Reduction of living space consumption as necessity for reaching energy targets – potentials, barriers, policies

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Keywords

living space, consumption, energy policy, distributional effects, change of behaviour

Abstract

Despite a more or less stagnating population, the living space in Germany significantly increases every year and leads to a growing living space consumption per capita. A further increase is expected in long-term scenarios and will make sustainability, energy, and climate targets in the building sector much more difficult to reach. It also causes a growing use of space and resources, as well as enormous infrastructure costs. In Germany there is a growing awareness of this problem, especially on a regional level. This problem is more significant in some population groups than in others since the per capita living space varies.

In this paper the potential for reducing the average per capita-living space in certain target groups by reorganising existing living space more intelligently is estimated. The most promising target groups that use a living-space far above average and might be interested to reduce it are identified. Retirees and households reaching retirement age are among those target groups. However, there are many barriers to the reduction of living space. For the selected target groups the barriers are analyzed.

To support households to reduce their living space a mix of policy instruments is necessary, consisting of both informational and financial instruments. In this study a set of novel instruments to support households of the target groups to reduce their living space is created. The impact of these instruments on energy consumption and emissions of the target groups is calculated. Furthermore it is analyzed whether or not these measures are attractive from the point of view of a household taking into account costs and benefits, and likely distributional effects are shown.

Introduction

Energy consumption for space heating in private households is stagnating despite all efforts to improve the energy performance of buildings and thus reduce consumption. Only between 2016 and 2017 it increased by 1.6 % [1]. Numerous policies aim at improving the energy performance of buildings and at increasing the use of renewable energies for space heating and hot water supply. Nevertheless, the energy consumption of the residential building stock and its emissions has not been reduced significantly. Although the renovation efforts have been successful in reducing energy consumption per square meter, the steady increase in per capita living space has counteracted this development [2]. The consequences of the steady increase in per capita living space, particularly for climate protection and thus ultimately for the achievement of climate targets, are increasingly becoming the focus of political decision-makers. Addressing the consumption of living space is an essential pillar of sufficiency policies.

The aim of the study was to develop and evaluate appropriate policy instruments to counteract or reduce further increases in average per capita living space. Based on the initial situation described above, the paper first examines the theoretical emission reduction potential of a decreased per capita living space in the target groups identified and described before. In a further step, barriers and chances for a reduction of living

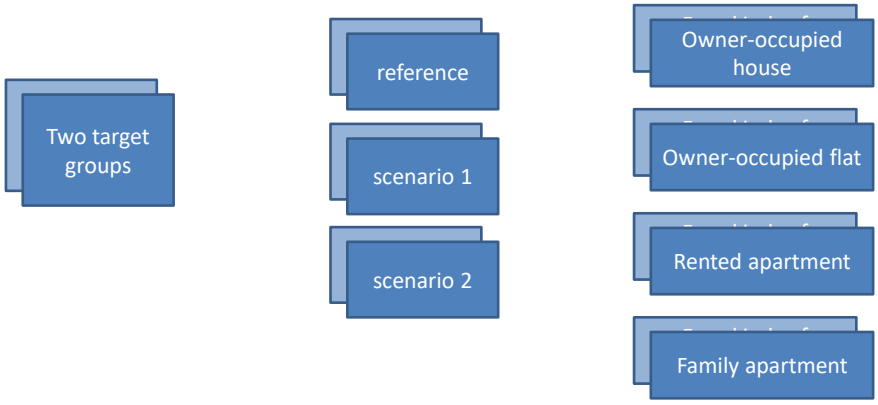


Figure 1. Overview of scenarios and housing situation.

space for the target groups were identified. Furthermore, a set of policy instruments was developed which, according to the studies carried out, appeared suitable to promote sufficiency approaches with regard to the consumption of living space in the target groups and to contribute to a reduction. The possible impact of these policy instruments in the target groups has been assessed.

In a final step, the economic effects of the selected policy instruments for the target groups are analyzed, having the main objective to draw conclusions about the distributional effects and the incentive-compatible design of the instruments.

It should be stressed once again that the study focuses on specific target groups and that the results apply to this target group and not to the entire population of Germany.

