Material Efficiency of Housing in Times of Demographic Change – Evidence from Case Study Research into two German Municipalities

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Abstract. Housing and construction have a significant impact on the consumption of resources of any society. At the same time, on all policy levels strategy documents towards sustainable development highlight the importance of improvements in resource efficiency. Against this background, this contribution presents results of research on the impact of demographic trends and changing user preferences on the use of resources within the housing sector with a focus on construction materials. The material intensity of different types of housing (in particular detached homes vs. apartment buildings) are quantified under different development scenarios drawn on the basis of two medium sized German case study municipalities showing declining and stagnating population development. Among other, the results indicate that the per capita stock of construction materials within the housing sector remains either stable or may even increase despite a falling population. With respect to alternative development scenarios, our results show, that under the condition of a stable or growing population a shift of housing supply from single-family (detached) homes towards a higher share of multi-unit residential buildings can contribute to a more efficient use of materials. An interesting option under the condition of a declining population is the conversion of a potentially growing number of vacant single-family homes into smaller multi-unit/multi-purpose residential buildings since it can help to avoid vacancy and keep otherwise wasted resources in use.

1. Introduction

Demographic trends and changing user preferences have a significant impact on almost all policy areas. With respect to the consumption of resources (raw materials, land, energy), the field of housing construction is of particular relevance. With respect to the focus of this contribution, estimates show that 30-50 % of total material use of societies goes to housing construction [1, 2, 3]. Depending on the type of housing under consideration per capita amount of built-up construction material differs considerably and may be twice as high in the case of detached single family homes compared to apartment buildings [4]. At the same time demographic changes at least locally lead to increased housing vacancy and, as a result, to a decreasing material efficiency of the housing stock.

Against this background, the research presented here investigates the impact of demographic trends and changing user preferences on the amount of construction materials used in the housing sector – or unused respectively. Adopting a case study approach, two medium sized German towns of roughly 30,000 inhabitants, one with a stable population development and a second with declining population, were scrutinized. To ensure comparability, the case studies were carefully selected e.g. with respect to
population and housing stock structures as well as geographical and general development context. Both are West-German municipalities with a share of senior population (aged 65 and older) > 20 % and a share of single- or two-family-houses > 80 % of the residential building stock. Based on a series of interviews with local experts and available municipal demographic (migration and natural population change) and housing data (structure of residential building stock and types of flats inhabited by the different household types) and using an advanced version of the IOER online housing demand forecast model [5, 6] future housing demand and alternative scenarios were projected with a time frame until 2045. Major input data were migration and natural population development figures and the structure of residential building stock and types of flats (size and number of rooms) as inhabited by different household types (younger 1–2 person households, elderly 1–2 person households and households with 3 or more persons). Finally, drawing on a building database and representative synthetic building types [7, 8] the material intensity of the housing stock was calculated and compared for different development scenarios. Overall the research aims at generating data and fostering awareness for the material resource implications of different housing preferences and development paths.

In the following, projections of demographic trends as well as demand and building stock developments are presented. This is followed by an estimation of the resulting resource implications in terms of the amount of construction material in use or fallow respectively. The final section provides a brief summary and outlook on options for action.

2. Population, household development and housing demand

For the purpose of this proceeding and since the results in general show similar trends, in the following the results for the case study municipality with a declining population (Case Study D) are focused. However, as far as the case study town with a stable population (Case Study S) reveals particular features they are described in the text.

The forecasts regarding population and number of households – as core driver of housing demand – for the period up to 2045 for both cases clearly show the expected ageing of the population and increase of the number of smaller households. Despite the general loss of population in Case Study D and due to the trend towards smaller household size, we initially see an increase in the number of households until the year 2030 followed by a decrease until 2045 (Figure 1).

**Figure 1.** Population and household development for 2015–2045 classified by age groups and household types for Case Study D (Source: Own calculation and presentation based on official statistical data)

With its largely stable population, Case Study S nevertheless shows a similar development regarding household developments. So for both cases housing demand can be expected to rise until 2030 and then to decline until 2045 towards a similar level as 2015 (Case study S) or even below (Case Study D).
Because of the considerable differences with respect to specific material resource intensity a distinction was made between demand for flats in single- or two-family-houses (STH) and multi-family-apartment-houses (MFH). In 2015 STH housing represented 57% of flats in Case Study S and 65% of flats in Case Study D. For the projection the basic assumption was made, that the preferred housing type and flat size by rooms and floor space by the various household classes does not fundamentally change compared to the initial situation as represented by 2015 housing statistics. Figure 2 shows the resulting trend scenario for demand for new flats per 5-year period as demand for STH and MFH.

![Figure 2. Demand for new flats per 5-year period in the trend scenario up to 2045 for Case Study D (Source: Own calculation and presentation based on official statistical data)](image)

Demand for new built flats rises until 2035 and then falls to a low level of constant “qualitative demand” for new built flats which typically exists independently from available vacant housing.

