Almost best friends: sufficiency and efficiency. Can sufficiency maximise efficiency gains in buildings?

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Abstract
The efficiency strategy to exploit the potential for energy savings in buildings still is applied rather slowly in most countries. In addition, there are indications that energy savings are partly compensated particularly by wealth but also rebound effects, the 'empty nest' (persistence of elderly people and couples in family homes), and cohort effects (e.g. vintages of people or buildings). In Germany, as in other European countries, the existing trend in housing is a continuously growing floor space per capita. Over the last decades it expanded from about 20 m^2 in 1960 to currently 45 m^2 per person. Forecasts expect a further increase to more than 50 m^2 per person. Obviously, more floor space needs more energy for space heating and cooling, ventilation, and lighting, but it also allows the household to operate more and or bigger appliances, all of which increase energy consumption.

On the other hand, housing projects emerge offering relatively small private living spaces in combination with various shared spaces to use. Many of them are based on private initiatives. But what is the motivation behind it? And is there a higher need for new living concepts in the future?

The proposed paper presents main drivers of increasing floor space per capita in Germany and discusses the question if more space is necessary for higher comfort. It presents different examples of housing concepts that strive to achieve good living with less space and suggests a 'building typology of sufficiency'.

Finally, the paper discusses qualitatively to which extent these housing concepts can lead to less energy use and emissions. In this way sufficiency could be best friend with efficiency and tackle wealth, rebound, and other effects that counter-act efficiency progress. But therefore, as the paper concludes, politics and policies should recognise sufficiency as a field of action instead of referring to individual decisions and lifestyles.

Introduction
The building sector is a broad and important field for energy efficiency activities. In its energy concept the German government set the target of an 'almost climate-neutral building stock' by 2050, enabled by 80 % less primary energy consumption for space and water heating and cooling, along with renewable energies (Federal Ministry of Economics and Technology 2010, 22 ff). Therefore, as well as for the success of the German 'Energiewende', a long-term renovation roadmap shall be developed. There is no doubt that the energy use in buildings has to be reduced. But the question 'How?' asking for the right efficiency technologies, measures, and policies is discussed controversially as well as their financial, social, environmental, and aesthetical effects.

So far energy policies set clear priorities on renewable energy and energy efficiency retrofit, technologies and appliances to lower energy consumption and greenhouse gas emissions, in the building sector as well as in general. As part of the wider Action Plan for Energy Efficiency, the German government is working on a strategy for buildings in 2015/16, with a renovation roadmap, an integrated strategy, and an integration of the legal energy efficiency requirements under the EPBD (laid down in the EnEV ordinance) and the legal requirements for renewable energies in buildings (EEWärmeG). However, in this paper we argue that in addition to energy consistency (renewa-

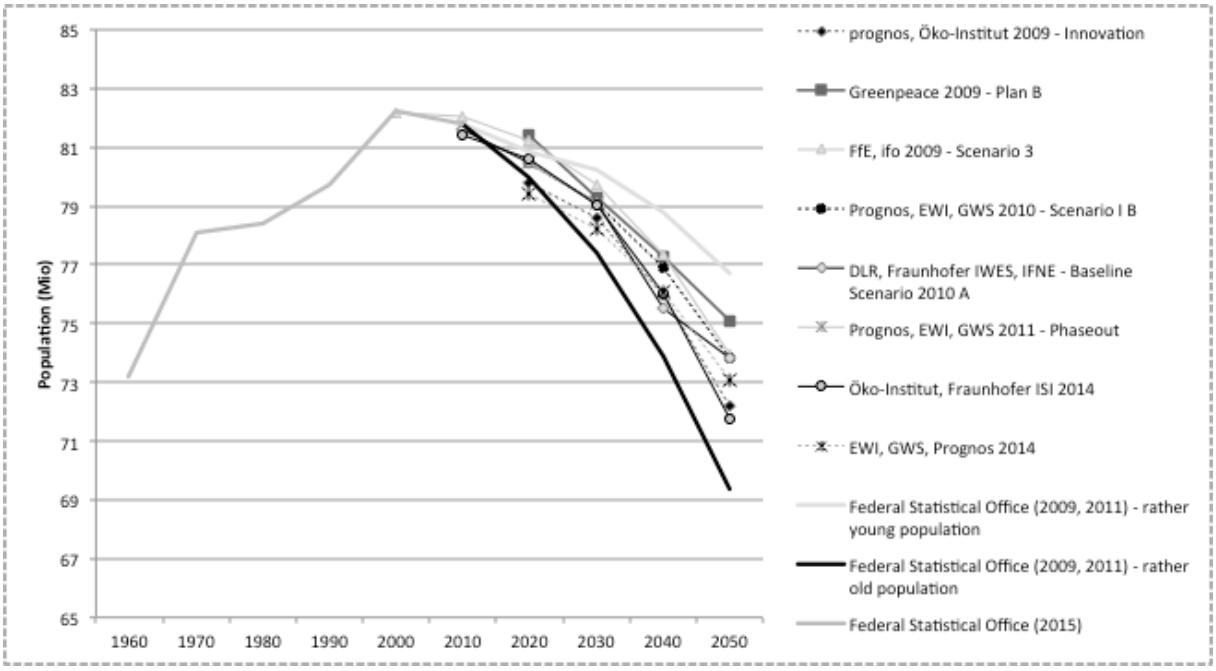

Figure 1. German population since 1960 and until 2050. Statistical forecasts and future scenarios expect a population in Germany shrinking from almost 82 million in 2010 to 69 to 77 million in 2050. Source: Own illustration based on scenarios mentioned above.

bles) and efficiency strategies, sufficiency policies are still lacking as the third principle for sustainable development.

