Conceptualising urban density, energy demand and social practice

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Abstract

In urban studies and in energy policy there is much debate about the relationship between energy demand and the density of residential areas, measured in units like those of population per hectare, or per Km2. In this paper we take a different approach. Rather than evaluating the relative merits of compact or sprawling urban forms we focus on the spatial configuration of the infrastructures, appliances and systems of provision on which city life depends. An interview based study of households living in the same extremely 'dense' neighbourhood in Hanoi allows us to show how practices of cooling, laundering and cooking (and the energy demands associated with them) are shaped by material arrangements that exist within the home and that stretch far beyond it as well. The conclusion that supply and demand are constituted across multiple spatial scales has practical implications for urban design, and for how the relation between energy demand and density is defined and understood.

Keywords: density, social practice, object relations, energy demand, urbanization

Practice relevance

- We show that energy demand is a consequence of how social practices are distributed and organised across space and time.
- We provide a means of conceptualising relations between material arrangements and energy demands at different scales: from the layout of the home through to more extensive infrastructures and systems of provision.
- We discuss the implications of these ideas for debates about urban density and design.

Introduction

In the field of urban planning, the contrast between cities that are densely packed or sprawling is a central concern (Ewing 1997; Gordon and Richardson 1997; Dieleman and Wegener 2004). Given the challenges of climate change and of reducing carbon emissions, the relation between urban form and energy consumption is an important topic. It is also controversial. On the one hand, authors like Duany, Plater-Zyber and Speck (2001) and Dieleman and Wegener (2004) argue that greater density represents a more efficient use of land, involving less extended infrastructures for energy, water, and sewage, and fewer transport-related emissions because of reduced car dependency and more efficient public transport. There are other arguments in favour of density. For example, higher densities are said to enable economies of scale, and enhance the technological and economic viability of certain energy technologies

and transportation systems (Haines 1986; Newman and Kenworthy 1989; Boyko and Cooper 2011; UN 2017).

On the other hand, authors like Neuman (2005) and Heinonen and colleagues (2013), point to important variations and exceptions to the rule. More historical research suggests that urban structures do not, in themselves, generate more or less sustainable arrangements. As Neuman (2005) points out, pre-twentieth-century versions of the compact city may have been sustainable, but not for reasons of density. They were sustainable because they relied on local materials and appropriately scaled technologies. In depending on local knowledge and resources, these settlements were integrated into their surroundings (Lefebrve 1991).

Heinonen and colleagues (2013), add to this debate, arguing that whilst cities might reduce the carbon intensity of some aspects of daily life, one needs to look at multiple forms of consumption (beyond energy and transport) in assessing the sustainability of the urban form. Their study of middle-class households in Finland shows that in less dense areas, larger family sizes and related economies-of-scale offset the advantages of living in a denser environment when the emissions were assessed on a per capita basis. Although city dwellers spend more of their money on services that are less carbon intensive to deliver, they also acquire more personal goods, and, most importantly, miss out on the efficiencies associated with larger household sizes which are more common in the countryside.

Despite reaching somewhat different conclusions, representatives of both schools of thought take the concept of density for granted. Whether it is seen as a good thing or not, density is treated as an explanatory variable defined in terms of the number of people, of buildings or of businesses (Newman 2014; Boyko and Cooper 2011) packed into a given area – as if seen from above (Neuman 2005; Tonkiss 2014). There are different methods of quantifying density, including techniques that estimate 'floor area ratio, dwelling density, people density, residential density, job density, net density, gross density, physical density, measured density, perceived density, internal density, spatial density and social density' (Dovey and Pakfa 2014: 67), along with composite indices that aim to overcome the limitations of individual measures.

It is tempting to conclude that these various metrics reveal different aspects of density as it exists in the real world. In this paper we take a more constructivist approach, recognising that methods and metrics are constitutive and performative. Following Hanson (1981), we argue that 'observation is theory laden' and that measures of density carry with them, and reproduce prior ideas and understandings about the relationships they describe. In the literature mentioned above, density is important not in its own right but in as far as it has a bearing on the efficiency of energy provision and on related economies of scale. This is consistent with representations of density that a) treat space as a bounded container, b) treat 'activities' as moments of localised performance, and c) focus on the relation between built form and the organisation of energy supply. These strategies make sense in their own terms, but as indicated below, they obscure potentially crucial routes through which energy demand and urban form shape each other.

