation analysis based on German Income and Expenditure Survey (EVS) 2008 (80 % scientific use file by the research data centers of the German Federal and Länder Statistical Offices). Extrapolated to 2014.

Measures in the area of mobility:

- Modal shift from car to bike: We assume a potential for shifting from car use to biking of 40 % for distances below 5 km, 30 % for distances between 5 and 10 km, 20 % for 10–15 km, 10 % for 15–20 km and 0 % for longer distances. This includes the use of electric bikes (about 50 % is shifted to Pedelecs), and carrier bikes. Given these assumptions, 6 % of car mileage would be avoided by 2020 and 10 % by 2030.
- Tele-meetings: It is assumed that about 20 % of work related travel can be saved via tele-meetings in 2020 and 30 % by 2030. Further, we assume that avoided work travel i) is distributed evenly across all modes of transportation (air travel, train, and car), ii) affects short and long distance travel equally (which might be a rather conservative assumptions given that longer distances might more likely be replaced), iii) concerns air travel in a way that about 30% of air travel kilometers are related to work trips.
- Purchase of smaller size cars: We assume that in 2015, 10 % of new car purchases are smaller size cars and that this increases by 10 percentage points each year, resulting in 60 % smaller size new car purchase in 2020. On average, specific energy use will be lower by 7.5 % in 2020.
- Reduction of private air travel: We assess the effect of cutting down on private air travel by 50 % in 2030. This does not imply that vacation time by air travel is generally reduced but that, for example, one longer trip might replace two short ones. This is contrary to current trends shifting from an average travel time of 11 to 10.3 days between 2005 and 2012 (DRV, 2013), and results in a reduction of private air travel by 30 % in 2020 and 50 % 2030.

Measures in the area of equipment and ICT:

- Reduction of multiple endowment with equipment or appliances: We assess the effects of reducing multiple use of the same kind of appliances, in particular TVs and refrigerators/freezers. It is assumed that only one TV and one refrigerator/freezer is used per household, compared to a baseline of about 1.53 for TVs (2020 and 2030) and 1.65 refrigerators/freezers in 2020 (1.72 in 2030).

- Absolute energy consumption limit for equipment: This measures aims to stop the trend of increasing the size of equipment which counterbalances the efficiency gains. We use the examples of TVs and assume that no TV consumes more energy in absolute terms than a medium sized TV (DEESY, 2013). The number of projected TVs in private households by size up to 2030 is taken from DEESY (2013).
- Change in use pattern: We assess a change in use patterns for two appliances, clothes dryers and TVs. With respect to clothes dryers, we assume that their use is reduced to 8 out of 12 months per year compared to a permanent use pattern. With respect to TVs, we assume that TV consumption is cut by 50 % (2 instead of 4 hours on average per day).

Measures/activities in the area of housing commonly affect the use of electricity, natural gas, heating oil and district heating (long and short distance), with the savings potential being highest for natural gas. In 2020, the measure "reduction of room temperature" has the highest total potential. In the area of mobility, measures affect the use of gasoline, diesel, aviation fuel and to a smaller extent electricity and biogas. In the area of equipment and ICT, reduction potentials only apply to electricity use. The potential of reducing multiple equipment endowment, in particular refrigerators and TVs, is highest of all the measures in this area. An overview of the measures/activities and their savings potentials by energy carries is shown in Figure 1.

The measure "reducing living space" reveals the largest savings potential. However, it is assumed to only be effective from 2030 on (compare Figure 1). Simultaneously, savings potentials for the other measures increase significantly over time, most prominently in the area of mobility for the measures reduction of air travel whose savings potential almost doubles. It is noteworthy that for a few measures savings potentials are lower in 2030 than in 2020. This might be the case if new and efficient equipment is used so that a change in user behavior is not as effective as for older and less efficient equipment. Similarly, the measures "insulation of heat distribution" is less effective in more efficient buildings in 2030 than in 2020. Such effects – as well as potential interaction of effects – is important to keep in mind. It also means that savings potentials cannot simply be added up as this might imply double counting.

It should be noted that information on expenditure for aviation fuel is not directly available from the German Income and Expenditure Survey. However, we derive this based on information on expenditure for individual air and package holiday travel available from the EVS and on the use of aviation fuel as reported in the German energy balances.

Evaluating the distribution of reduction potentials

To arrive at distributional effects of these energy savings activities we assign savings potentials to households proportional to their respective energy consumption. In many cases, we use additional, specific information on which households might

