Implications of declining household sizes and expectations of home comfort for domestic energy demand

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Abstract

Techno-economic approaches largely avoid delineating necessary energy uses or questioning how excessive lifestyle expectations may curtail attempts to achieve ambitious climate change targets. In this Perspective I present data suggesting a general trend of increasing domestic floor area per capita globally and argue that this ought to be a key focus in future energy research considering that house size is the largest determinant of domestic energy consumption. Particular attention should be directed at the confluence of factors that influence floor area per capita and questions of lifestyle expectations, energy sufficiency, and invisible energy policies which have enabled the rise in floor area per capita both deliberately and inadvertently. Overall, this elucidates why energy research must consider lifestyle expectations and demographic trends that are generally seen as outside the remit of energy policy.

Introduction

Despite extensive investment in efficiency, global energy consumption continues to rise. As such, it is now widely agreed that any effective response to avoid risky climate change will require new ways of living, working and relaxing.[1] This is in part because there are limits to the dominant strategies of energy efficiency improvements and behaviour change campaigns, as these approaches take existing understandings of energy needs for granted and do not radically challenge social conditions in which needs are defined.[2] Furthermore, global demographic changes and processes of (sub)urbanisation undermine energy reduction from technical solutions. In this Perspective I bring together government data sets on floor area per capita which, combined with previously published data on house and household size, suggest that increasing house size and parallel demographic trends of decreasing household size are resulting in a global shift towards more domestic space per person, which may significantly impact energy consumption. This highlights opportunities for energy researchers to contribute to debates over the human drivers of carbon emissions[3] and homes in on an apparent contradiction: why do we need larger homes for smaller households? Declining household size has substantial demographic momentum, but rising house size is the result of norms and policies that can be changed[4]. Thus, the final section of this Perspective points to areas of invisible energy policy—non-energy policies which have unacknowledged, or insufficiently acknowledged, impacts on energy demand[2] - deserving more attention in energy research.

Household size, house size, and floor area per capita

Household size decline has important energy implications[5,6] and shifts in household size are an important determinant of energy consumption and carbon emissions per capita[4,7,8,9,10]. This research, largely emerged from household and environmental demography, highlights the neglect of households in development studies and suggests that household size is often a better predictor of carbon emissions than population[3,7,8,9]. The decline in household size is a global trend. For instance, Bradbury *et al.*[7] found that household size has been declining increasingly since 1900 and most low- and middle-income countries have also seen an accelerated decline since 1987, albeit with erratic patterns. Currently around 40% of Scandinavian households and 30% of UK and US households are one-person households[11].