In Figure 3 we can see the rise in vacancy rates, especially for STH flats (with the majority being detached single family homes), when the number of households begins to fall again from 2030 onwards. This general finding is also true for Case Study S although there vacancy rates do not exceed 6% for MFH flats and 10% for STH flats.

![Figure 3. Development of the flat vacancy rate (percentage) in STH and MFH in the trend scenario up to 2045 for Case Study D (including the “natural vacancy rate” necessary for market flexibility; Source: Own calculation and presentation based on official statistical data)](image)
3. Implications for material efficiency of the housing stock

Here, as above, the results for the Case Study D are illustrated graphically. Particularities of the Case Study S (with stable population development) are mentioned in the text. Drawing on a database of typical residential buildings and assuming a representative mix of building types and construction materials within the existing building stock and for new construction, the square meters of housing demand were translated into construction material masses. A trend scenario and two alternative scenarios were calculated.

3.1. Trend Scenario

For the trend scenario we can clearly observe an increase in the stock of materials as a whole as well as an increase in the stock of materials within vacant buildings. For Case Study D, despite the decreasing population, construction materials in the housing stock sum up to 4,309 kt in 2045 compared to 4,139 kt in 2015. Thereof in 2045 STH vacancy is accountable for 531 kt (2015: 247 kt), and MFH vacancy for 71 kt (2015: 46 kt). It is interesting to note, that with these figures the amount of construction materials used for the related urban infrastructure is not yet considered. As a rough estimate this can be assumed to add 60% of the building related material mass in the case of STH neighbourhoods and 30% in the case of apartment buildings.

Adopting an efficiency perspective, a cost-benefit analysis of the housing stock can be conceptualized by the indicator tonnes of construction materials accumulated in the housing stock per resident (t/resident) with tonnes of construction material understood as ‘cost’ and residents served understood as ‘benefit’. Figure 4 shows the “material load” per resident for the case study municipality as a whole as well as for the stock of vacant housing. In addition to the effects from demographic trends (smaller households and population decline), we can clearly see the higher resource intensity of STH compared to MFH housing.

3.2. Alternative scenarios

In order to estimate the impact on resources of alternative development paths, two further scenarios – “Conversion of STH” and “Concentration of MFH” – were calculated in addition to the trend scenario.

3.2.1. Scenario “Conversion of STH”. In the scenario “Conversion of STH”, it is assumed that the demand for smaller flats (maximum of 3 rooms) can be satisfied by converting vacant single-family houses into two small flats [9]. As a result, this reduces vacancy rates in the SFH segment as well as the need to construct additional MFH, thereby making the case study town “lighter on resources”. By 2045 the material intensity of the housing stock in this scenario adds up to 159 t/resident in total compared to 161 t/resident in the trend scenario. For the STH-segment it is 170 t/resident (trend: 173 t/res.) and for...
the MFH segment it is 133 t/resident (trend: 132 t/res.). The slightly higher material intensity for the MFH stock results from the higher specific material intensity of the converted former STH flats.

It is interesting to note that the conversion scenario cannot be meaningfully applied to Case Study S, since in this case the demand for housing up to 2035 is not met by an adequate, convertible stock of vacant single-family houses; further, demand will decline in the following years to such an extent that there is no longer any additional requirement for living space gained through such conversions. Hence, the conversion scenario in this case is almost identical to the trend scenario in terms of material intensity.

3.2.2. Scenario “Concentration of MFH”. The basic assumption underlying the second alternative scenario “Concentration of MFH” is that small households made up of elderly individuals begin to increasingly favour MFH and construction of such housing is intensified. This scenario is motivated by statements in the interviews that while senior citizens are looking for “retirement apartments” in the town centre (“reurbanization”), the supply of such housing is currently insufficient to meet demand.

In terms of resource usage, the increased occupancy of MFH in this scenario means that the resource intensity per resident is clearly lower compared to the trend scenario for this segment. At the same time, however, the higher vacancy rate in the STH stock (19% compared with 16% in the trend scenario for Case Study D) leads to a significantly higher resource usage per resident in this sector. In total, the resource usage per resident also rises as a result of the increased construction of MFH and the abandonment of STH. By 2045 the total material intensity of the housing stock in this scenario adds up to 162 t/resident compared to 161 t/resident in the trend scenario. For the STH-segment it is 181 t/resident (trend: 173 t/res.) and for the MFH segment it is 121 t/resident (trend: 132 t/res.).