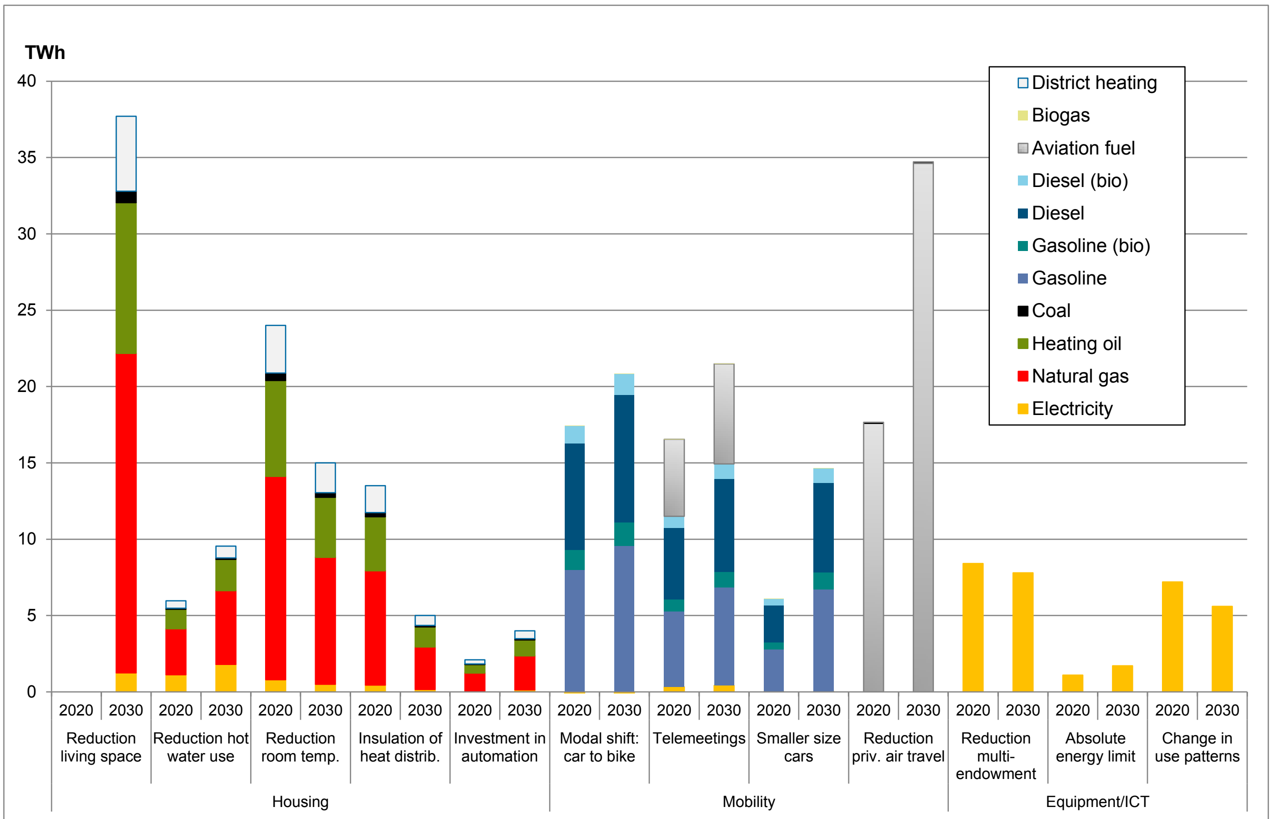

Figure 1. Energy savings potentials by measure in 2020 and 2030 by fuel type – in TWh.

Table 3. Additional information on main target groups for measures/activities.

Measure/Activity	Main target group	Operationalization
1 – Reduction living space	Retirees and singles as their per capita living space is higher than those of families	Persons in households with living space of more than 40 m^2/capita
2 – Reduction hot water use	All	Energy savings per person
3 – Reduction room temperature	All	Energy savings per household
4 – Investment in automation	House owners (one and two family homes)	All house owners living in their own houses (one and two family homes and condos)
5 – Insulation of heat distribution	House owners (one and two family homes)	All house owners living in their own houses (one and two family homes and condos)
6 – Modal shift from car to bike	All	
7 – Tele-meetings	Only employed people	Employees, self-employed persons and civil servants
8 – Purchase of smaller size cars	All	Households which have at least 1 car and belong to the group of highest 50 % in terms of consumption expenditure
9 – Reduction private air travel	All	All households which travel by airplane
10 – Reduction multiple endowment with equipment	Mainly higher income households	Households with more than 1 TV per capita and more than 1 refrigerator
11 – Absolute consumption limit for TVs	All	Households with TVs
12 – Campaign change in use patterns	Only those with clothes dryers. All for TVs.	Only those with clothes dryers and TVs

be most responsive/affected by an activity (main target groups) and apply a weighted scheme to assign potentials to households. Such additional information might be based on statistic indicators, such as per capita living space or per capita number of cars or equipment. Additionally, insights from both expert judgment and literature studies on behavioral science are also taken into account. This also helps to identify households that might not at all be affected by a measure. If no additional information is available, we assume that households are uniformly attained relative to their energy use. Table 3 provides an overview of the additional information and how it is used within the analysis.

As we aim to allocate the entire fuel specific energy savings potentials for 2020 and 2030 to households, we derive savings in monetary terms by multiplying physical energy savings with energy price projections for 2020 and 2030.[7] These monetary savings are then considered in relation to the expected household income in the same year. For expected household income we assume a real growth rate of 1 % p.a. from 2014 onwards.