Methods

CHARACTERIZATION OF TARGET GROUPS AND ANALYSIS OF BARRIERS

The selection of the target groups was preceded by a comprehensive literature study and desk research. On this basis, the target groups for the policy instruments to be developed were determined. Target groups which have a particularly large per capita living space and which might be most likely to be open to a reduction in living space have been selected. The quantitative description of the target groups was carried out using the data of the last completed wave of the German Income and Expenditure Survey (IES [9]) in 2013. This survey is conducted by the Federal Statistical Office together with the State Statistical Offices every five years. The IES is an administrative data source and contains detailed information on income and consumption patterns of households as well as information on other household characteristics such as social status, household type, age, housing situation, etc. The survey is the largest of its kind in Germany and covers around 60,000 households. Participating households document their individual income and expenditure at the personal and household level for one quarter of the year. The IES is statistically representative for the whole of Germany. The allocation of the population to the target groups via the IES was based, among other things, on age, marital status, occupational activity, and household size.

Barriers and chances of reducing housing space for the target groups have been identified by a literature study and desktop research as well. The identified barriers and chances were supplemented, detailed and verified by means of semi-structured interviews with various experts. The experts were identified by desk research. The following experts have been interviewed:

- three representatives from municipalities and other political stakeholders (City of Vienna, City of Frankfurt am Main, Federal Association of Senior Citizens' Organisations [BAGSO]),
- two representatives from housing associations and cooperatives (Hansa Hamburg, Association of Berlin-Brandenburg Housing Companies [BBU]),
- five representatives from communal housing projects and associations (Regional Working Group for Community Housing Rhineland-Palatinate, Forum Housing Projects, konvisionär Heidelberg, hagebutze Heidelberg, K76 Darmstadt), and
- two experts from counselling institutions for senior citizens (Housing advice NRW, Caritas Starnberg).

ASSESSMENT OF THEORETICAL REDUCTION POTENTIALS

Scenarios

The theoretical reduction potentials for energy consumption and emissions through the reduction of living space per person were estimated using scenario calculations. Theoretical potential is understood as the reduction potential of the measure without considering the various barriers to implementation. The estimation was carried out for two target groups. For this purpose, an Excel-based scenario tool was developed. For each of the two target groups three different scenarios have been calculated, each for four different kinds of housing situations[1] (Figure 1).

Table 1 shows the data used in the scenarios. The per capita living space is calculated from the mean living space per household and the mean household size. The three scenarios differ only in the development of per capita living space; the development of all other parameters is the same in each housing situation and each scenario.

1. Since housing situations play a decisive role in the development of suitable policy instruments, these are presented separately in the basic data and in the scenarios. With the term family flat, the Federal Statistical Office designates a situation where people live in a dwelling provided by a family member.

Table 1. Framework data and sources used in the scenario tool.

Input data	Source 2013	Source 2030
Mean living space per household	IES 2013	assumption
Mean household size	IES 2013	according to [6]
Number of households in target group	IES 2013	according to [5, 6]
Mean energy consumption per household	IES 2013	according to [7]
Fuelmix	IES 2013	according to [7]

Therefore the scenarios can be characterised as follows:

- Reference scenario: "Increase in per capita living space" as assumed in the 2017 German projections report on the development of greenhouse gas emissions [7] by annually 0.56 % (2016–2020), 0.59 % (2021–2025) and 0.65 % (2026–2030),
- Scenario 1: less ambitious reduction of per capita living space by 0.5 % per year,
- Scenario 2: ambitious reduction of per capita living space by 3 % per year.

The base year of the scenarios is 2013, with reductions being reported from 2018 onwards. The identified theoretical potential relates to the target groups under consideration and do not represent absolute reduction potentials.

Database for the base year from IES

The data basis for the base year of the scenario calculation is the German Income and Expenditure Survey (IES) from 2013. On this basis, the current consumption by energy source was determined for each type of housing of the two target groups.

Development of framework data

The development of the size of the target groups was derived from the population projection and the projection of the number of households of the Federal Statistical Office [5, 6].