One obvious limitation has to do with the fact that energy and other resources circulate and flow through urban systems and through the infrastructures on which they depend. To be more specific, conventional measures of density tell us little about how material arrangements are configured across different spatial scales (Ferrão and Fernández 2013; Tonkiss 2014), or about the social geographies of access, and the politics of how energy supplies circulate unevenly through the urban fabric (Graham and Marvin 2001). In this respect there are important differences between studies of density and of urban metabolism.

Second, and as already mentioned, debates about urban density and energy demand implicitly focus on the relative efficiencies of supply at a given moment in time. The tacit assumption is that people living in dense urban areas have the same 'needs' and demands as those living in the countryside or in the suburbs and that what varies with density are means by which these needs are met. In taking present arrangements for granted, established discourses of density miss significant transformations in daily life including the rise in online shopping, or escalating expectations of comfort. The more complicated point that routines, practices and related patterns of consumption co-evolve with urban planning, building design, and related infrastructures and systems of provision (Shove and Trentmann 2018) is similarly out of scope.

Third, measures of urban density do not provide any insight into the ways in which different building layouts and urban designs hardwire aspects of energy demand into daily life and thus into the more extended networks of sewerage, gas and electricity that cut across the cityscape (Duan et al. 2019). As a result they tell us little about how supply and demand connect, or about how the practices of households, consumers and providers are inscribed in the material form of cities, of neighbourhoods and of homes.

These themes – the role of the built environment in recursively constituting demand; the extent to which demand in any one location is defined by systems of provision that extend beyond it, and how features of the built environment shape the longer-term evolution of 'need' – generate different questions about the spatial organisation of energy supply and demand. These questions are in turn linked to a distinctive method of conceptualising energy systems and how they are organised.

In this paper we start from the view that energy demand is an outcome of social practices, organised across space and time. In working through the implications of this approach we address themes of circulation, flow and co-constitution that relate to discourses of density but that are obscured by the terms in which that debate is framed. In order to bring what is an otherwise abstract discussion of spatial and material relations to life, and in order to learn more about how energy demands and practices are configured at different spatial scales we zoom in to a single neighbourhood on the outskirts of central Hanoi, Vietnam. Since we are interested in relating discourses of density to theories of practice, and to more relational theories of geography and material culture we describe and discuss the experiences of two households both living in Linh Dam, an area that is by normal measures an extremely dense part of the city.

By starting with the details of our respondents' daily lives, and working outwards, we are able to describe some of the routes through which systems of provision and related features of the built environment and

design interact with the fine-grained configuration of social practice. Despite living in the same neighbourhood, there is considerable variation in the technologies and appliances that exist within these two households, and in related patterns of consumption and use. These relations are defined by social and material connections that reach into the architecture of the home, and that extend beyond it as well. In following these threads we demonstrate the relevance of conceptualising urban settings not as containers of activity but as crossing points of intersecting relations that extend across spatial scales.

In the final section we comment on steps that can be taken to describe and compare the spatial and material 'textures' that enable and that are part of contemporary configurations of social practice. The methodological strategies that we describe do not add up to a single practice-theoretically informed tool-kit. Instead, the more limited aim is to show that there are ways of capturing and representing relations between urban systems and practices and that methods of this kind are needed to inform interventions that favour lower carbon ways of life. The approaches we outline do not augment methods of representing density, per hectare. Instead and as we insist, they depend on a substantially different method of conceptualising the spatial organisation of supply and demand.

In working towards this conclusion, we start (section 2) with a brief account of what a focus on social practices means for understanding the spatial organisation of energy supply and energy demand. In section 3, 'Density in daily life: experiences from Hanoi' we describe the conjunctions of objects, systems and everyday routines in two households (Dwelling A and Dwelling B) both located in Linh Dam, a neighbourhood of Hanoi. In section 4, 'Reconceptualising the spatial organisation of energy demand' we take stock what these cases reveal about the configuration of energy demand not in one location or another (a home, a neighbourhood, a city) but in how material relations and connections develop and change over time.

Social practices and the spatial organisation of energy demand

We are not the first to consider the relation between urban density and social practice. Writing in 2014 Tonkiss suggests that 'the kinds of physical and environmental strategies offered by both advocates and critics of urban density or compactness are at bottom concerned with social practices: they bear on norms of household formation, patterns of living and working, consumption and travel behaviour, and attitudes towards the proximity of others' (Tonkiss 2014). Since our approach depends on what has become known as a social theory of practice, it is important to say more about what we take this statement to mean.