Sufficiency is often defined as frugality, awareness in user 'behaviour' and lifestyle, and reduced consumption (e.g. Alcott 2007, Schäpke, Rauschmayer 2012). As such, the responsibility for sufficiency is reduced to the individual level of decision making and everyday action ('behaviour') and is rarely developed as a field of action for policy makers.

From the perspective of energy policies, combining energy-efficient decision making and 'user behaviour' is sometimes mentioned as relevant to improve energy efficiency while minimising rebound effects and avoiding energy waste. In the building sector, it is mainly addressed through information, labelling, financial incentives, and efficiency standards in building regulations. In this way, policies address individual decisions and action supporting the installation, use and consumption of efficient buildings, technologies, and appliances instead of inefficient ones. But that does not equal a sufficiency policy supporting less use of living space, equipment, and consumption. In Germany this lack can be seen in a constantly growing number of (albeit efficient) cars and technical equipment (Federal Statistical Office 2014b), and in the increase of living space per person and household (Federal Statistical Office 2014a).

The present paper focuses on the latter trend. It is based on the fact, that efficiency gains in German buildings leading to lower final energy use per square meter were for a long time almost compensated by the increasing demand for living space per person; only in the recent past years, overall consumption declined somewhat (see Table 1), which may have been driven both by increasing energy efficiency and increasing energy prices. The paper describes main drivers for the growing living space and compares a range of assumptions for future demand drawn from the current trend in different long term scenarios and studies.

In addition, the paper presents examples of an opposite development. The Tiny House Movement, for example, promotes living in small homes. Moreover, new forms of co-operative living appear as the size of families and households is shrinking – and with it social interaction, support and care.

Comparing both trends, the paper aims to raise the discussion if current building policy in Germany towards more and bigger flats really meets future demands, as households get smaller and people get older. The scenarios show that this development impedes future efficiency gains as it did in the past. As such it is not compatible with long-term targets of energy and greenhouse gas reduction.

People's primary motivation behind living on less space may not necessarily be the reduction of energy use or consumption or other aspects of a sustainable lifestyle. But it may be worth supporting it anyway to achieve both, future demands of individual living and social life as well as saved energy, resources and emissions.

More space for fewer people

Contrary to the forecasts German population grew slightly in the last two years (Federal Statistical Office 2015). But so far this is not defined as change of the actual trend of a shrinking population. Between 2010 and 2060, the Federal Office for Statistics forecasts a decrease between 9 % (with a relatively younger population) and 21 % (with a relatively older population). Based hereon, the assumptions in most recent German long-term energy and climate scenarios expect a decrease in population between 9 % and 12 % (see Figure 1).

But despite a shrinking population, living space in Germany is growing continuously and the same scenarios as above assume this development to continue at least until 2030 (see Figure 2).