The framework data on the development of specific energy consumption and the share of renewable energies in the fuel mix for space heating are based on the "Further Measures Scenario" of the Federal Government's 2017 projections report [7]. The following assumptions have been made:

- Reduction of energy consumption per m² by 15 % between 2013 and 2030 as a result of refurbishment activities. This assumption is the same in all scenarios for all target groups and housing situation.
- Increase of the share of renewable energies in decentralised heat supply by 70 % between 2013 and 2030[2]. This assumption is the same in all scenarios for all target groups and housing situation. The increase in the share of renewable energies is at the expense of coal and oil.

The emission factors used correspond to those of the "Further Measures Scenario" of the projections report [7] as well.

2. According to IES, the proportion in 2013 varies depending on the type of housing used by the target groups. In 2013 it lies between 2 % and 10%, in 2030 between 3 % and 17 %.

DEVELOPMENT OF POLICY INSTRUMENTS AND ASSESSMENT OF EMISSION REDUCTION AND ECONOMIC IMPACT

Based on the interim results of the literature analyses and interviews, new policy approaches for increasing the efficiency of living space consumption were developed. The policies selected should address as many of the identified barriers as possible. Two policy instruments have been developed and selected for further investigation:

1. Financial support for the structural division of single-family houses, and
2. Municipal advice and support center for the efficient use of living space

For these instruments an assessment of the reduction effect on living space, energy consumption and emissions as well as the economic impact was carried out. In contrast to the estimation of the theoretical potential in the first step of the analysis, barriers to the implementation of the measure have been taken into account for the assessment. The emission reductions reported are achieved within the target groups and do not represent absolute reduction potentials for Germany. The impact assessment was also carried out using the Excel-based tool.

The assumptions considered the fact that only part of the target groups is capable to implement the measure. Decisive factors for this include the demand for housing in the specific region, i.e. whether the demand exceeds the housing supply and thus there is a demand for the newly created flat, and the age of the members of the target group, since some of them will be too old to implement the measure. The measures considered are the reduction of living space through (1) conversion of single-family houses through structural division into two self-contained apartments and letting the second apartment, (2) subletting, and (3) moving into a smaller apartment. The results of these analyses are shown in Table 2. The assumption on the development of the fuel mix and energy performance of the building stock is the same as in the scenarios of the theoretical reduction potentials. It is also assumed that there will be a constant fuel mix after implementation of the measure.

The financial effects of the instruments were determined in detail and differentiated within the group of implementing households. The Öko-Institut's microsimulation model, which is based on data from the 2013 German Income and Expenditure Survey (IES), was used for the analysis. In concrete terms, the heating energy saved is converted into monetary savings with the aid of the projected prices [7] and set in relation to the disposable income of the household. The expected additional income from the use of the available living space, saved expenses for heating energy known from the IES, and necessary investments are taken into account, too.

Results

SELECTED TARGET GROUPS

The following target groups have been identified:

Target group 1: "Pensioners with large living spaces"

Target group 1 covers households with non-working persons over 65 years and pensioner households (above and under 65). All members of the household must be registered in the IES. Only those households of the target group whose living space exceeds 80 m² for single persons and 100 m² for couples are included. This target group comprises 4.43 million households and thus one third of all senior households and more than 10 % of all households in Germany. The average per capita living space of these households is 81 m², compared to an average of 46.3 m² per capita for all households.

Target group 2: "Soon retiring"

Single and couple households are counted in this category if there is a person in the household who is about three years younger than the typical retirement age and whose children have already moved out. In addition, the household must not yet belong to target group 1. Target group 2 includes households that have a large per capita living space. Analogous to target group 1, living spaces from 80 m² for single households and 100 m² for couple households are considered large. Target group 2 consists of 0.68 million households and about 2 % of all households in Germany. An average household in this target group consists of 1.64 persons and the average age of the head of household is 63 years. In Table 3 a characterization of the two target groups is shown.

SCENARIOS FOR ESTIMATING THEORETICAL REDUCTION POTENTIALS

Important for the reduction potential in 2030 is the development of the size of the target groups. This development was assumed in the scenarios: The size of both of the target groups increases, whilst the size of the households is assumed to be constant in the scenarios (Table 4).

Table 4 also shows the scenario results regarding the development of the target groups' living space. The average per capita living space in target groups 1 and 2 decreases significantly in the scenario calculations, but even in the more ambitious scenario 2 it is still well above 50 m² per capita and thus above the current average of 46.5 m² and 46.3 m² in 2013, respectively [8].