Rather than trying to summarise an entire philosophical position, we use this section to highlight four features that are especially relevant for a discussion of urban density and energy demand.

The first of these has to do with the definition of social practices. As described by Giddens (1984) and by others since (Reckwitz 2002, Shove et al. 2012), social practices – which might include showering, laundering or preparing and eating dinner – exist across space and time. Conceptualised as meaningful entities in their own right, practices have histories and trajectories of their own. Although they depend

on recurrent reproduction by social actors, they cannot be reduced to these actions alone. This is one reason why 'practice' is not a synonym for activity or behaviour.

Second, practices are to some degree constituted by many and often distant organisations and institutions. For example, water companies; food manufacturers; appliance designers and energy providers are involved in making and reproducing the material arrangements on which everyday practices depend. So although practices are enacted in specific locations and moments, they exist beyond these instances: they are 'carried' and reproduced across space and time. This is another reason why practices should not be equated with the actions of individual citizens or consumers.

Third, patterns of consumption (and of energy demand) are outcomes of social practice: as such they are inherently unstable and changing all the time. As historical studies demonstrate, infrastructures, building designs and energy demanding practices co-evolve, never in isolation but always recursively and always together (Trentmann and Carllson-Hyslop 2018). In short, material arrangements are interwoven with the practices to which they relate.

Finally, practices exist at the intersection of infrastructures, appliances and energy demands. As well as documenting the increasing number of household devices (Parr 1999; Cowan 1997), sociologists and historians of consumption (Trentmann 2016), have shown how these are embedded in always evolving practices including those of food provisioning, laundry, computing and watching TV. These arrangements are in turn crucial for more distant flows and systems of provision (Coutard and Shove 2018). Documenting the lives of practices and showing how these evolve and change together depends on paying attention to developments across these spatial scales.

Although these propositions are quite well established in social theory, bridging between these traditions and research on urban density and energy demand depends on bridging between contrasting interpretations of spatial and material relations.

As already mentioned, there are obvious differences between those who treat space as a clearly demarcated container of activity (as is the case with much of the literature on density) and those who argue that space and place are relational concepts. In her well-known chapter, 'a global sense of place' Massey highlights the many distant relations and connections that are materialised, that play out within, and that define the features and characteristics of one street in London (Kilburn High Road) (Massey 1994, 2005). Massey does not write about urban density as such, but as McFarlane points out 'processes of de/re-densification do not occur in isolation. They bring into relation multiple space-times within and beyond a given site, including through global political economic relations, migration, environmental processes, the circulation of ideas, knowledge and practices, and forms of technological hinging.' (McFarlane 2020: 5). McFarlane's emphasis on circulation and flow is echoed by others who write about the spatial organisation of energy. For example, Head et al. (2013) argue that 'however solid the physical dwelling, it is in one sense nothing more than a membrane through which energy and stuff flows'. Head et al. do not treat the house as a discrete space or a bounded container in its own right: rather it is viewed a terminal and a junction point through which more extensive networks run (Kennedy et al., 2011).

These ideas suggest that although they might appear to be solid and fixed, appliances, floor plans, neighbourhoods and cities are always in flux. They are so in that connections and relations between them are constantly reconfigured as practices change (Rinkinen, Jalas and Shove 2015). Rooney's description of the arrival of consumer goods in Hong Kong gives a sense of this dynamic:

> Throughout the 1960s consumer items such as refrigerators, washing machines, radiograms and coffee tables became more evident in the home, changing the focus of the space layout. The kitchen was not designed to accommodate something as bulky as a refrigerator, which meant it had to be placed in the living area instead, closer to where people ate, rather than where food was prepared. As the television came to replace the radio as in the home, tenants had to arrange their seating for easy viewing. The prevalent 1960s styling of the time, designed as a free-standing unit on four thin legs, was not space-saving; yet these consumer products often appeared in the midst of a very crowded and cluttered space (Rooney 2003: 61).

It is not just that number of household objects in a given space has practical consequences for how rooms are laid out and used. The more important insight is that over the longer run homes are designed, and re-designed, to accommodate an influx of material goods.