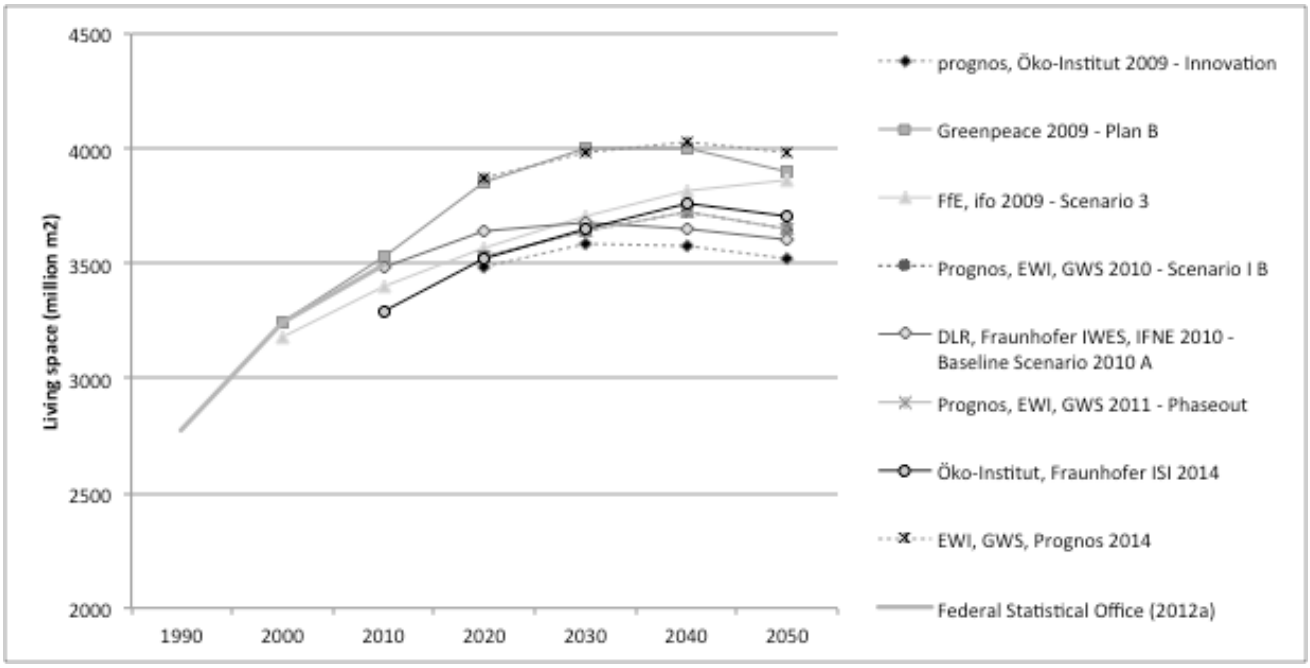

Figure 2. Development of living space in Germany since 1990 and until 2050. Long term energy and climate scenarios assume a further increase of living space in Germany at least until 2030. Source: Own illustration based on scenarios mentioned above.

Table 1. Final energy use for space heating in German households between 1995 and 2012.

		1995	2000	2005	2010	2012	Development 1995–2012
Final energy use for space heating	*TWh*	536	589	509	476	466	- 13,1 %
Population	*million*	79.8	82.3	82.4	81.8	80.5	0,9 %
Living space	*million m²*	2,774	3,245	3,395	3,723	3,763	35,7 %
Final energy use per person	*kWh/capita*	6,717	7,157	6,177	5,819	5,789	- 13,8 %
Final energy use per square meter	*kWh/m²*	193	182	150	128	124	- 35,9 %

Source: Own illustration and calculation based on Federal Statistical Office 2008, 2013a, 2014c, 2015.

WASTING ENERGY SAVINGS

This development is one of the reasons why efficiency gains do not lead to the reduction in final energy use in the residential sector that could be expected with regard to energetic retrofit and efficient buildings. In 2012, German households consumed 15 % less energy for space heating compared to 1995 (Federal Statistical Office 2008, 2013a). But as they used more living space at the same time the savings per person are only 16 % while per square meter of living space they are 36 % (see Table 1).

From an efficiency perspective, this development can be seen as a waste of possible energy savings. To tap the full potential of efficiency, it would be necessary to avoid further increase in living space. Therefore, it is necessary to address the current trends in living and building that demand and deliver constantly growing floor space. In the metaphor of the International Energy Agency and others calling efficiency the 'first fuel' and an 'invisible powerhouse' (e.g. IEA 2014), sufficiency is the 'technology' that reduces overall demand growth.

From a social and political perspective, on the other hand, the idea of limiting living space can be perceived as a sensitive point. "Any call for a general political framework which encompasses the free individual self-determination of our lives is perceived as … a threat. People swiftly resort … to terms like 'the compulsion state', 'eco-dictatorship' or 'neo-socialism'" (Schneidewind, Zahrnt 2014).[1] But do sufficiency policies supporting living on less space necessarily mean a transgression into individual comfort? Or are there potential synergies between sufficiency and social policy? To approach this question, it is necessary to take a closer look at the drivers and effects of increasing living space.

1. This is different for people receiving government aid. In this case housing benefits are tied to a max. price per square meter (depending on the local housing market) and max. living area per person.

THE DRIVERS OF GROWING LIVING SPACE

There are several and partly interdependent reasons for the increase of total floor space in the residential sector.

- **Bigger flats.** One of the drivers for the increase of living space simply is new built houses and flats mostly offering more floor area than buildings of earlier years. While the number of rooms stayed almost constant over the years, the floor space per flat increased between 1990 and 2012 by more than 10 % (Federal Statistical Office 2014c).
- **Detached houses bigger than flats.** Floor space in detached, semi-detached and terraced houses always has been remarkably higher than in flats (Federal Statistical Office 2013b). Single family houses are the most built residential building in Germany. Thereby, as their share in the total number of dwellings increases, the share of bigger living units is increasing too, and with it the average floor space per person (dena 2014, 37 ff).
- **Smaller households.** The number of households in Germany has been growing for decades while at the same time the number of persons per household is shrinking (see Table 2).

  Fewer children are born, which leads to smaller households in younger years. The rising life expectancy on the other hand leads to smaller households with elderly people (see section 'Empty nest'). Moreover, the structure of households, family and living arrangements changed over the years. There are fewer marriages but more divorces, which lead to more single and lone parents with children households (Federal Statistical Office 2011).

  Generally, it can be stated that smaller households use more space per person. The main reason is the shared use of kitchen, bathroom and corridor in households consisting of two or more persons (Federal Office for Environment 2013).
- **Owners in bigger flats.** People who live in their own house or flat occupy more space per person than those in rented flats. In 2011 the ownership rate in Germany was at 45.8 % (Federal Statistical Office 2013c) and is expected to continue rising (BBSR 2010).

Table 2. Number of households and persons per household since 1961 and until 2030.