The results of the scenarios with regard to the development of energy consumption and emissions are shown in Table 5. Accordingly, the reduction in annual energy consumption of the target groups compared to the reference in 2030 amounts to 18.3 TWh/a – minus 13 % compared to consumption in 2013 in scenario 1, and 52.9 TWh/a – minus 38 % compared to the consumption in 2013 in scenario 2, respectively. Annual emissions in 2030 can be reduced by 4.3 million t/a CO_2e (minus 13 % as well, scenario 1) or 12.4 million t/a CO_2e (minus 38 % as well, scenario 2) compared to the reference. These numbers show that the reduction in per capita living space could make a considerable contribution to climate protection in the target groups, which would in particular supplement the efforts to upgrade the energy performance of the building stock. The identified potentials show additional reductions in structural and technical measures to increase the energy efficiency of the building stock. The reduction of energy consumption per m² due to refurbishments amounts to 15 % in the same period (according to [7]). In addition to the potential for climate protection, the positive effects on resource and land consumption, which have not been examined, must also be included in an assessment.

BARRIERS

The barriers in the target groups that have been identified can be assigned to (1) psychological barriers resulting from the wishes, ideas and knowledge of those affected, and to (2) infrastructural and monetary barriers. At the same time, the barriers

Table 2. Assumptions for the impact assessment of emission reduction.

	Combination of instrument1 and instrument 2, measure structural division	Instrument 2, measure subletting	Instrument 2, measure moving into a smaller apartment
Considered target group and housing situation	Target group 1 and 2, owner occupied house	Target group 1 and 2, all housing situations	Target group 1 and 2, all housing situations
Proportion of these households living in regions with low housing demand (based on IES and [10]) and who will therefore not implement the measure.	21 %		
Proportion of remaining households being too old to realise the measure [based on 5] and who will therefore also not implement the measure.	20 %		
Proportion of remaining households implementing the measure (assumption)	0,5 to 1 % per year	0,25 to 0,75 % per year	0,1 to 0,25 % per year
Reduction of living space, energy consumption, and emissions of the implementing household (assumption)	50 %	25 %	40 %
Start of effect	2020	2020	2020

Table 3. Characteristics of target groups in terms of housing situation and household size; base year 2013.

Housing situation	Number of households	Living space	Size of household	Per capita living space
	mill.	m²/household	persons per household	m²/capita
Target group 1: Pensioners with large living spaces				
Owner-occupied house	3.22	133.1	1.63	81.7
Owner-occupied flat	0.39	104.3	1.31	79.6
Rented apartment	0.59	104.3	1.30	80.2
Family apartment	0.23	122.3	1.48	82.6
Total	4.43	126.2	1.55	81.4
Target group 2: Soon retiring				
Owner-occupied house	0.49	136.3	1.74	78.4
Owner-occupied flat	0.08	108.6	1.39	78.1
Rented apartment	0.10	109.7	1.39	78.9
Family apartment	0.01	109.3	1.43	76.5
Total	**0.68**	**128.7**	**1.64**	**78.5**

Source: Micro-simulation based on the German Income and Expenditure Survey (IES 2013); 80 % scientific use file of the FDZ of the Federal Statistical Office and the statistical offices of the Länder.

Table 4. Development of number of households and of living space of the target groups by 2030.

	Number of households 2030	Living space per household	Living space per person
	mill.	m²/household [reference / sc.1 / sc. 2]	m²/cap [reference / sc.1 / sc. 2]
Target group 1: Pensioners with large living spaces			
Owner-occupied house	4.06	147.2 / 127.5 / 91.6	90.3 / 78.2 / 56.2
Owner-occupied flat	0.50	115.3 / 99.9 / 71.8	88.1 / 76.3 / 54.8
Rented apartment	0.74	115.4 / 99.9 / 71.8	88.9 / 77.0 / 55.3
Family apartment	0.29	135.3 / 117.1 / 84.2	91.5 / 79.2 / 56.9
Target group 2: Soon retiring			
Owner-occupied house	0.59	150.8 / 130.6 / 93.8	86.7 / 75.1 / 53.9
Owner-occupied flat	0.09	120.1 / 104.0 / 77.0	86.4 / 74.9 / 53.8
Rented apartment	0.12	121.3 / 105.1 / 77.8	87.0 / 75.3 / 54.1
Family apartment	0.02	120.9 / 104.7 / 75.2	84.8 / 73.4 / 52.7

Table 5. Energy consumption and emission reduction compared to reference by target groups by 2030.