Hand et al.'s research (2007) leads to much the same conclusion. These authors describe a study in which people living in two bedroomed terrace houses discussed the 'need' to accommodate dishwashers and washing machines and talked about rooms that were becoming increasingly cramped as the number of material possessions rose. Hand et al. go on to describe the changing status of the kitchen. In many of the homes they studied, the 'kitchen' was no longer simply or only a place for cooking: it had become a place in which meals were eaten, where the family gathered and where socialising went on (Hand et al. 2007; Maller et al. 2012). Such practices, in turn, called for specific configurations of furnishings, multi-purpose spaces and (energy demanding) appliances, and for new patterns of provision and flow, beyond the home and behind the scenes.

If we are to characterise relations between urban form and everyday life and if we are to do so in these terms, we need to consider:

- How resources (gas, electricity, water), appliances (cookers, washing machines etc.) and practices of daily life combine;
- How they do so across different urban scales, within homes and beyond;
- Whether connections between practices and resource use are tightly coupled (densely interwoven) or not;
- How multiple relations between practice, materials and space combine in any one location;
- Whether urban forms have a bearing on the types of practices, and the patterns of energy demand that follow.

In the next part of the paper, we approach these questions not from a 'bird's eye' point of view, and not by looking down at the structure of the urban form. Instead, we start within the home and at the point at which practices are enacted, and at which devices and appliances are used, and at which gas and

electricity are consumed. From there we work *outwards,* identifying features of the built environment that sustain and enable specific ways of life, and following the grids and networks to which homes and neighbourhoods connect.

Density in daily life: experiences from Hanoi

In keeping with this approach, we proceed by describing the experiences of two households, one living in 'Dwelling A', the other living in 'Dwelling B', both of which are located in an exceptionally dense (by conventional measures) neighbourhood in Hanoi. The reasoning behind this methodological strategy is that by documenting the details of cooking, cleaning and cooling and by identifying the appliances, built forms and infrastructures associated with them, we are able to 'see' connections that matter, and to identify linkages that are not visible to those who deal with standardised units (floor area, hectares, Km2); or whose analysis stops at the front door. It is only by detailing the material arrangements around which daily lives revolve that we can identify the spatial organisation of social practice as that is reproduced within homes, neighbourhoods, and more extensive infrastructures and systems of provision.

The cases we describe are situated within Linh Dam, an area 7km from the centre of Hanoi. Before discussing Dwelling A and Dwelling B in detail, we begin with a brief account of this location and its history.

Hanoi which is now home to just over 8 million people is packed into an area of 3359 km2 (GSO 2019). In terms of population, it is the second largest city in Vietnam behind Ho Chi Minh City. Hanoi has developed rapidly over the last few decades, driven by a political and economic commitment to growth (Cira 2011). Before the economic reforms of the Doi Moi (1960-1985) many people were living in khu tap (2-5 storey collective living quarters built by the government). Although Hanoi's tradition of apartment living dates from the communist period the liberalisation of the economy and increasing levels of income have enabled private investors to finance high-rise apartment buildings in newly developed urban areas outside the old districts (Luan 2014). From the 1990 onwards, urban districts have been built on agricultural land in a deliberate effort to rebalance densities between the center and fringes of the city and to meet housing demand from the emerging middle-classes (Leducq and Scarwell 2018).

As in other cities, the buildings of which similarly dense (in terms of activity per unit of space) neighbourhoods are composed have different histories. Most would agree that Linh Dam, the area in which Dwellings A and B are situated, is densely packed. It is covers around 200 hectares, including a 74 hectare lake now surrounded by buildings. A ring road cuts through the neighbourhood, providing good connections to other parts of the city. In 1997 two new two residential areas, namely Bac Linh Dam (Northern Linh Dam) and the Linh Dam peninsula general service area, were established. This was one of the first parts of Hanoi to feature high rise apartment buildings with elevators and Linh Dam is often described as a model urban development, marking the birth of a 'real estate economy'. (Phương and Town 2012; Tạp chí Kiến trúc 2020).

Initially, the Linh Dam project was designed to make more efficient use of urban land, and to provide housing that would help improve residents' quality of life. In recent years, the Linh Dam peninsula has

become increasingly cramped: the population has risen fast and many new apartment buildings have sprung up. The land in the center of the peninsula, initially set aside for offices and commercial use has been given over to housing. New apartment blocks with a land acquisition coefficient of over 90% and a height of 33 floors have broken the spatial structure of this part of the city. The 5 hectares of land devoted to the 'general service center' connecting the north of Linh Dam, the Linh Dam peninsula, and the southwestern and southern parts of the neighbourhood have also been turned into residential zones including 12 apartment buildings, each with a height of 36 - 42 floors. Yet more apartment blocks have been constructed on the land between the ring road and the old village, changing the urban landscape and the lives of the 70,000 people who now live in the area. (Phương and Town 2012).