The measures or activities investigated in this study are sufficiency measures in nature, i.e. no investments are needed to implement the measures, except for measure 4 and 5. Moreover, no other costs have been considered in this study that might occur before or during implementation (e.g. transaction costs, hidden costs, loss of benefits etc.). While these costs might occur and have been discussed in the literature (e.g. Keay 2011, Valentová 2010, DECC 2012, Jaffe, Newell and Stavins 2004 or Gillingham and Palmer 2014), no quantification is available that provides sufficient information to be included in this study. For this reason, all measures/activities in this study reveal a monetary benefit in form of savings on energy expenditure. Real total savings might be either lower (e.g. if transaction costs apply) or higher (e.g. if in case of a modal shift from car to bike use not only fuel costs are saved but the car is discarded altogether and additionally taxes and fees can be saved). As costs are not integrated, the current analysis cannot be considered as a welfare analysis.

Results

In this section, we discuss the results of our analysis. Due to space constraints, we limit our presentation to the year 2030. Generally, the results on savings for the year 2020 point in the same direction, but are smaller in absolute terms. Any deviations from this rule will be picked up in the discussion. Rather than presenting a whole set of tables and numbers, we try to describe our results more qualitatively in light of our main questions of i) which role monetary savings might play in triggering energy savings and ii) which household group(s) would be most promisingly and fairly tackled when designing policy measures. More detailed quantitative results can be obtained from the authors.

7. Energy price projections are taken from the ongoing project "Klimaschutzszenario 2050" for the German Environment Ministry; Öko-Institut, Fraunhofer ISI, dezentec.

MONETARY SAVINGS AND INCENTIVE STRUCTURES

As discussed above, all measures lead to monetary savings because less energy is consumed and needs to be paid for. On average, the investigated measures/activities lead to monetary savings potentials of between 0.03 % and 0.25 % of the expected net household income in 2030. By far the highest savings potentials can be observed for the reduction of living space. This is followed by three mobility measures, a modal shift towards bike use (0.17 %), a shift towards tele-meetings (0.16 %) and a reduction of air travel (0.14 %) and a measure in the area of equipment, i.e. reducing second or third appliances (e.g. beer refrigerators) (0.14 %). These monetary savings are shown in Table 4 differentiated by measure/activity and net equivalent household income.

Differentiating households by income group, we observe general differences between income deciles. For all those measures that affect households of all income groups uniformly (e.g. reduction of hot water usage, reduction of room temperature, change of use patterns), monetary savings in low income households are relatively higher than in households with higher income. This is due to the fact that low income households need to spend a relatively larger share of their income on energy consumption. In 2014, the average low income household spent about 13 % on electricity, heating energy and fuels, while the highest income decile only spent about 5 % of their household income - at the same time using about three times as much energy in absolute terms. Monetary savings are thus more visible for low income households and play a more important role in everyday decision making. In economic terms, these savings are expected to bring a higher utility to low income households, which then have additional income to meet basic needs. This implies that low income households may be more receptive to a policy that informs and points out monetary savings related to certain activities.

The German government has picked up on this fact in its National Climate Initiative and designed a novel approach for *specific advice and consultancy service to low income households.* The project encompasses a training programme for long-term unemployed in combination with household-level energy saving advisory services for low-income households. The project is considered very successful as it provides simultaneously for new employment and socio-economic group specific advice in energy savings, resulting in changes in user routines and low-budget investment. An evaluation revealed that in the previous two phases, participants managed to reduce their electricity consumption by around 16 % which is complemented by learning effects for future applications (Öko-Institut et al. 2012). In its current phase, the project has been expanded to provide advisory services also with respect to heating behavior and to complement advisory services with financial incentives to foster investment in more efficient appliances and thus to cover a broader range of mitigation potential.

For some measures, however, the picture looks different in that higher income households show higher monetary saving potentials than lower income households. This applies in particular to measures in the area of mobility. Higher income households tend to use larger size cars and travel more frequently (by car or plane). Moreover, they tend to have jobs that in general qualify for a shift towards tele-meetings resulting in less work-related travel. As they use more energy for mobility activities, saving measures lead to larger monetary savings. On the one hand, the "largest" monetary savings are in this case associated with the largest savings in terms of physical energy. On the other hand, however, higher income households are expected to value monetary savings less than lower income households, as basic needs are easily met and money is not at the forefront of daily decision making. Thus, policies and measures that concentrate on providing information on monetary savings cannot be considered suitable for this income group. Instead, a different type of incentive may be necessary. Examples in the area of mo-

Table 4. Relative savings per measures in 2030 differentiated by income group.