	Energy consumption reduction		Emission reduction	
	TWh/a		mill t/a C_o2	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Target group 1	13,725	38,734	3.25	9.18
Target group 2	4,587	14,162	1.05	3.25
Total	18,312 (-13 %)	52,896 (-38 %)	4.30 (-13 %)	12.43 (-38 %)

can be pitted against chances. Major barriers and chances are shown in Table 6.

POLICY INSTRUMENTS

A bundle of measures is needed to give the target groups support and an incentive to reduce the living space. For the further processing of the research project, two instruments were conceived. For these two instruments the further analyses were carried out:

- Instrument 1: Financial support for the structural division of single-family houses (funding instrument)
- Instrument 2: Municipal advice and support center for the efficient use of living space

This selection resulted from the previous work.

Instrument 1: Financial support for the structural division of single-family houses (funding instrument)

Instrument 1 consists of financial support for the planning and implementation of conversion work to create a second self-contained dwelling in an inefficiently used single-family house. It, thus, addresses owners of owner-occupied single-family houses who no longer wish to use the entire building, i.e. essentially

Table 6. Barriers and chances for the target groups.

Psychological barriers the lack of knowledge: people have no idea how they can change their situation, what alternatives there are, the lack of awareness of the problem and/or the missing motivation, the emotional attachment to the house or apartment and to the furnishings, the wish to stay in the familiar environment, in the familiar quarter, the wish to keep guest rooms available, the fact that a move is a major upheaval
Infrastructural and monetary barriers the high expenses/transaction costs, the (supposedly) lack of profitability, a lack of financial resources, a low value of the real estate, which makes a sale not worthwhile or leads to the fact that the proceeds from the house sale are not sufficient to acquire a smaller, modern apartment, as well as the missing alternative for moving (no smaller alternative apartments available) or a smaller apartment is more expensive.
Chances reduced maintenance costs/lower incidental expenses, the generating of rental income (if applicable), the move to a modern, barrier-free apartment, the move to a quarter with a better infrastructure or to the town centre, and no longer having to live alone.

members of target groups 1 and 2 who live in their own house (housing situation "owner-occupied house").

The members of target group 1 "Pensioners with large living spaces" and target group 2 "Soon retiring", each with the housing situation "owner-occupied house", represent the largest subgroups within the described target groups. Due to demographic change, the size of these target groups will increase significantly by 2030.

A major barrier to a reduction of living space is people's desire to stay as long as possible in their familiar neighbourhood and/or house. The instrument meets this wish. It also addresses people's desire to "no longer have to live alone", possibly to receive help in the garden, and a certain need for security, which is opposed by living alone in a single-family home in old age.

By a financial support a part of the financial burdens and risks of a change would be alleviated, and the barrier of the missing financial means would be addressed.

The most significant barriers to moving to a smaller apartment, namely the lack of alternative housing and the excessively high costs for smaller apartment, do not occur with this instrument, since one's own living space is reduced by conversion.

Instrument 2: Municipal advice and support center for the efficient use of living space

Instrument 2 offers advice and (organisational) support for owners and tenants of inefficiently used houses or apartments. The advice and support center should offer the following services: Brokering of potential tenants, letting management, relocation advice and support, provision of information on the legal situation (e.g. tenancy law) and on financing, providing architectural examples for structural division and annexes, advice on tax issues relating to structural division, brokering of smaller alternative flats in the same neighborhood or district, organisational and financial support for the relocation, assumption of the costs for "double" rents, payment of a relocation bonus, counter-financing of the "net rent" taken along.

This instrument addresses several barriers from Table 6, e.g. the transaction costs and the lack of knowledge.

This instrument is aimed at members of the growing target groups 1 and 2 of all forms of housing. This instrument is also relevant for members of target group 3, who will soon belong to target group 2. It addresses the barriers of a lack of knowledge (no knowledge of options/ alternatives), legal uncertainty, high transaction costs, and lack of potential tenants for subletting and lack of small dwellings.