The two households we examine were both located in Linh Dam, and both were home to 'middle class' respondents as defined by our local research partners. The residents of Dwelling A and Dwelling B were identified and recruited via the personal and professional networks of our research associates, who helped us organise and conduct semi-structured interviews with household members. These lasted for around an hour and both took place in respondents' homes. A Vietnamese speaking research assistant helped translate in the interview situation. In both cases we discussed the use of household appliances with special emphasis on air-conditioning and heating, laundry, cooking and entertainment and we asked about present and past routines and practices. The interviewees showed us around their home, letting us examine their appliances and the layout of the rooms.

Before we introduce these two homes and those who live in them, it is important to be clear about the methodological status of these vignettes. The purpose is not to generalise from these examples but to use them to identify some of the ways in which layouts, appliances and practices connect and configure more extensive spatial relations and material arrangements. To reiterate, our aim was to discover how differently energy-intensive practices of air-conditioning and heating, laundry, cooking and entertainment hang together and change, and how the house, and its position in the wider infrastructure, figured in these dynamic processes. We begin with Dwelling A.

Dwelling A

Dwelling A is a typical narrow Vietnamese house built in 2001 on three floors and with two main bedrooms. The house is designed around a series of spaces that open to the outside: it has a balcony, a roof terrace, and a traditional kitchen located at the back and partly extending outdoors. This open structure has practical implications for the organisation of daily life within the home. For example, the design of the house allows the inhabitants to keep doors and windows open and to allow the air to flow through. Air conditioning is used very sporadically in the two bedrooms and only when it is very hot. In other rooms, the family uses different types of fans to keep cool. The living room is, for instance equipped with five types of fans, several of which are used when guests call in.

<FIGURE 1 >
Figure 1. Floor plan of dwelling 1 (not to scale)

The arrangement and location of the house is also important for how and when laundry, cooking and shopping are done. Although this household does own a washing machine, it is significant that it is covered with a plastic sheet. Most clothes are washed by hand and the machine is only used for bigger loads, such as bedding. Clothes are hung out to dry in the open space on the roof. The drying clothes provide shade from the direct sunshine and this helps cool the upper floor. The traditional Vietnamese kitchen, which runs through to the back of the house is equipped with a gas stove and an electric one, but most cooking is done on gas. The open space and ready access to the front and back of the house means that it is easy to chat to people outside. It is a short walk to the shops and fresh food is bought on an almost daily basis.

This type of property enables cooling, drying, and cooking outdoors. It channels resource flows (gas, air, food) and is plugged into more extensive networks (water, electricity) in ways that both facilitate and reflect specific domestic routines. On all counts the house 'scripts' the lives and practices of its inhabitants, and in so doing influences the amount of energy they use.

Dwelling B

Dwelling B is an apartment in a 16-storey block built in 2006. The apartment is on one floor and it has two bedrooms, a living room, a bathroom and a small kitchen. It is occupied by a brother (Don) and sister (Sheila), and its total floor area is less than that of Dwelling A.

<FIGURE 2>
Figure 2. Floor plan of dwelling 2 (not to scale)

The windows cannot be fully opened and there is no shade from vegetation. Since there is no natural air flow, the householders have installed an air-conditioning unit in the living room, which they turn on when it is too hot at night or during the day, leaving their bedroom doors open. The air conditioning unit is also in use when Sheila is teaching, something which she does at home. The electric fans are always on when the house is occupied and there is a plan to install more air conditioning units.

There is a washing machine that is used several times a week. Since the indoor air is too humid for drying clothes, the residents have also purchased a mobile dryer which they use regularly. The apartment has a small Western style kitchen equipped with a range of domestic appliances. Although most Vietnamese kitchens have a gas cooker, this one has an induction hob. There is a fridge freezer and most food is cooked using the microwave or the rice cooker. Don and Sheila shop at a big supermarket 10 kilometres away once or twice a month. They go there on a motorbike, and fill up the fridge completely. They buy instant coffee, juice, cakes and bread, washing powders, milk (in a box), and sometimes yoghurt and frozen fish. They buy fresh vegetables and meat at a nearby market every other day after work.