		1961	1970	1980	1990*	2000	2010	*2020*	*2030*
Households (total)	*million*	19.5	22.0	24.8	28.2	38.1	40.2	*41.0*	*41.0*
Persons per household		2.77	2.64	2.43	2.23	2.15	2.04	*1.95*	*1.88*

** Until 1990 area of former West Germany. Source: Own illustration based on Federal Statistical Office 2009, 2011, 2014 and 2015.*

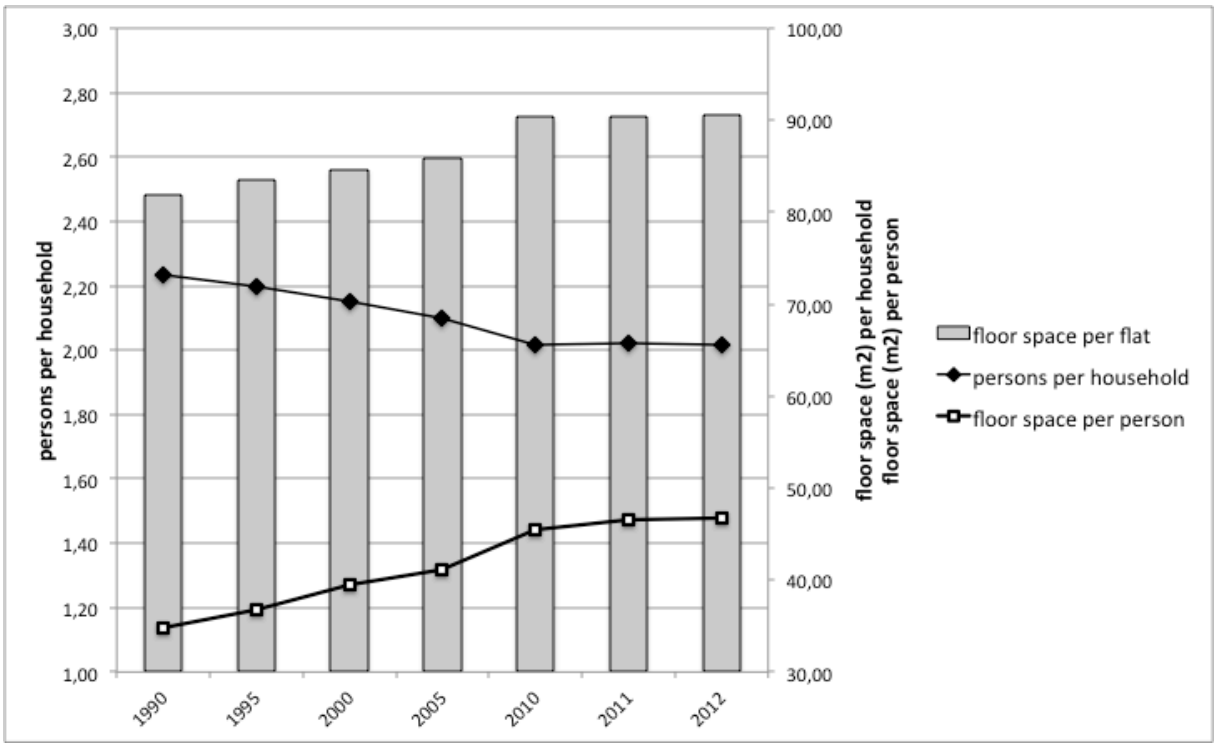

Figure 3. Floor space per flat, persons per household and floor space per person in Germany between 1990 and 2012. Source: Own illustration based on Federal Statistical Office 2014c.

Table 3. Average living space per household in Germany with regard to the age of the household's principal earner.

		18–25	25–35	35–45	45–55	55–65	65–70	70–80	80+
Living space per household	m^2	56.5	76.1	100.3	99.8	96.5	92.1	93.4	89.7

Source: Own illustration based on Federal Statistical Office 2013b.

- **Aging effect.** Older households use more living space than young ones (Federal Statistical Office 2013b). This can be explained with biographical changes that demand more space like family formation on the one hand and wealth effects on the other hand, meaning a rising income over the years, which makes bigger flats affordable.
- **Cohort effect.** The cohort effect describes the living standard of an age group. In this case it says that the households over 65 always lived on less space than the younger cohorts today (Empirica 2005, 9). Looking at Table 3 it can be assumed that due to the cohort effect the demand for living space in the age-groups from 65 will increase in the coming years when the today wealthy cohorts of younger households will reach that age.
- **'Empty nest'.** Elderly households often combine several of the drivers mentioned before. With a good income, over the years they were able to afford a big flat or built a family house when they got children. But once settled in a comfortable flat or house, people often want to stay even if the children moved out already and even if they are widowed. This 'empty nest' effect is a main driver for the increasing demand of living space in Germany (Federal Office for Environment 2013).

IMPLICATIONS OF FLOOR SPACE INCREASE

In Germany, 13.6 % of the total 357,000 km^2 were used as residential and transport area in 2013. More than 12,000 km^2 of this (25.5 %) were used for living (Federal Statistical Office, 2013d.). From 2004 to 2013, the area used for living grew by 9 % while population decreased by more than 2 %. The conversion of new building land at cities' outskirts follows the strategy to attract new inhabitants by offering land for single family houses. The motivation for this is that local authorities receive a part of the income tax. It is a competition between (especially shrinking) cities and regions for more citizens (Spars 2006). But because German population is shrinking in total, it is easy to calculate that not all cities and regions can grow and reverse local shrinking tendencies. So apart from the disputable aesthetic of new built suburban single family and semi-detached houses architecture and the squandered energy savings and emission reduction potential mentioned above, the ongoing urban sprawl has further environmental, economic and social impacts and influences urban development.