ASSESSMENT OF THE EFFECTS OF THE INSTRUMENTS

Set of instruments for the structural division of single-family houses

Both the financial support for the structural division of single-family houses (Instrument 1) and the advisory services of the municipal advice and support center (Instrument 2) contribute to the implementation of the measure "structural division of single-family houses" and thus to reducing the owners' consumption of living space and creating additional small dwellings. The impact is therefore estimated for the "instrument set" of both instruments.

Out of the 4.6 million households of target group 1 and 2, owner-occupied house (Table 3), 3.0 million households are eligible for a structural division of the single-family house in 2030 due to the region and their age. Of these, 0.5 to 1 percent divides the house annually. This means that by 2030 5.5 percent to 11 percent of the potential conversion households will have implemented the measure.

The results of the impact assessment are shown in Table 7. Accordingly, in 2030 the instrument will make a contribution to the reduction of energy consumption of 1.3 to 2.8 TWh/a and to the reduction of emissions of around 0.33 to 0.66 mill. t. CO_2e.

Figure 2 shows the financial impact of the instrument set. The rent of the newly built apartment generates rental income of €8/m². The conversion results in investment costs of €35,000. These are converted into a regular monthly payment with the aid of an interest rate of 0.75 % in order to compare them with the saved expenses for heating energy and the additional monthly rental income.

Table 7. Effect of the instrument set for the structural division of single-family houses.

	contribution to reduction of energy consumption in 2030	contribution to emission reduction in 2030
Target group 1, owner occupied house	1,188 to 2,377 GWh/a	0.28 to 0.57 mill. t CO_2e
Target group 2, owner occupied house	197 to 395 GWh/a	0.04 to 0.09 mill. t CO_2e
Total	1,287 to 2,772 GWh/a	0.33 to 0.66 mill. t CO_2e

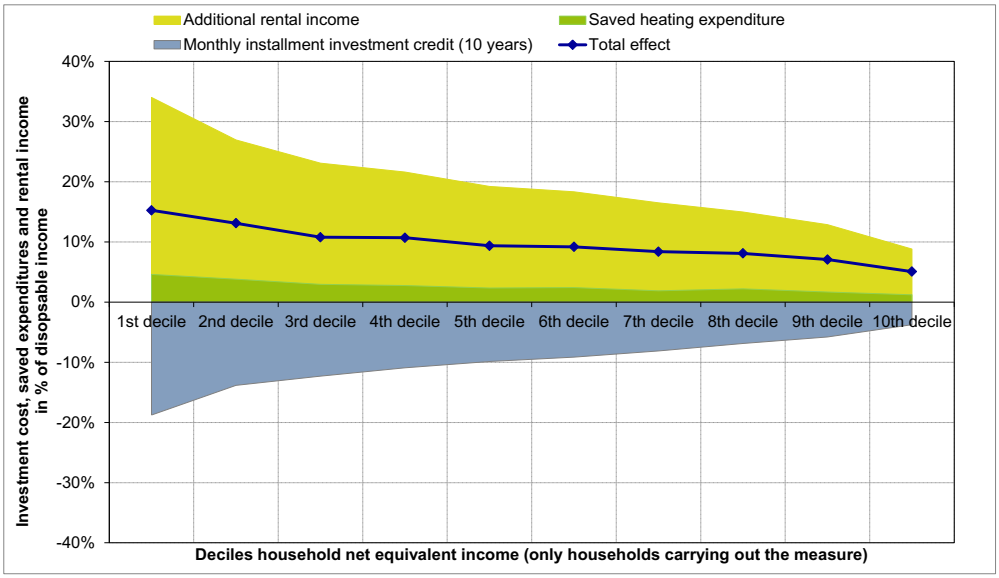


Figure 2. Financial effects for a household dividing their house. Source: Micro-simulation based on the German Income and Expenditure Survey (IES 2013); 80% scientific use file of the FDZ of the Federal Statistical Office and the statistical offices of the Länder.