Decile net equivalent household income[1)]	Net equivalent household income		Buildings					Mobility				Equipment		
	Average	highest income (percentile)	Reduction living space	Reduction hot water use	Reduction room temp.	Insulation of heat distrib.	Investment in automation	Modal shift: car to bike	Telemeetings	Smaller size cars	Reduction priv. air travel	Reduction multi-endowment	Absolute energy limit	Change in use patterns
	Euros per month		Potential in % of net household income											
Lowest 5%	780	973	0.32	0.17	0.21	0.02	0.02	0.15	0.07	0.04	0.07	0.17	0.07	0.27
1st decile	924	1 186	0.27	0.15	0.19	0.02	0.01	0.15	0.06	0.03	0.08	0.14	0.06	0.22
2nd decile	1 357	1 511	0.22	0.12	0.15	0.02	0.02	0.18	0.09	0.03	0.08	0.14	0.05	0.17
3rd decile	1 638	1 765	0.24	0.11	0.14	0.03	0.02	0.19	0.12	0.05	0.13	0.16	0.04	0.15
4th decile	1 886	2 014	0.25	0.10	0.12	0.03	0.03	0.20	0.14	0.08	0.13	0.16	0.04	0.13
5th decile	2 142	2 267	0.24	0.10	0.12	0.04	0.03	0.20	0.15	0.11	0.13	0.16	0.04	0.12
6th decile	2 406	2 552	0.26	0.09	0.11	0.04	0.03	0.20	0.18	0.15	0.16	0.16	0.03	0.12
7th decile	2 724	2 915	0.25	0.08	0.10	0.04	0.03	0.20	0.18	0.16	0.15	0.16	0.03	0.10
8th decile	3 154	3 436	0.26	0.08	0.09	0.04	0.03	0.19	0.19	0.17	0.15	0.15	0.03	0.09
9th decile	3 850	4 383	0.26	0.07	0.08	0.04	0.03	0.17	0.18	0.17	0.16	0.14	0.03	0.08
10th decile	6 124	.	0.24	0.05	0.06	0.03	0.02	0.12	0.15	0.12	0.16	0.11	0.02	0.06
Total / Average	2 561	.	0.25	0.08	0.10	0.03	0.03	0.17	0.16	0.12	0.14	0.14	0.03	0.10

[1)] Equivalence weighted with new OECD scale for population in private households. Source: Micro simulation analysis based on German Income and Expenditure Survey (EVS) 2008 (80 % scientific use file by the research data centers of the German Federal and Länder Statistical Offices). Extrapolated to 2014.

bility include creating privileged parking zones for small cars, introducing general speed limits of 30 km/h in cities, improving bicycle pathways and infrastructure and revising taxation structures for company cars. Monetary penalties, such as motor vehicle, CO_2 or air traffic taxes would also provide incentives in the area of mobility. However, such penalties raise concerns in terms of equity. Although, as we have shown above, a tax on motor fuels would affect the average high income household more than the average low income household, it may still lead to equity concerns regarding the effect on individual households. For example, a low income breadwinner might have no alternative to commuting to work on a daily basis by car. A tax would present an additional cost that cannot be avoided and put additional stress on tight money situations. Systems with financial penalties would thus carefully need to be designed so that they tackle those target groups with high savings potentials that can "afford" to choose between penalty payment or change in lifestyle or behavior. They could allow for a tax-free basic minimum consumption at the average level of low-income groups.

The discussion shows, that it is indispensable to define and take a deeper look at specific target groups, which are supposed to be reached and incentivized to change behavior or lifestyle.

In order to generate additional information on potential target groups, we also look into the distribution of savings by social status of the main income earner. The analysis reveals similar patterns: the higher a household's share of basic spending on energy, the higher its relative savings. Households whose main income earner is unemployed, non-working, a student or worker have lower incomes and are more receptive to financial savings/incentives. The measures "reduction of living space" as well as "reduction of room temperature" would lead to higher savings due to lower demand for heating fuels for people who spend more time at home, such as retired, not employed, unemployed persons and also - to a lower extent - self-employed persons. The expansion of the above mentioned advisory project for low income households within the German National Climate Initiative picks up on this fact and now additionally provides advice on heating behavior.

Retirees present a special group as they show mixed income levels and have distinct use patterns. Their savings potential relating to a reduction of living space and/or room temperature is most pronounced. Many retirees still live in their former family home with large living space and heating demand. This is not always a comfortable situation for the inhabitant, as the sizeable homes may become increasingly difficult to maintain, and may also be expensive both in terms of rent (if rented) and energy cost. If people moved to a smaller dwelling, this could be a win-win-win situation for the former inhabitants, the new inhabitants and the environment: The elderly citizens could save effort, energy and maybe cost, and the bigger dwellings could be used by families. This would in turn reduce the need for new construction and put a halt to the expansion of per capita living space, reducing both energy and land consumption.[8] However, even though benefits of living on smaller space might be substantial, other factors might play a larger role and present significant barriers to changing behavior or lifestyle. Besides personal reasons relating to being attached to the family home or to social networks in the neighborhood, practical barriers exist. Suitable new dwellings might not be available or affordable, and if they are they might not be easy to find. Negotiations with owners and real estate agents might be challenging as is financing and organizing the move itself. A suitable policy measure to overcome these barriers might be to support the set-up of one single contact point agency which provides financial and practical information, serves as a broker between relevant agents (property owners, banks, public authorities etc.), organizes the house or flat sale and the move into the new dwelling, serves as a contact point for all questions and concerns and thus serves as an all-in-one-agency.

MONETARY SAVINGS VS. ENERGY SAVING POTENTIALS

In order to get a more refined picture of the physical energy savings potentials and how they relate to monetary savings and household group, we provide a set of figures which combine these pieces of information. In the following, we show potential physical savings together with monetary savings in 2030 for selected measures, in particular those measures which reveal high saving potentials and interesting distributional effects. Again we look at it from the angle of whether financial incentives might play a role and for whom - and how household groups might be most effectively and fairly be tackled by policy measures.