Ecological effects also incur due to longer distances that lead to increasing traffic and with it to air pollution, noise and emissions. The converted and partly sealed land is mainly to the detriment of agricultural area, soil quality and environmental values such as habitat for flora and fauna, flood area, or microclimatic importance.

With the inhabitants moving to the suburbs, purchasing power leaves the city centres, followed by retailers and suppliers of daily services giving up businesses, which leads to a loss of functions in the inner cities (Pesch 2003). So especially in regions with shrinking population, this development leads to vacant sites and abandoned buildings in urban centres. Vacancy rates are rising, prices in the housing market are decreasing, buildings stay empty and are no longer maintained, which further enhances decline. Nevertheless, the expansion of settlement and transportation area can be observed all over Germany (BBSR 2012) disregarding population development.

The new settlements have to be connected to services and infrastructure that not only need to be constructed but also have to be maintained in the future. Especially in shrinking cities, these costs aggravate the balance of local authorities' revenue expenditure and financing. For the inhabitants, this means rising service charges which come on top of other – also rising – costs for living and housing e.g. for energy and maintenance. This burdens households, the bigger the house or flat the more, and, thus, not only tenants but owners as well.

To own a house supposingly benefits financial security and provision for one's retirement. But a growing number of householders is overloaded with their property. Especially if there is a lot of space to heat and the building's performance is poor and thus energy costs are high, the danger of old-age poverty comes along with the danger of energy poverty.

Another aspect of overload due to the size of a flat is the housekeeping. As shown in Table 3, older households live in bigger flats, especially homeowners. But with reduced physical capacity, almost one third of older homeowners indicate that the house is too big for them – against one tenth of tenants living in smaller flats on average (Federal Ministry of Transport, Building and Urban Development 2011, 31). What was meant to be a comfortable private retirement home becomes an uncomfortable burden.

Sufficient buildings – building sufficiency

To summarise the drivers and impacts of an increasing living space it can be stated that it is still the predominant trend in Germany but not sustainable in many ways. Maybe that is why another so far rather nondescript trend develops heading into the opposite direction: living on less space.

At this point of the paper it may be necessary to explain more precisely how "sufficiency" is understood here.

1. Sufficiency often is equated with abstinence and reduced welfare. As Alcott (2007) illustrates: "[Sufficiency] … is not … boiling only the amount of water needed for the cup of coffee … [but] doing without the cup of coffee …". Follow-

ing this approach strictly the question appears if sufficiency means to drink (only) hot water instead of coffee, or even not to boil water at all. Translated to the building sector this would mean the most sufficient way to live is homelessness which surely is a misconception of the word. Sufficiency is not the concept of suffering and shortcoming but is a synonym for 'enough' – neither more nor less. On the question what is enough, indeed, there is more than one opinion.

2. This is the point where politics come into play. If the sum of the very distinct needs and wants of people exceeds natural capacities politics have to introduce caps and absolute limits. As stated in the introduction, this paper argues that the responsibility for sufficiency cannot be solely left to individual action (often termed 'behaviour') and decision. Infrastructure, economic interests, existing affluence, cultural and social pressure – there are many influences and obstacles that oppose sufficiency (understood as sustainable livelihood and voluntary decision) or make it unfeasible.[2] Therefore, politics have to build a framework in which individual sufficiency is possible and supported (Schneidewind, Zahrnt 2014, 27 ff).

3. Sufficiency is not the opponent of efficiency. Thus, the paper does not aim to quantify what brings more in terms of emission reduction or other environmental targets. Instead it argues – as the title indicates – that both (in company with consistency) are components of the same strategy aiming for sustainability. That implies, that sufficiency should be implemented – as efficiency and consistency as well – both individually and politically.

But back to buildings.

MOTIVATION FOR LESS SPACE

The individual decision to live on less space (than before or than others) is not necessarily driven by ecological reasons. More often it is not an intrinsic decision but due to external constraints, such as financial or social restrictions that limit living space, e.g. in case of income losses. If someone becomes dependent on government aid, he or she might have to move to a smaller flat due to the statutory limitations for housing benefits. Financial limits are also relevant when children move out. They often start their own household on less space than they had at their parents' house – while parents suddenly have more space.

Living space per person is shrinking, too, when children are born and parents do not move to a bigger flat. Or couples split and both leave the big house that they built together and move to smaller flats. These biographical incidents as well are a rather externally driven motivation.

Furthermore, there are internal motivations that are not aiming for living space reduction but living on less space is rather the 'natural consequence'. These can be singles, couples or families living together in a shared house or flat in order to have the social connection, a relevant motive for elderly people, too. Elderly also might look for security and care in a community or want to reduce strains of housekeeping to stay independent as long as possible. Similarly, families with young children hope to find support within a community, e.g. care for children, and social connections.

Brech (1989, 80 ff) divides the following groups of motives of people living in a community consisting of more than the own family:

- economic reasons
- social and psychological reasons
- political, ideological, ecological, religious and ethical reasons.

In addition to this we suggest a fourth group of motives which is:

- challenge, adventure, self-experiment.

Though this might be close to psychological reasons, this group differs from psychological reasons like wish for security or contact. Especially people who reduce their living space to a minimum often express an almost scientific curiosity regarding experiencing self-limitation. Extraordinary tiny houses or flats are not only an individual challenge but a playground for architects and designers, creating flexible and multi-functional interior. Ideas and concepts behind it are based on the simplification of life and sustainability.