Table 8. Impact of the Municipal Action Point for efficient use of living space (Instrument 2) by 2030.

	contribution to reduction of energy consumption in 2030	contribution to emission reduction in 2030
(1) Effect of subletting	709 to 2.127 GWh/a	0.16 to 0.48 mill. t CO_2e
(2) Effect of relocation	454 to 1.134 GWh/a	0.10 to 0.25 mill. t CO_2e
Total	1,163 to 3,261 GWh/a	0.26 to 0.73 mill. t CO_2e

With a credit period of ten years, the financial advantage of (additional) rental income and reduced heating energy expenditure exceeds the investment payments made. For an implementing household with a low income, an additional income (or avoided expenditure) of approx. 10 % of the disposable income is generated. In terms of disposable income, the financial advantage decreases with increasing income.

Instrument 2: Municipal advice and support center for the efficient use of living space

The impact of instrument 2 is estimated on the assumption that (i) yearly 0.25 to 0.75 per cent of the potential implementation households sublet a room and (ii) yearly 0.10 to 0.25 per cent of the potential implementation households move into a smaller apartment. The potential implementation households correspond to target group 1 and 2, all kinds of living situations, and thus about 5.1 to 6.4 million households (Table 3).

According to this estimate, a reduction in final energy consumption of 1.2 to 3.3 TWh/a and a reduction in emissions of 0.26 to 0.73 million t./a CO_2e within the target group can be achieved in 2030.

A look at the financial effects shows that in the case of subletting, the relatively low expenses of €1,500, which are assumed, are compensated by the reduction in heating energy expenditure alone. An average household with a low income will save around 300 kWh of heating energy per month. If the €1,500 investment costs are paid in regular payments over five years, the implementing households expect additional income of approx. 10 % of the disposable income. If the entire sum of saved heating energy and additional rental income is used to compensate for the €1,500 investment costs, subletting is already worthwhile after three months.

If the living space is reduced by moving into a smaller apartment, a household with low income will save approx. 500 kWh of heating energy per month, while a household with the highest income decile will save 850 kWh per month. The financial advantage in case of a move to a smaller flat results exclusively from the reduction of the heating energy consumption and the

Table 9. Comparison of the theoretical potential of the measure "Reduction of living space consumption" in the target groups with the reduction potential of the considered policy instruments.

	contribution to reduction of energy consumption in 2030	contribution to emission reduction in 2030
Theoretical reduction potential	18.3 to 52.9 TWh/a	4.3 to 12.4 mill. t/a CO_2
Effect of considered instruments	2.5 to 6.0 TWh/a	0.6 to 1.4 mill. t/a CO_2

associated lower expenses, since it is assumed that the (total) rent for the smaller flat corresponds to the rent or the housing costs before the move.

If the €1,000 invested for the relocation is converted into regular monthly payments over five years, the household making the move receives regular surpluses of 0.5–2.0 % of its disposable income from the saved heating energy. If the saved expenses for heating energy are used to compensate for the removal costs, the move will have been worthwhile after an average of 1.5 years.

Discussion

When evaluating the theoretical potentials identified and the reduction effect of the selected policy instruments, it should be noted that these relate to the target groups under consideration and do not represent absolute reduction potentials for Germany. The reduced living space in the target group will continue to be used and emissions will continue to occur there, but these will be distributed among a larger number of residents. Thus, in addition to per capita living space, per capita emissions in the buildings and target groups considered are also significantly reduced.

An overarching effect results from the fact that the need for new buildings is significantly reduced if the need for living space can be covered to a large extend in existing buildings. This avoids emissions from the otherwise erected new building, both from the construction phase and from the period of use. The emissions from the period of use of the new building would presumably be lower than those from the existing building, since new buildings have higher energy standards than existing buildings. However, the avoided new construction will have numerous other positive effects in other policy and action areas, such as a reduction in the need for space and resources, reduced development and infrastructure costs for municipalities, and effects on local development and urban planning. The additional supply of especially small apartments in locations often close to the town center contributes to a better availability of living space.

Working people with large living spaces are probably hard to motivate for a reduction in living space. In the group of senior citizens, especially for those for whom the living space is too large, not age-appropriate, and has become a burden, a reduction in living space certainly offers opportunities. Thus, the measure leads to an improvement in living conditions and, by living closer together, to the improvement of other social aspects.