The analysis shows distinct patterns. First, physical savings can be positively correlated with monetary savings across household characteristics. Examples for this are "reduction in air travel" where both physical and relative financial energy savings increase with income or for "shift towards tele-meetings" where physical and relative monetary savings correspond across social status groups. For the measure „reduction of air travel" (compare Figure 2), higher income households can save relatively more physical energy and also have larger financial savings than lower income households. Financial savings amount to 65 Euros per year on average across households. The distribution of savings, however, is more skewed even within a single income decile than for any of the other measures as some households do not undertake air travel at all while other households' air travel represents by far the largest energy consumption in the sector of mobility. In that sense, it is important to keep in mind that we are showing decile averages here and that savings can only occur for those households which take trips via air travel. Similarly, for the measure "tele meetings" both physical and financial savings are highest for those households whose members are employed in jobs that allow for such measures (e.g. employees, civil servants, self-employed, compare Figure 3). Again, the potentials rather lie with high income households.

This information can help in designing and implementing policy instruments targeting those groups with highest savings potentials. Financial savings resulting from behavioral/lifestyle changes would be increased for these target groups if energy use for such travel would be made more expensive. This could be achieved through a number of instruments. Examples include, revising tax schemes for motor vehicles (based, for example, on CO_2 efficiency) and motor fuels, revising air traffic taxes that could be related to GHG emissions, introducing VAT

8. Alternatively, the building or apartment could be transformed in order to accommodate more people, e.g. a house could be split into two separate flats. Or an additional bathroom or separate entrance could be created in an apartment to allow for subletting a room or facilitate communal living.

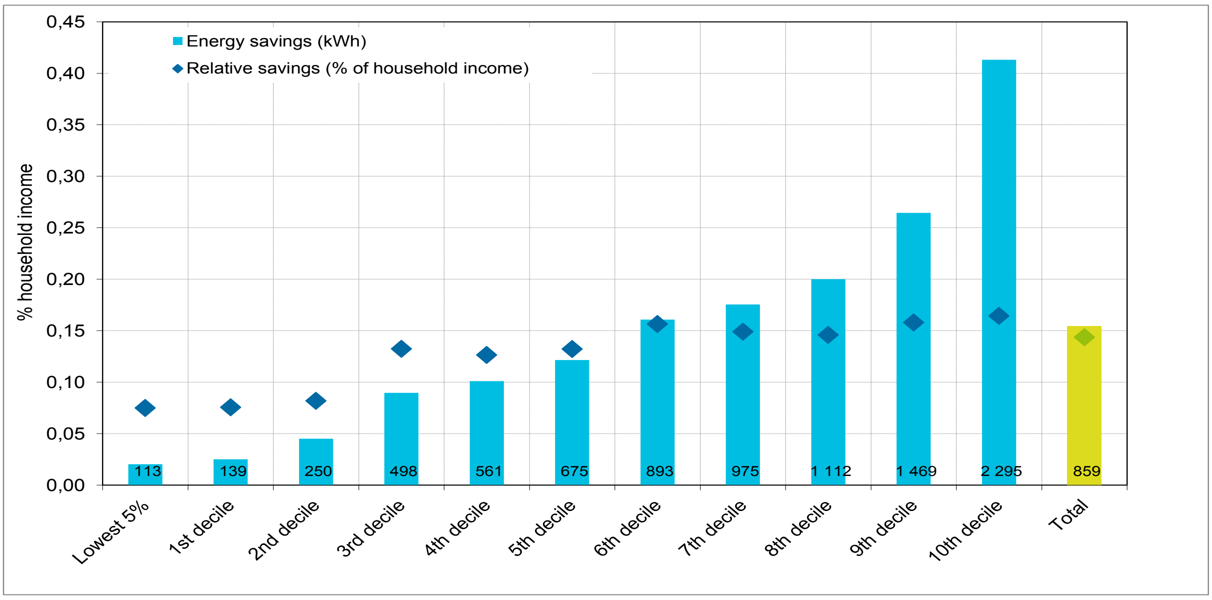

Figure 2. Measure "Reduction of private air travel" in 2030: Energy savings (kWh) vs. financial savings (% net household income) by income group.