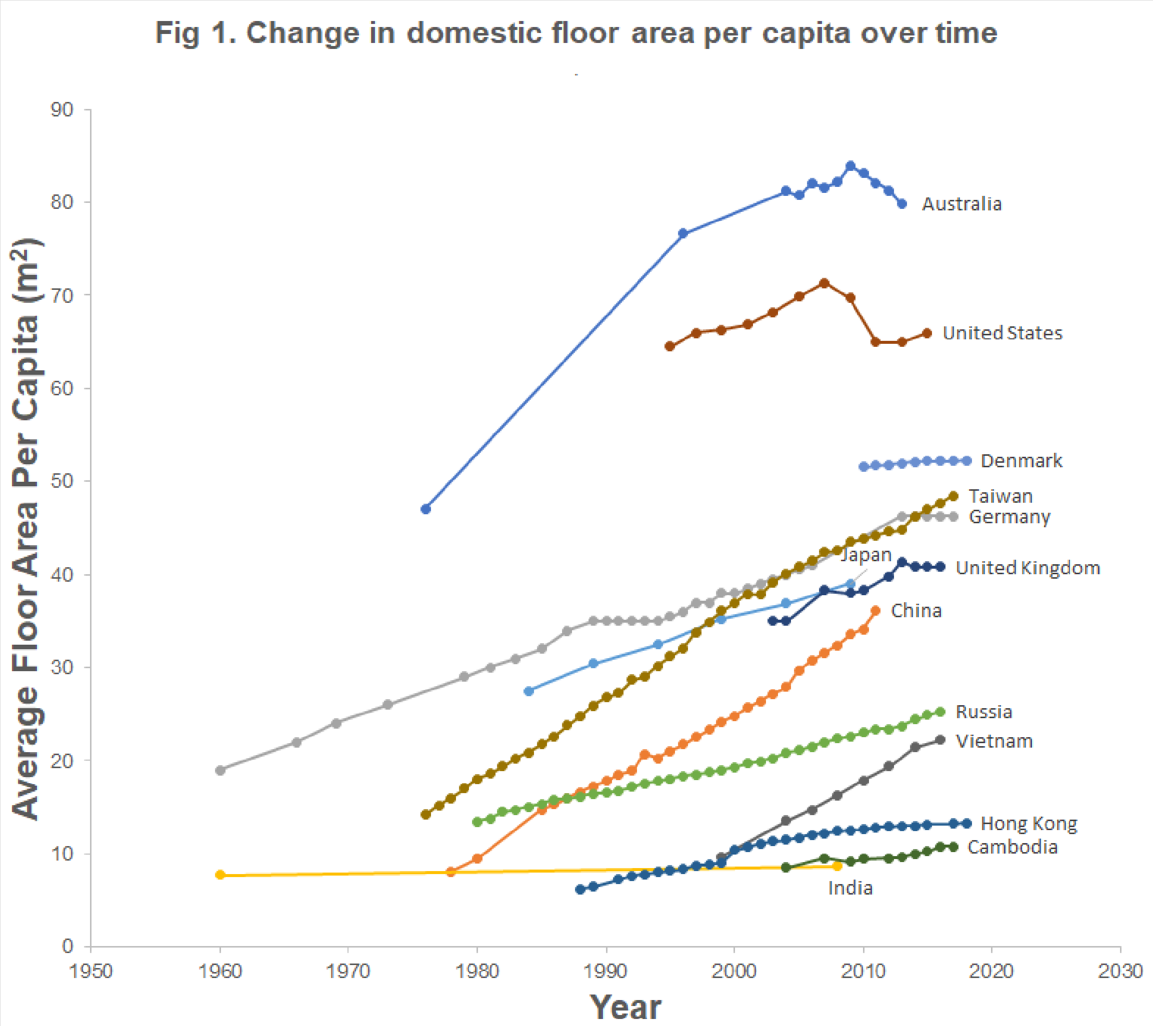
Even though social and economic development often slows rates of population growth (e.g. declining total fertility rate), development also yields more and smaller households[7]. This can increase consumption per capita in terms of building more houses and the carbon emissions embedded in construction and materials in the home (e.g. cement, timber, glass, plastic, electrical goods) and due to a loss of economies of scale and sharing[4,7,8,9,10]. For instance, there is a greater demand for household goods such as refrigerators, internet routers and washing machines as these are not shared within a larger household. The energy for baseload demands such as heating are also greater per capita as they are not shared amongst as many household members. Across a range of national contexts, other things being equal, smaller households have been found to increase (direct and indirect) energy and resource consumption, waste generation, and biodiversity loses[8,12].

Yet there is little empirical testing of the mechanisms for why co-habiting would reduce consumption per capita and norms of sharing and how communality is practiced is over-simplified[13]. For example, individuals living alone can be creative in strategies to achieve economies of scale (i.e. cook in bulk and freeze leftovers) and can still be part of wider communities that might share food, tools, or clothing. Nonetheless, an empirical study suggests that on average an additional household member reduces carbon emissions by 6% per capita[12]. This study cautioned that decline in household sizes is outstripping another potential benefit of development to reduced carbon emissions: increased urban density. Indeed, declining household size is often attributed to suburban sprawl and anti-suburban narratives, especially in relation to environmental sustainability (see Charmes & Kiel[14] for critical assessment of the preference for density in urban studies).