Dwelling B, and the appliances it contains, have a bearing on the practices of those who live in it, and the amount of energy they consume. As described above, some aspects of energy use are 'hard wired' into the building itself including the need for air conditioning, for a clothes dryer and for an elevator as well.

These few observations do not amount to a strict comparison. Because there are different ways of living in these houses – as shown in the descriptions above – there are no guarantees that the former is any less energy demanding than the latter. Instead, the point is that these two homes, and the appliances they contain, enable and sometimes require very different ways of doing cooking, cooling and drying. In general terms, the fact that buildings have different types of affordance is not surprising and it is not news either. What is missing is a means of reconciling conclusions of this sort with an account of how resources, materials and practices combine and extend across multiple scales.

Before addressing this challenge, we comment on the ways in which the domestic practices we observed form a continuum with the wider urban environment in which they are enacted. We have not sought to quantify the energy used in Dwelling A and B. As indicated above, such an exercise would be of little meaning or value since the services provided are so different. It is nonetheless clear that some buildings are more obviously and more consistently dependent on infrastructures and systems of energy provision than others. It is also plain that these arrangements and interdependencies develop and change over time.

In Hanoi newer apartments are generally equipped with built-in socket outlets, enabling air conditioners in each room. Since properties like these do not have good external sun blinds, and since there is no through ventilation, residents are more or less obliged to install one or sometimes two air conditioning units, and to pay for the electricity they consume. Not all city centre neighbourhoods are made of buildings like this, but for those that are, there are quite direct links between energy demand and urban form, including well known issues such as the heat island effect (Santamouris 2014). This is important in that it suggests that far from reducing energy demand, some urban environments: i.e. those characterised by buildings like Dwelling B, are likely to drive it up, locally and in the wider neighbourhood as well.

Paying attention to the connections between material arrangements within the home and beyond alerts us to other forms of spatial interdependence. In the descriptions presented above, we commented on the use of fridge freezers – as appliances that take up a lot of room in the home, and as devices that enable certain patterns of shopping and diet. However, we have yet to notice that these devices link households to a much wider ‘hinterland’ of food provisioning, refrigerated transportation, supermarkets and more (Shove and Southerton 2000; Hand and Shove 2007; Rinkinen, Shove and Smits 2019). From this point of view, fridge freezers and their contents represent the endpoints of refrigerated networks that are part of a web of urban and extra-urban relations that span the globe.

We are not in a position to say whether those who live in densely populated environments are on average more dependent on fridge freezers than others, but it is clear that reliance on frozen and refrigerated food is enormously important for energy demand and for the spatial configuration of ‘town’ and ‘out of town’ provisioning. Other appliances, including clothes dryers, air conditioning units, rice cookers and washing machines are part of similarly extensive systems of provision. Although these devices are clearly located within the home, they are not simple or static ‘consumers’ of energy. When they are used, and how, is, as we have seen, part of a more complex set of relations involving other material arrangements (the open yard, the cooling breeze; the built-in air conditioning; the type of clothing that is worn, or the

meals that are cooked); variously tied to established and emerging practices as these spread and change through the population as a whole.

In summary, the two cases described above show how infrastructures, appliances and the layout of the home matter for how rooms are used, and for the practices they accommodate and enable. In aggregate, these arrangements are in turn important for the types of energy demand that arise, not only within the home, but across the city as a whole. In the final part of the paper we elaborate on the significance of these practice theoretically inspired observations for the conceptualisation and analysis of urban density and energy demand.

Reconceptualising the spatial organisation of energy demand

Urban planners continue to discuss the importance of increasing density (typically defined in terms of activity per unit of area) as a means of responding to the challenge of reducing energy consumption and carbon emissions. In our view, prioritising the efficiencies of a compact spatial form overlooks more fundamental questions about how resource intensive practices are configured and how they change. In this paper we have argued that energy demand is not a consequence of the amount of activity in a given space (whether indoors or out). Rather it is a feature of how social practices and material arrangements are defined, distributed and organised in space and time, and of how those relations develop over time.

In taking this approach and in describing some of the practices enacted in Dwellings A and B, and some of the systems of provision on which they depend, we took heed of Kennedy et al.'s (2011) advice to think of the house not as a discrete space or as a bounded 'container' in its own right but as a 'terminal' and a junction point through which more extensive networks run. This might sound like a small or semantic point, but it is symptomatic of a fundamentally different way of conceptualising spatial relations. In essence our more relational approach supposes that what appear to be readily identifiable 'attributes' of the built environment – such as activity per m2 – do not have any meaningful existence aside from the practices in which they are embedded, and which they help constitute.