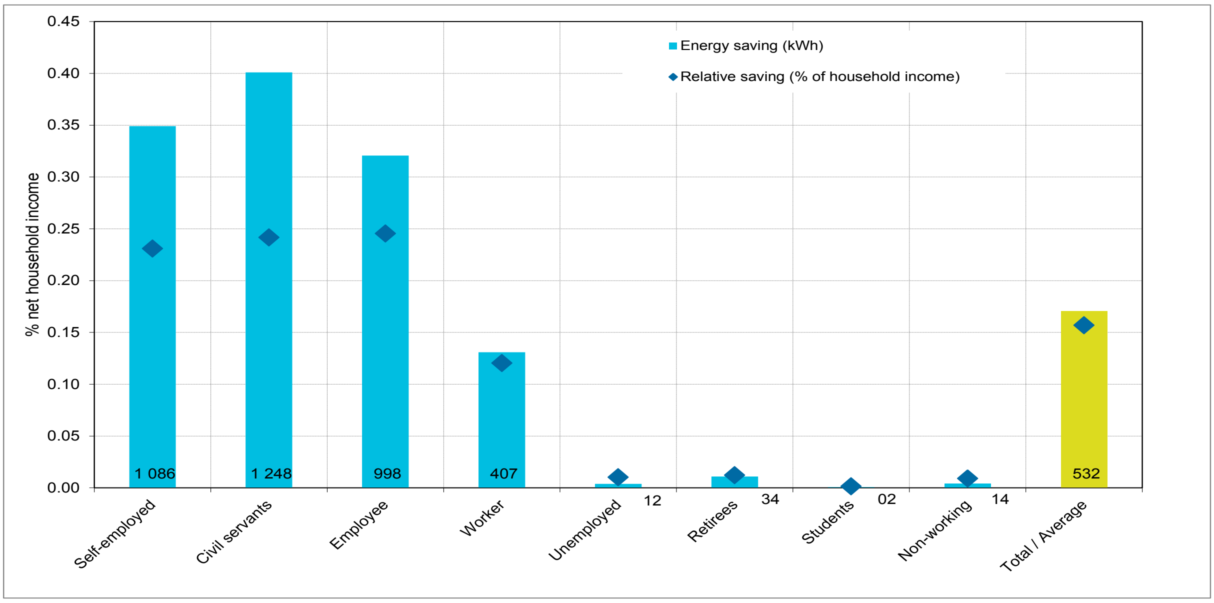

Figure 3. Measure "Tele-meetings" in 2030: Energy savings (kWh) vs. financial savings (% net household income) by social status of main income earner.

on international flights, introducing road and parking tolls, fee-bate systems and revising taxes on corporate cars. With such measures that increase the price of (CO_2-intensive) mobility, financial savings will become more visible for higher income households and may provide stronger incentives for changes in behavior. At the same time, such measures could be designed in a way as to not place any additional burden on lower income households. It should be noted that in case of tele-meetings, part of the activities/savings might occur for employers rather than employees. This qualifies employers as another target group which should also be considered when designing an appropriate policy instrument (e.g. introducing award systems for low-CO_2 travel in companies).

Second, physical and monetary savings can be negatively correlated, implying that households with lower physical saving potential save relatively more in monetary terms than households with higher physical saving potential. This is mostly the case for those measures, where energy use is reduced proportionally across all households (e.g. reduction of room temperature or hot water use). For example , the measure "reduction of room temperature" applies uniformly to all households as they reduce their energy consumption relative to their total current use (compare Figure 4). In financial terms, poorer households (e.g. unemployed, students, non-working) benefit significantly more from even a small scale reduction of energy use as a higher share of their disposable income is spent on energy. At the

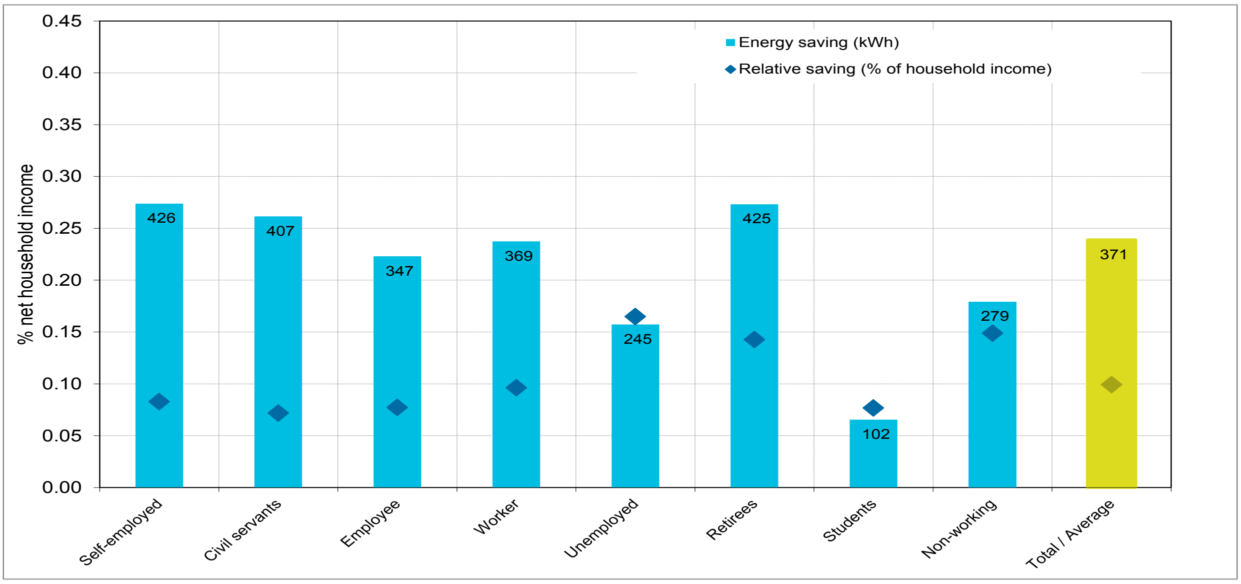

Figure 4. Measure "Reduction room temperature" in 2030: Energy savings (kWh) vs. financial savings (% net household income) by social status.

same time, however, their share in physical savings potentials through a reduction of room temperature is rather small. Mostly, they live in smaller size homes and energy use for heating is lower than in higher income households. On the other end of the scale, higher income households (self-employed, civil servants, employees and retirees) show savings potentials of about 400 kWh while the accompanying financial savings in relation to the disposable income is small.