Housing and urban policy studies have commonly discussed the need and demand for alternative housing forms due to wide recognition of decreasing household size[15]. Urban studies importantly explore the environmental impact of demographic changes and suburban sprawl[16,17] often focusing on the energy implications of construction, travel patterns and infrastructures, environmental impact from consumption broadly, or modelling on a metropolitan or neighbourhood scale (cf. Charmes & Keil[14]; Gray *et al.*[17]; Stephan *et al.*[18]). However, there are still underexplored gaps relevant to addressing the paradox of decreasing household size and increasing house size, such as why small households do not live in small houses[15,19] or how floor area per capita, as opposed to density of housing, influences energy consumption per capita.

Within energy research, house size has received limited attention despite clear evidence that building characteristics such as house size and typology are the largest determinant and predictors of energy consumption (see Huebner & Shipworth[20] for an excellent overview), accounting for up to 42% of performance variability[20,21,22]. In comparison, the impact of occupant characteristics such as household size and income is much lower, ranging from 4.2 to 20%[21]. Moreover, increasing house sizes in high-income countries are negating energy savings from improved efficiency standards and building regulations[5,6,23,24]. For instance, Clune *et al.*[23] calculated that increased house sizes in Australia decreased efficiency standards by 38% over a 6-year period. Other research has found that a smaller house built to a lower energy standard in many cases uses less energy than a large house built to a high standard[6,23,24]. Indeed, large houses are often not built in more efficient ways as features such as grand staircases (e.g. double height spaces) or multiple roof lines (e.g. complex geometry) to present a grand entrance are more likely, despite their impact on building performance[6,24]. This should be a significant concern in domestic energy research and policy considering evidence of increasing house sizes in high-income countries[5,6]. For instance, Viggers and colleagues[6] find that while flats and apartments in Australia, Canada, New Zealand, The UK and the US have stayed a similar size over the past century there has been a significant increase in larger detached homes. Previous domestic energy research has generally considered only household or house size, without bringing them together to explore their joint influence on domestic floor area per capita.

Based on government data from thirteen countries, Fig. 1 gives an indication of a general increasing trend in floor area per capita, with the highest average of 84m^2 in Australia (2009) and the lowest stable average in India of 7.7m^2 (1960) to 8.7m^2 (2008). Upper-middle (China, Russia) and lower-middle income countries (Cambodia, India, Vietnam) generally have lower average floor area per capita than high income countries (Australia, Denmark, Germany, Hong Kong, Japan, Taiwan, United Kingdom, United States of America), but these averages do not capture variations due to urban and rural divides (i.e. Hong Kong data highlights space per capita constrained by urban density) or low and high income within a country. There are limitations to these comparisons as government's measure house size differently (e.g. measurement by the external wall or internal usable space, inclusion or not of garages or second houses), definitions of "household" have varied across time and between countries, and there are variations in how measures of occupation and house size are combined. Nevertheless, these data suggest that changes in house size and household size are converging to result in increasing floor area per capita. This has implications for energy consumption per capita considering that space heating and cooling are the main use for energy in homes (i.e. buildings account for nearly a third of global final energy consumption: three-quarters of this is domestic buildings and nearly 70% is for heating[25]). Thus, despite efficiency improving globally and reducing the energy use per unit of floor area at an average annual rate of 1.3%, the growth of floor area, which has an average annual growth rate of 3% globally, results in rising demand[26].



Influence of demographic changes

Declining household size is one aspect of advanced societies undergoing urbanisation and post-industrialisation and has been a pattern recognised since the 1980s as the 'second demographic transition' (see Lesthaeghe[27] for an excellent overview and Sobotka[28] who highlight diversity and complexity in how this manifests in different countries). Fertility declines, partnering and parenting are delayed, divorces and household dissolutions increase, and the number of multi-generational households decrease[7,10]. In some countries, increased flexibility in transitions to adulthood result in more opportunities throughout the life course to live alone while remaining parents are living longer and maintaining smaller households after children move out[7,29]. These shifts are generally attributed to an increase in income (e.g. less dependent on economies of scale to meet the cost of domestic goods); a shift in ideals and the importance of self-actualisation, autonomy and individual privacy (e.g. urbanisation and living in cities results in more human contact, with the home becoming a greater source of escape and autonomy); and a reduced availability of kin to co-habit with (e.g. sharing a home is seen as a family matter and this intimacy is not extended to strangers and friends)[3,9,30]. The implication is not just that household size decline can, or should, be stopped due to its impact on energy consumption per capita[3,8,12], but rather that these trends raise opportunities to consider engaging with invisible energy policies and relate to understanding changing expectations of energy needs.