For the Case Study S the MFH scenario shows a favourable drop in total material intensity until 2035, as here – due to higher demand – vacancy in STH stocks is limited. Nevertheless, until 2045 it also ends up with an increased total material intensity compared to the trend scenario. All in all the scenario shows that the mere provision of alternative, even less material intensive housing tends to increase the material consumption of the building stock as a whole. However, under conditions of demographic stability or growth, as it is the case for Case Study S until 2035, it makes sense to attempt to steer housing demand towards flats in MFH. In addition, from a wider perspective, additional benefits of this scenario can be understood as arising through a reduction in the volume of commuter traffic, since people move closer to the city centre. Ideally, it would thus also be possible to demolish vacant buildings of the STH stock in the outlying districts to create green space or to reuse the plots for new buildings.

4. Conclusions

Overall, the projections of the impact of demographic change on the housing stock at the level of the surveyed case studies indicate that the material intensity of the housing stock remains either stable or may even increase despite a falling population. This is of particular relevance, if we take the amount of construction material accumulated in the housing stock per resident as an indicator of an important dimension of urban resource efficiency. A key factor driving this development is the increase in per capita living space, driven not only by rising prosperity but also, by the reduction in the size of households and, more generally, by higher levels of vacant housing.

Thus, municipalities – especially those outside growing regions – will have to adapt to vacant housing stocks in the longer term. Assuming unchanged preferences and demand for existing or new residential buildings, the model calculations indicate increasing vacancy rates also for STH stocks from 2030 onwards. Even for the case study town with a basically stable population development, the model calculation for 2045 shows a vacancy rate in the STH sector of up to 10%. Under demographic change demand for such housing is simply insufficient to deal with the increasing number of vacant buildings. This development leads to the “generational housing bubble” [10], an issue that is far from being widely recognized on the political agenda.

The model-based investigations of alternative scenarios show that approaches aimed at modifying the housing stock can theoretically ensure considerable savings in material consumption. In practice,
however, this can most likely only be implemented to a very limited extent due to the quite ambitious and theoretical assumptions. Therefore, with a view to options for action, commitment to the continued use of established housing stocks – and the embodied materials respectively – seems to be not only a prudent option but also the most feasible. Here a large number of organizational as well as structural/spatial approaches and good practice examples can already be found in urban development literature and exchange networks. However, this needs awareness of local decision makers for longer term trends beyond the short term temptation of apparently easy solutions with new built green field developments.

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References
[1] ECORYS and Copenhagen Resource Institute 2014 Resource efficiency in the building sector; Final report (Rotterdam: DG Environment) p 19 http://ec.europa.eu/environment/eussd/pdf/Resource%20efficiency%20in%20the%20building.pdf; accessed Oct 10 2018
[2] Schiller G, Blum A and Behnisch M 2012 Resource efficiency of settlement structures: terms, conceptual implications and connecting factors to the resilience debate Raumforschung und Raumordnung vol. 70(4) pp 377–86 https://doi.org/10.1007/s13147-012-0168-9
[3] Halls S 2003 The building and construction sector: cornerstone of sustainability UNEP Industry and Environment April – September pp 3-4
[4] Blum A, Martinsen M and Krauß N 2016 Single family home stocks in transition – implications for urban resource efficiency Proc. Int. Conf. Sustainable Built Environment (Hamburg: ZEBAU) pp 1050-58 https://doi.org/10.5445/IR/1000051699
[5] Oertel H 2017 Kleinräumige Vorausberechnung von Bevölkerungsentwicklung, Wohnungsnachfrage und Wohnungsbautätigkeit Wege zur Umsetzung von Ressourceneffizienzstrategien in der Siedlungs- und Infrastrukturplanung (IÖR-Schriften 74) ed G Schiller (Berlin; Rhombos) pp 29-56
[6] Iwanow I 2008 Struktureller Wandel der Wohnungsnachfrage in schrumpfenden Städten und Regionen: Analyse und Prognose von Wohnpräferenzen, Neubaupotenzialen und Wohnungs leerständen. (Berlin: LIT)
[7] Gruhler K and Böhm R 2011 Auswirkungen des demografischen Wandels auf das Stofflager und die Stoffflüsse des Wohneinrichtungsgüterverbrauchs – Deutschland 2050 (Reihe Wissenschaft 25) (Stuttgart: Fraunhofer IRB)
[8] Gruhler K, Deilmann C, Böhm R and Schiller G 2002 Stofflich-energetische Gebäudevergleiche – Gebäudevergleiche und Hochrechnungen für Bebauungsstrukturen (IÖR-Schriften 38) (Dresden:IÖR)
[9] Lindenthal J and Mraz G 2015 Neues Wohnen im alten Haus. Sanierungsoptionen mit Zukunft: vom Einfamilien- zum Mehrpersonenhaus (Wien: Österreichisches Ökologie-Institut) http://www.ecology.at/rehabitat.htm; accessed Oct 10 2018
[10] Myers D and Ryu SH 2008 Aging baby boomers and the generational housing bubble: Foresight and mitigation of an epic transition J. Am. Plann. Assoc. 74(1) 17–33 https://doi.org/10.1080/01944360701802006