The discrepancy between physical and financial savings potentials again underline the general challenge associated with energy savings measures. The highest absolute potentials are most difficult to reach as they occur in households that are least likely to appreciate related financial savings. Policies need to be designed to take this into account. Financial measures, such as taxes, would make energy use more expensive, but burden lower income households relatively more than higher income households. Moreover, in light of the small financial savings for higher income households they are not expected to provide much of an incentive. In these cases, where physical and monetary savings diverge, information and disclosure projects can be considered most promising. This includes the above mentioned low income advice project within the National Climate Initiative, but also smart meters and bills, technical support programs (for heat or hot water devices), pilot programs for new and advanced technologies (to bring about a pioneer spirit), campaigns to raise or reiterate awareness. Potentials for retirees are correlated with potentials for smaller living space, as much of their heating expenses are due to more than average per person living space. Rather than reducing their comfort room temperature they might appreciate support in choosing the appropriate size of their home.

A third pattern is that physical saving potentials might vary but monetary savings are rather uniform across household characteristics. An example is the reduction of multi-endowment of appliances which shows stable monetary savings at around 0.15 % of household income for all income groups while physical saving potentials increase with income (compare Figure 5). This indicates that all households independent of their net income have multiple equipment in use, however the number of multi-appliances increases with net income. Absolute physical savings potentials are highest for higher income households which can afford multiple appliances in the first place. Financial savings are skewed at the extreme end of income groups. They are lower than average for the two highest income groups and higher than average for the lowest income group which again spends a significantly larger share of their income on energy implying that financial savings are higher even if physical savings are comparably low. In terms of policy design, this pattern implies that again financial incentives or disincentives do not seem promising schemes. They would put lower income households at a disadvantage and at the same time not stimulate the potentials of high income households. Measures that target the issue at hand more specifically, i.e. supporting the disposal of secondary appliances, are likely to be more effective. These could include free collection of old appliances, scrap bonus, life cycle cost indication at point of sale, information campaigns and specific advisory programs.

Summary and conclusion

In this paper, we analyze the distributional effects of selected energy savings measures at the household level in Germany. The investigated measures are sufficiency measures which were identified in a research project on national energy savings measures conducted by Öko-Institut, IREES and the Free University of Berlin for the German Federal Environment Ministry in 2013 and 2014[9]. The measures were selected based on the criteria of saving potential, implementation challenges and policy attention received so far. For our analysis we consider only those measures in detail which distinguish savings by energy carrier (12 measures). The measures cover a range of

9. Report to be published in 2015.

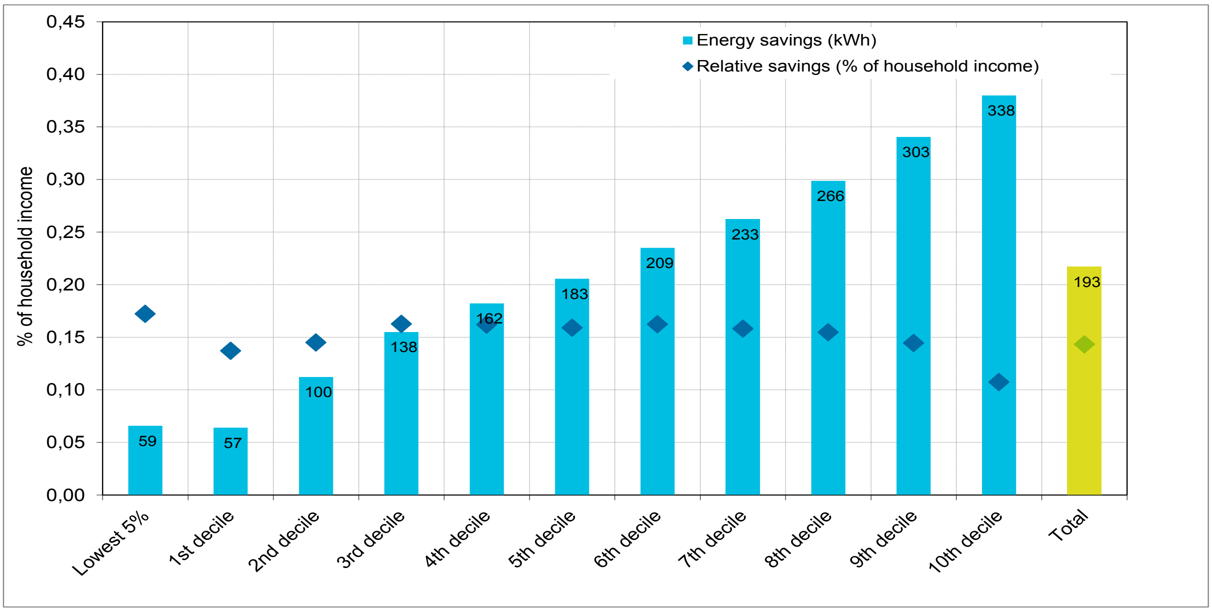

Figure 5. Measure "Reduction of multiple endowment with appliances" in 2030: Energy savings (kWh) vs. financial savings (% net household income) by income group.

behavioral changes (e.g. reduction of hot water use, reduction of room temperature, more efficient use of appliances) and lifestyle changes (e.g. less frequent air travel, tele-meeting, reduction of living space).