It can be assumed that the motivation of most people is a mixture of different aspects mentioned above. Elderly people for example state the wish for social contact, security in a community as well as the benefit of less domestic work in smaller flats (Federal Ministry of Transport, Building and Urban Development 2011). Whatever are the initial reasons, it is obvious e.g. from this and other studies that there are a significant number of people who are interested in or in need for a smaller living space than they live in today.

As broad as the motivations are the groups of people that initiate and benefit from less conventional living concepts and individually usable buildings. Yet, to the authors' knowledge, no representative studies have examined the potential need and demand for more flexibility in buildings to develop more individual living and housing concepts. Nor have the potential effects on living space and related energy use and emissions in Germany been quantified if these forms of living were supported politically. The synergies between building less and energy and climate policy are not yet discussed in future scenarios (see above).

However, literature discusses current trends and future visions that come along with a potential decreasing demand for living space, e.g. new forms of living for elderly people (Federal Ministry of Transport, Building and Urban Development 2011, 28; Empirica 2012), shared flats for employed people and long-distance commuters (Kunz, Vogel 2010), families with children seeking for support and help on daily care (Schneider 1989), and other groups of specific interest and visions of living. Generally, a noticeable increase of projects of joint building groups can be stated (BBSR 2014; Kläser 2006). But buildings not always fit to other needs than those of a standard one- to four-persons households.

TYPES OF MORE SUFFICIENT BUILDINGS AND THEIR USE

The following section is a first attempt to classify an ongoing collection of so far more than 20 projects, architectural concepts, buildings and their use, having in common that inhab-

2. The absence of cycling pathways is just one example where the individual wish to act in a sustainable way is aborted by infrastructural inadequacies.

itants and users demand less space than the average. Table 4 suggests a classification of projects and buildings into types of floor space reduction by building and use characteristics. Most buildings and projects include more than one of the aspects mentioned in the table.

It has to be noted that the focus of this paper lies on living space, room and architecture. Thus, projects and concepts of efficient or sufficient building use such as reduced stand-by functions or room temperature are not part of the collection. Although the main focus so far is on residential buildings, there are some non-residential projects and examples, too, as in several examples both takes place in the same building or flat. Moreover, with regard to flexibility and sharing there are different and partly more innovative concepts for non-residential uses than for residential.

Due to the limited length of this paper, it is not possible to present all projects but some will be mentioned for each type of building and user concept.

Building design

The group of building concepts covers projects, in which the architectural planning and room concept demands reduced living space. This means that the built environment limits the space. However, in order to maximise energy savings, these buildings should still be very energy-efficient.

Less

In early 2013, the architectural competition adAPT NYC in New York City ended. The task was to develop a "micro-unit apartment building" as a housing model for the "small household population". The winner and finalists all planned various community areas and strove for multi-functionality in the building (Vinnitskaya 2013).

Another example is the Small House Movement. The idea started in the late 1990s in the USA, where 2002 the "Small House Society" was founded (ResourcesForLife 2015). The promotion of small and tiny houses (usually up to 50 m^2 in total) comes along with support of sustainable lifestyles and an unmortgaged property.

Flexible

There are various concepts of flexible architecture, residential and non-residential. One example is the standardisation and prefabrication of units that can be aligned flat or piled vertically. The idea is to extend a building if needed and subtract elements when less space is needed or to deconstruct the building in case it is only temporary needed. The elements can be reused for the next temporary building. Examples can be found in schools that have to be refurbished. Temporary classrooms are installed on the school playground or in the neighbourhood and deconstructed afterwards.

Another possibility is to provide flexibility inside a flat, e.g. movable walls, curtains, or furniture. Especially the latter can be often found in small apartments. More effort is needed if it is necessary to build or deconstruct walls to change the floor plan, for example single family houses, that provide the opportunity to be split up into two (or more) smaller flats.

Furthermore, architecture can support multi-functionality of buildings, flats and single rooms.

Shared

Sharing concepts are well known, like car or bike sharing, but can also be part of architectural concept and design. A project that consequently realised a sufficiency approach through sharing is the Kalkbreite in Zurich, Switzerland. 230 people in 89 flats agreed to live in smaller private flats for the benefit of having several community areas. Including these spaces, the inhabitants live on 35 m^2 per person, which is 6 m^2 below the Zurich average (Genossenschaft Kalkbreite 2010).

Building use

Other than above, the projects listed in the building use column are not necessarily designed and built from the beginning for reduced space demand. More often new forms of living and use move into existing buildings.

Less

Companies' demand for room and space in office buildings can be reduced, when employees are able to work (partly) from home or elsewhere. By now, home office became customary in

Table 4. Classification for building design and user concepts that reduce floor space demand.

Concept	Building design	Building use
Less	• Tiny houses/caravan, container housing • Studio flat	• Management • Virtual rooms
Flexible	• Growing/shrinking floor space • Inner development • Multi-functional planning	• Multiple use • Reuse/change of use
Shared	• Residential homes for special groups • Community areas/rooms	• Shared areas/rooms • Shared furnishings • Interim use

Source: Own illustration.

many professions and companies due to the increasing possibilities of internet – networks, online communication, etc. Virtual companies that only consist of an electronic infrastructure are reduced to the minimum without any need for a physical bureau. On the other hand, if employees have both, an office in the company and a home office, floor space will increase.