First, in demographic literature the desire for increased privacy is commonly identified (although debated) as a driver of declining household sizes[7,30] because the second demographic transition is founded on the rise of 'higher order needs' such as self-actualisation and individual autonomy[27]. Arguably, experiencing greater autonomy could shift images of a desirable home life and make people more resistant to sharing their (future) homes. For example, although preferences vary between cultures[31], after living on your own during higher education, you may be less willing to move back with your parents or in with your partner's kin and the inclination instead is to set up your own household[29].

Second, declining fertility, mortality and morbidity present novel challenges which also have implications for energy consumption per capita[9]. Older people are increasingly living alone, with figures as high as halve of over 65 years olds in high income countries[32]. For example, in Japan there has been a shift from taking care of parents being 'a natural duty' of children with 66% of women surveyed in 1950 expecting children to support them in old age decreasing to 16% expecting this forty years later due to not wanting to be a burden[32]. With the decline of multi-generational households, 'empty-nesters' may be advised to invest in energy efficiency or undertake energy saving activities but one of the most effective ways for them to reduce their consumption is by downsizing or taking on lodgers: recommendations generally seen as outside of the remit of energy advice and policy[20,33].

Downsizing has benefits for energy reduction, yet the mismatch between the number of bedrooms households have versus need is generally uncontested[20]. There are numerous reasons why people would be unwilling or unable to downsize: strong attachment to one's home; a perceived lack of storage in smaller dwellings; fear of losing autonomy if moving to collective housing; not wanting to leave the wider community and networks of support in which their home is situated; protecting inheritance and financial security; and a lack of adequate housing options to move to[20,34]. Importantly, these final two issues highlight clear avenues for energy research and policy. First, capital gains, real estate transfer or stamp duty land taxes result in a financial loss for householders and concessions on these have been identified by multiple authors as a key way to support downsizing[5,20,24]. Second, developers have been widely criticised for failing to build a range of options to allow for downsizing in many high-income countries[20,23]. For example, in German cities, 40–50% of the population live in one person households and 30% in two person households yet 3-4 room flats are most common. The result is two to three times as many one person households as 1-2 room flats[5]. Longer life spans and a desire for more privacy suggests changing needs over the life course and there are opportunities to provide more flexible housing forms. For example, homes that have bedroom(s) that can be adapted for renting to avoid extra space before or after having children, communal housing that has shared facilities to accommodate guests, and co-housing. Energy researchers should engage with architects, urban planners and developers on attractive alternative designs that respond to the needs of smaller household sizes and predicted future demographics.

Discussion

The trends identified above of increasing house sizes and floor area per capita undoubtedly impact expectations of home comfort and aspirations for the ideal home. Just as standardisation and globalisation has resulted in homogenisation of indoor temperatures across the globe over the past forty years[35], so too can increasing floor area per capita shift norms and expectations of how much space is 'enough'. Consequently, the notion of energy sufficiency is important; absolute reduction in domestic energy demand cannot be achieved without measures to limit average floor area per capita[5].

Challenging the perception that 'bigger is better' is a clear area for future energy research considering the emphasis on house size as a determinant of energy demand and that living in appropriately sized homes significantly impacts energy consumption[19,22]. Instead of information and behaviour change campaigns on savings from upgrading boilers or installing efficient light bulbs, marketing could target the drawbacks of larger homes (i.e. affordability, cost of heating/cooling, more time and labour to clean and maintain, unsuitability later in life with stairs); instead of eco-home road shows, showing off high-quality, compact homes could shift perceptions of space needs[24,36,37]. Furthermore, regulations that could encourage developers to shift their own practices are needed. For instance, measuring an house's total energy demand rather than the current dominant practice of calculating energy efficiency by m^2 which incentivises building larger homes because larger homes benefit from economies of scale[5,6,23,24]. Moreover, covenants by developers which establish minimum floor areas or restrict sub-divisions limit options for creating small, space-efficient homes[23,24]; the rationale for covenants and their variability presents an avenue for future research. Finally, changes to government land-use zoning could encourage denser residential areas and more building around transport hubs2,[23,24]. Indeed, policies supporting urban infill (e.g. granny flats and tiny houses) could encourage more diverse and affordable housing[23]. Considering the demographic trends identified above more small and even short term accommodation are needed to meet changing housing needs over the life course (e.g. young adults moving out earlier and living on own, older generations wanting to maintain autonomy and privacy).