The goal of our analysis is to assess how saving potentials from these measures are distributed across households or household characteristics in 2020 and 2030. We specifically look at both the distribution of physical reduction of energy use and the distribution of the associated monetary savings. In order to determine which households are most affected by a specific measure, we use additional information about the target group of each measure and who within this target group would be most affected. Two main questions are in the center of our discussion: In how far do financial savings play a role in triggering energy savings and which households groups would be most promisingly and fairly tackled when designing policy measures?

The analysis reveals that if measures affect all households uniformly (e.g. reduction of hot water use, changes of use patterns), absolute savings in kWh are often highest for high income households, while monetary savings relative to household income are higher in lower income households. This is due to the fact that low income households spend a relatively lager share of their income on energy. To trigger these potentials, policy measures would best be designed to address specific needs of the target groups. Low income households which would highly value financial savings would best be approached with information and advice programs, such as the above mentioned *specific advice and consultancy service to low income households,* a project funded by the National Climate Initiative. The project encompasses electricity and now also heat consumption and provides at home advice on energy savings plus ad-hoc measures for energy efficiency (distribution of efficient light bulbs, plug-in switches). It will be further extended to provide investment subsidies for refrigerators including disposal of old appliances. For higher income households where physical savings potentials are higher but relative monetary savings are lower and less valued, other policy measures would be needed to trigger behavioral changes. Measures might apply to the technological or pioneer spirit of those income groups in providing smart meters, alert gadgets and detailed (electronic) bills that allow for self-evaluation. Also, new technologies might appeal to reconsider user routines. Negative financial incentives (e.g. taxes) would not be considered as effective. They would put a relatively higher burden on lower income households and have a regressive effect, while at the same time likely not trigger sufficient savings for higher income households to really notice.

For other measures the picture looks different. Measures in the area of mobility (e.g. less frequent air travel or purchase of smaller size cars) concern mainly higher income households and (relative) monetary saving potentials are thus higher and more proportional to physical energy savings in this group. The downside, however, is that those savings are still relatively small (less than 0.2 % of household income for an individual measure) and that money is not at the forefront of daily decision making for higher income households. Thus, incentive oriented measures might be more effective, e.g. creating privileged parking zones for small cars, introducing general speed limits of 30 km/h in cities, improving bicycle pathways and infrastructure and revising taxation structures for company cars. Monetary penalties, such as motor vehicle or CO_2 and air traffic taxes would also provide incentives in the area of mobility. However, such penalties would only overcome concerns in terms of equity if they tackle only those target groups with high savings potentials that can "afford" to choose between penalty payment or change in lifestyle or behavior. To do so, they could allow for a tax-free basic minimum consumption at the average level of low-income groups.

The insights are similar if households are differentiated by social (employment) status of their main income earner. If measures are designed to target specific employment groups which have higher expenditure shares in this particular area, potential savings are consequently more pronounced in those particular groups. Retirees deserve special attention here as they tend to live in larger than average dwellings at higher than average room temperatures. Policy measures that are designed to address this target group, such as the mentioned one-in-all-agency that serves as a single contact point for all matters related to relocating, can help overcome barriers to changes in behavior and lifestyle. In terms of household composition/types, an interesting overlap with social/employment status and household income can be observed for some measures, such as the reduction of room temperature. Considerable savings – both in physical and monetary terms can be observed for female singles followed by male singles and couples without children, the extent being similar to those of retirees and non-working persons and reflecting that these groups overlap.

All in all, the analysis reveals that monetary savings are rather small compared to household income. This might still provide an incentive for measures that are fairly easy and relatively burdenless to implement, such as for example a reduction of hot water use or a change in use patterns of appliances. It is, however, less clear whether those measures where energy savings efforts can be considered quite ambitious will be implemented given the relatively low monetary savings. The highest absolute potentials are often most difficult to reach as they occur in households that are least likely to appreciate related financial savings. This is aggravated by the fact that additional hidden costs might apply which might offset or counterbalance these savings. Introducing financial penalties (such as taxes) would increase financial savings, but at the expense of lower income households, especially if they concern consumption patterns that are distributed uniformly across all groups (e.g. hot water or electricity use). Thus, additional incentives will be needed in the form of policies and measures that specifically address barriers or provide additional motivation to implementing these potentials. Some examples of specific policies and measures in the different areas were outlined in this paper. Differentiating target groups and understanding their distinct characteristics and incentive structures is therefore indispensable. Designing tailor-made, target group specific policies and realizing that financial incentives are limited helps triggering potentials specific to each group in a fair and promising way.

Our distribution analysis across German household characteristics provides background information on consumption patterns and target groups and might thus provide helpful information to policy makers in the process of designing and implementing policy measures. Furthermore, the potential tension between realizing high savings potentials and furthering distributional goals was highlighted. In future research, we will widen the range of measures and activities to account for efficiency measures that require investments, such as refurbishments in the buildings sector, and include associated costs and benefits.

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