Flexible
Most existing buildings and rooms are suitable for more than one kind of use. At the same time, most rooms and buildings are used temporarily only. Thus, it is self-evident to reuse existing buildings when they fall empty and to integrate more than one use and users into temporarily used buildings.

In Germany's rural areas, some villages suffer from the leaving local supply. Many small shops are not economic any more especially with a shrinking population. The idea of 'multiple houses' (Reichenbach-Behnisch 2011) and the 'DORV' initiative (DORV 2013) was born from this development. In both cases empty buildings or shops are reused for several different uses and developed as new supply but also social centre in the villages. According to the needs and wishes of the inhabitants in the villages, local supply is organised and offered: food, medical care, bank, drugstore, café, etc. The operators share the costs for the building and organise themselves regarding space and time they use building, e.g. develop a daily changing order.

For multiple use, flexible interior can be necessary that easily can be changed. In a PR agency in Haarlem in the Netherlands, tables are hanging from the ceiling and can be pulled up after work – with computers and papers on it. The cupboards have castors and can be rolled aside. Like this the room is free for other uses in the evening, e.g. yoga courses, party or art workshops. This is then, at the same time, also an example of shared uses.

Shared
The widest spread form of shared use supposingly are students' communal residences where students live together. Other than boarding schools or residence halls, students living together can be found in all kinds of houses and flats. Usually the rooms are the private areas while bathroom, kitchen and sometimes living room and bureaus are shared.

Another well known example is interim rent. If someone uses a flat or house only partly or has to leave for a longer period, he or she can rent the flat for the time not used. This works for residential use as well as for non-residential. A high vacancy rate of storefronts in city centres can lead to further decline as empty buildings invite for vandalism. Therefore, some cities and companies offer platforms and services for interim use to support contact of owners and potential users (e.g. Zwischennutzungsagentur Wuppertal 2010).

DISCUSSION OF STRENGTHS AND WEAKNESSES

Less
Small houses have a great potential to reduce space per person. As usually detached houses are much bigger than flats (Federal Statistical Office 2013b), small house concepts are a great opportunity from a sufficiency perspective. However, from an efficiency perspective, it has to be stated that detached houses are the least efficient form due to the ratio of a relatively small volume and a big surface area (A/V ratio). So while they will certainly use less energy than bigger homes, they will use more than apartments of the same size and insulation standard. As another weakness of the concept, it can be assumed that is supports urban sprawl and land use change, as it is designed for living in a natural environment with green, garden and vegetable patches around.

In the housing sector, less use and the reduction of living space either means moving to a smaller flat or renting parts of the flat. As existing houses and flats are usually not designed for splitting, single rooms or parts of an 'empty nest' may remain vacant and even not be heated anymore. Thus, energy consumption is reduced but not space. Moreover, in rooms that are not heated properly condensation can lead to dampness and mould.

Flexible
Therefore, buildings with flexible room arrangements and changeable floor plans could address a group of people very relevant for the increasing living space per capita. This could be single family houses offering the opportunity to be split into more than one flat or the option to separate single rooms from a flat for other inhabitants or use. But most existing buildings today are not designed to be flexible, thus the concept works mainly in the field of newly built houses or interior reconstruction.

The construction and deconstruction of temporary buildings works well in the non-residential sector, but it appears to be questionable to which extent the possibilities of flexible ground floors in residential projects really are used. It would be interesting to study the projects in some years again to see how many of the inhabitants made use of it.

The flexibility of use of rooms and buildings is very much dependant on design, size, and installation. There are many examples of offices turned into flats, former industrial buildings used as cultural centres or co-working spaces, and school sports halls and class rooms temporarily used by sports clubs or societies in the evenings. Nevertheless, shape and design of a building and given possibilities for interior (and exterior) reconstruction determine possible changes of use or temporary use and the potential for sufficiency: Rooms and buildings can be too big or too small, missing acoustic insulation can hinder specific kinds of use, missing privacy—e.g. due to lack of separate entrances – can hinder shared use, missing installation (water, electricity, sanitation) can limit public use, or requirements for fire security change with the use, etc.

Shared
Sharing buildings and living space does not only have some sufficiency potential but also supports social life and exchange between the neighbours. The concept has been realised several times by now. Not all projects have as strict rules as the Kalkbreite (limited space per person, no car, etc.). Thus, some projects offer shared uses that from a sufficiency perspective are questionable (e.g. swimming pool, library, gym). It is obvious that these projects rather address a high income group and thus do not contribute to the need of affordable living space in the growing areas of Germany like Munich, Hamburg, Cologne etc. These projects need a closer look to find out if they really lead to less living space per person. However, it is obvious that the projects imply the risk of a sufficiency rebound: The reduced

private space is (at least partly) compensated by shared spaces and uses that a single household would rather not have. So the question appears how much shared space can be offered until the sufficiency gains are compensated?

As a flexible use is limited by the building, one could say that a shared use of rooms, flats, buildings, or furnishing is limited by the people involved. Conflicts arise where different levels of personal engagement for the community, different perceptions of cleanliness or expectations against the community and its benefits appear to be unfulfilled (Brech 1989; Schneider 1989).

Generally speaking, the user approaches bear less weaknesses of rebound, efficiency losses, urban sprawl and land use change than the design approaches. This is not surprising as the reuse of existing buildings has an inherent sustainable quality, the less constructional change is needed for it, the better: The grey energy once used to build the house is saved, no development of land or connection to the supply infrastructure is needed.