Moreover, energy researchers should not simply focus on restricting increasing house sizes but should also ensure that housing provides adequate occupant satisfaction in terms of privacy and personal space as this is assumed to be a part of modernisation and a driver towards smaller household sizes. Drawing on the rich literature on meaning and making of home[38,39] and the OECD[40] framing of the basic necessities of housing suggests that having a sense of control and 'being able to do what you want' is arguably as important to occupant's wellbeing as ensuring housing allows occupants to be sufficiently warm or cool. For example, in the UK, poor sound-proofing and disturbance from neighbours is one of the most common complaints about living in flats and justification for the desire for a detached house[41]. Improving standards of visual and acoustic privacy in high-density housing or creating opportunities for personalisation in rented accommodation (e.g. not being able to decorate in rented properties, halls of residence) present other invisible energy policies that could improve satisfaction with smaller, communal and high-density forms of housing necessary to reduce absolute energy consumption.

In conclusion, floor area per capita ought to be a key focus in future energy research considering that house size is the largest determinant of domestic energy consumption[20, 21, 22] and is on the rise[5,6] at the same time as household sizes are declining globally[4,8,10,12] and smaller households have been found to increase (in)direct energy consumption[8,12]. Smaller households, potentially driven by increased expectations of privacy, self-actualisation and individual autonomy, are recognised to be part of the process of development and (sub)urbanisation[7,10,15,27]. Increasing floor area per capita and numbers of bedrooms and bathrooms in homes highlight these changing collective conventions that shift perceptions of what is necessary for a basic standard of living. Techno-economic approaches largely avoid delineating necessary energy uses or questioning how excessive lifestyle expectations may curtail attempts to achieve ambitious climate change targets. There is thus much to be gained from engaging with invisible energy policies such as the ways in which housing standards, zoning regulations, and marketing of home improvement impacts house size and floor area per capita. Exploring the notion of energy sufficiency, challenging the perception that 'bigger is better,' measuring energy efficiency by building rather than m^2, engaging with land-use zoning regulations, and improving standards of visual and acoustic privacy present ways forward to connect processes that have significant, yet largely ignored or invisible, impacts on energy demand.

Fig. 1 Caption

Citations identify sources for each data point and clarification is provided on variation in measures for some countries: Australia: 1976 & 1996[41]; 2004-2013[42]. Australian data is only on average floor area for new residential buildings (rather than a sample of the whole housing stock) and these figures were divided by the average household size for the closest corresponding year. Cambodia: 2004-2017[44,45,46,47,48,49,50,51,52,53]. China: 1978-2012[54]. The Chinese dataset distinguished between rural and urban floor area per capita. Rural figures (2-5m^2 higher than the urban measure) were used because these provide a continuous dataset from 1978 while the urban measure is distinguished from 2002. Denmark: 2010-2018[55]. Germany: 1960-2006[56]. Hong Kong: 1988-2018[57,58,59,60,61,62,63,64,65,66,67,68]. Figures for Hong Kong are based on public housing only. India: 1957[69]; 2008[70]. Japan: 1993-2013[71]. Japanese data collected every 5 years, including average floor area per dwelling and average household size in the same census. Russia: 1980-2016[72]. Taiwan: 1976-2017[73]. United Kingdom: 2003-2007[74,75,76]; 2009-2016[77,78,79,80,81,82,83, 84]. UK figures are based on English data, which does not calculate floor area per capita and mean floor area was divided by the average household size for the closest corresponding year. US: 1993-2015[85,86,87,88,89,90,91,92,93,94]. Vietnam: 1999[95], 2004 – 2016[96,97,98,99,100,101].

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