Only a part of the target groups considered here will be open to actually reduce the living space and to hand over a part of their flat or move into a smaller flat. The numerous barriers identified suggest this. This circumstance is taken into account in the estimations carried out by the low assumptions for the proportion of households that take action. Table 9 shows the difference between the theoretical potential and the estimated impact of the policy instruments considered. According to the estimates carried out, 5 to 33 % of the theoretical potentials can be raised by the instruments, depending on the chosen scenario and composition rate.

From the point of view of the greenhouse gas balance, reduction potentials from the more efficient use of living space are to be seen in addition to those in the projections report [7], since no measures for addressing the living space per person are considered there.

Such a measure is financially worthwhile for the implementing households after a relatively short time. The expected additional rental income from partitioning and subletting will have a far greater financial impact on the average transferee household than the reduction in heating energy expenditure. It should be noted that the assumptions regarding additional income from new lettings were determined on the basis of an average m^2 price and that the transaction costs actually required for division and relocation may deviate from the assumptions made. In order to determine the exact effects for a specific household in a specific region, more differentiated assumptions may be necessary. This should be taken into account in the valuation.

Conclusions

In addition to the effects on growing land and resource consumption, housing shortages and social coexistence, the constantly increasing per capita living space in Germany has direct negative effects on climate protection due to the associated increase in energy consumption and rising specific emissions. The population group with the largest average per capita living space in Germany is the seniors and pensioners. About 4.4 million households in Germany are senior citizen households with a living space of at least 80 m^2 for single-person households and at least 100 m^2 for two-person households. This is more than 10 % of all households in Germany. The average per capita living space in this group is 81 m^2. In addition, there are 0.7 million households with equally large living spaces, which will soon reach retirement age[3]. The population groups, which currently or in the near future inhabit particularly large living spaces, thus comprise a total of almost 8 million households and thus account for almost 20 % of all German households.

The theoretical emissions reduction potential is high. For the target groups it accounts to 18.3 to 52.9 TWh/a, and 4.3 to 12.3 mill. t/a CO_2. Without this measure the energy con-

3. Additionally there are 3.2 million households with almost adult children, who also live in very large living spaces after the children move out; these were not considered in this paper.

sumption as well as the emissions of the target groups would, according to scenario results, even rise slightly by 2030. Measures for the refurbishment of buildings and the increasing use of renewable energy sources would be compensated by the increasing living space per capita. Effects of the increasing size of the target groups are also a reason for that and underline the importance of the problem.

Policy instruments designed to slow down this development must take into account or address as many of the barriers identified as possible. A bundle of suitable policy instruments seems promising. So far, the issue has only rarely been discussed in policy debates on federal level.

The energy consumption and emission reduction potential of a reduction in living space is enormous, even with a small proportion of households that implement a living space reduction. According to this estimate, in 2030 the two instrument sets examined could reduce final energy consumption by 2.5 to 6.1 TWh/a, and CO_2e emissions by 0.59 to 1.39 mill. t/a within the target group in 2030. By way of comparison: According to the estimates of the Further-Measures-Scenario (MWMS) of the Projection Report 2017 [7], a further development of the KfW promotional programme Energy Efficient Construction and Renovation, for example, will reduce final energy consumption by 4.4 TWh/a in addition to the Further-Measures-Scenario and avoid 1.1 million t/a of CO_2e.

In addition, there are numerous unquantified positive effects on land and resource consumption. It was shown that under the assumptions made, all instruments considered have the potential to reduce the financial burden on the implementing households. In relation to the total population, the households concerned tend to be in the higher income deciles, since the larger living spaces can also be found there. However, there are also considerable differences between households within the target group in terms of their income. These are important considerations that can help in the incentive-compatible design of instruments and advice for households.

Addressing the rising consumption of living space through policy instruments is therefore both necessary and promising. Further research and pilot projects are needed to develop appropriate instruments.

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Acknowledgements

The study was supported by the Federal Environment Agency of Germany and was conducted by a consortium of the Öko-Institut and the ifeu-Institut.

The authors would like to thank the Federal Environment Agency Germany for its funding and Mr. Matthias Weyland for his competent and constructive support. We also wish to thank the entire project consortium for their contribution and in particular Ms. Corinna Fischer as project coordinator.