But though there are some sufficiency weaknesses in the building design approaches and difficulties , it can be assumed that both the building design and user concepts have the potential to reduce living space per person. As such, sufficiency could have an impact on energy use and emissions from the residential sector in Germany and might lower the expected need for efficiency and renewable energies in the long term scenarios shown above. Of course, the reused buildings still need to be refurbished to high energy efficiency standards.

SUFFICIENCY POLICIES FOR LESS BUILDING

The fact that most projects are initiated privately or by building cooperatives shows that many people are interested in other forms of living than the standard detached house or single flat. And it shows that 'living individually' is not equal to 'living alone'. Though sufficiency may not always be the main motive for people, more projects offering individual living situations can have the same effect. Therefore, it is necessary to know what local people and inhabitants want and need. This participatory culture still has to be learnt in the housing sector and can be developed with the number of projects. Architects and planners can play a major role here. Their task is to advise people, to identify their needs by dividing needs from wants, develop space-saving solutions for them, discuss the long-term use of the building and its correspondence to the users' future, and inform about renewable building materials.

Though the focus of the paper are buildings and their use, it shall be pointed out that there are factors outside the building that support – or hinder – sufficiency as well. For private households this is the question of local supply and if daily care can be managed by foot or bike. Another point is the regulation to provide parking spaces with the building. Instead of regular parking spaces, it should be supported to provide space for bicycles, electric vehicles and car sharing. Other than energetic refurbishment, renewable energy supply and new energy-efficient buildings, sufficiency is not supported comprehensively yet in the building sector.[3] On the contrary, the existing policies for sufficiency with regard to space reduction so far mainly address the least income households: those who are dependent on government aid are limited by legislation to a maximum space per person, although due to the low disposable income these households usually do not live in big flats or houses anyway. Thus, this regulation for sufficiency addresses households with the least potential to reduce space.[4]

The examples show that building policies for sufficiency partly intersect into other fields, e.g. social, family, transportation. While in social politics the need for action due to demographic change is widely discussed already, building policy still supports mainly an outline of life that corresponds to the population of the 1950s with the core family living together in a flat or house. Here is the need for an organised exchange between political institutions to align the different strategies. To respond to the need for future-oriented projects that can be assumed due to demographic change and changing housing preferences, current building policy needs a new focus. Some concrete policy proposals supporting the exchange of dwellings and particularly the move to smaller dwellings can be found in Thomas et al. (2015).

At the same time, support programmes for the reuse of buildings and innovative residential projects have to be extended and those for new developments reduced. German building incentives still support new buildings nationwide disregarding local structures. To consider the cities' different conditions and perspectives, it is necessary to regionalise national funding. While growing cities still need support to offer enough room that is affordable also for low income households, shrinking cities rather need support for the reuse of buildings and refurbishment, deconstruction, and urban mining.

Conclusions and future research

It is possible that some of the suggested politics would lead to indignance in public. But as we showed, there are many motives and reasons for building and living other than conventionally and more sufficiently. Against the background of demographic and social change and the wish of many elderly to live in smaller homes, the need for further projects and an adjusted building stock that allows more individual living concepts is high.

Though the potential of emission mitigation of less building in Germany has not been quantified yet, it is obvious that buildings can be designed and used more sufficiently than today and thus save energy. Still, these new or reused homes will have to be built or refurbished in a very energy-efficient way. Then efficiency and sufficiency together can maximise energy savings. But it is obvious as well, that the development of energy-sufficient building projects so far is more or less a private initiative, politics in Germany did not yet introduce a sufficiency strategy in building.

Analyses of future living space demand usually forecast current trends – people demanding more space over age and stay as long as possible, wealth effects, etc. – into the future. Variance results from size of population and old age dependency

3. The KfW bank included the reuse of non-residential buildings as residential buildings in their refurbishment programmes as eligible costs and there are programmes tackling the reuse of agricultural buildings. Furthermore, social policy supports communal living for older people who need professional care.

4. Of course this regulation is not meant to lower living space demand due to sustainability reasons but to avoid waste of taxpayer money.

ratio mainly. Social and cultural trends including changes in living preferences are not considered, e.g. preferences of future old people might differ from those of elderly people today. As such most analyses come to a further distinct increase of living space demand.

These forecasts then are taken as input for long term energy and climate scenarios. A reversing trend in living space increase assuming a possible national sufficiency strategy is not part of the scenarios[5]. It would be interesting to know what energy demand, share of renewables, and networks would look like in emissions, costs, and employment in a sufficiency scenario with a decrease of living space to e.g. 38 m^2 per person by 2050.

The classification of projects (see Table 4) can be seen as a first step towards a "Building typology of sufficiency". The idea is to collect more projects and concepts for each category and evaluate living space reductions referring to the type of project or building. It might be difficult to distinguish between the different concepts as many projects use both building design and building use approaches. Nevertheless, it appears to be interesting and relevant to follow up on the question, to which extent building design can enable sufficient use of buildings. Or are users able to adapt to all kinds of buildings with a sufficient style of living? To be researched …

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5. An exception can be found on local level in a study presented at the eceee Summer Study 2011 (Bierwirth, Reutter, Schuele 2011).

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