These observations have further consequences, in particular for the project of describing, comparing and evaluating the relative merits of different spatial arrangements, whether in terms of the layout of a home, a neighbourhood or the urban form. Metrics of density (of all forms) provide a shared language and a set of agreed, universally applicable terms with which to describe empirically observable features of the built environment. But in the context of debates about energy and sustainability, approaches of this kind are counterproductive. They are so in that they reproduce assumptions about the fixity of spatial arrangements and their importance for efficiency and supply. In the same move they obscure potentially crucial questions regarding the constitution and also the transformation of demand. In our view it is no wonder that there is ongoing debate about the salience of density, as it is conventionally defined. Such debates are impossible to resolve not because of a shortage of empirical evidence or because of disagreement about terms and metrics, but because the concept of density, the container view of space, and the reliance on fixed 'units' are simply incapable of representing the recursive and dynamic relation between urban form and energy demand.

This is not a negative conclusion. In writing about Dwellings A and B, and in exploring methods of revealing and characterising different systems of provision and practice, we have begun to specify forms and types of measurement that are consistent with a more comprehensive, and also more historical view of the spatial configuration of energy. In bringing the paper to a close we identify a portfolio of approaches, aspects of which are already established in other fields.

Each of the methodological strategies outlined below represents a partial response to the problem of representing and perhaps influencing the recursive relation between social practices and the material infrastructures and urban settings on which they depend. Whilst each has its limitations each also provides something of a way forward.

As already mentioned, one challenge is to represent the extent to which practices (and energy demands) are (or are not) hardwired into the design of buildings and infrastructures and into the urban fabric as a whole. If we go along with the view that it is not population or activity per hectare that matters, but the form that conjunctions of infrastructures and practices take, we need to think again about the scope for policy intervention, and about what this might involve. One practical consequence is that urban planners and environmentalists should be alert to opportunities for engendering more and less rigid systems of provision, and to their role in fostering more and less flexible, and variously demanding conditions and conventions. In the examples we have discussed there are clear differences in how energy demands are 'hard wired' into Dwellings A and B. It is, for instance, fair to say that Dwelling B locks its inhabitants into patterns of living that depend on forms of infrastructural provision and energy consumption that are inscribed in the fabric of the house and in the systems to which it connects. In effect the building is a critical node within and as part of a distinctly and unavoidably resource intensive social-material configuration.

One way of thinking about how this feature might be measured and compared is to think about how 'resilience' is evaluated and assessed. For example, how well would a property and its inhabitants fare in case of disruption: a power cut, for example? Are there multiple (possibly redundant, possibly inefficient) means of delivering broadly similar services or, conversely, is there only one possible option? Methods of representing resilience have their own traditions and their own conceptual baggage, but it might be possible to appropriate already established techniques and adapt them in order to quantify and assess aspects of 'inscribed demand'.

A second challenge is to show how energy, water, waste etc. move through diverse infrastructures and systems laid down at different times in the past. Again, there are some precedents on which to draw. Methods of describing and representing 'urban metabolism' generally overlook this historical aspect, but they do attend to movement and circulation. As Ferrão and Fernández put it, 'the flow of units, energy, materials, products, services, information, people, biodiversity, and so on defines the nature of urban space and delineates the measures and assessments of resource intensity and urban sustainability' (Ferrão and Fernández 2013). Building on these ideas, it might be possible to combine analyses of urban metabolic flow with techniques designed to reveal the systemic interdependencies that characterise

urban energy patterns and processes (Pincetl, Bunje and Holmes 2010). Metrics and measures that cut through, or disregard, the spatial boundaries of buildings or neighbourhoods are clearly needed if there is to be any hope of characterising the extent and energy intensity of the 'support systems' associated with different and changing complexes of social practice, and if there is to be any chance of documenting the emergence of more and less demanding systems of provision as these are threaded through the cities of the world.

Whilst these are promising approaches, there are risks attached. In particular, it is important to recognise that systems of provision do not simply meet existing needs, nor do they arise by chance. As our description of Dwellings A and B demonstrates, buildings and urban networks have an active role in constituting what people do and in reproducing the conventions and expectations they share. This is important in that the buildings and neighbourhoods that 'script' consumption and demand are, to some degree, outcomes of design decisions and styles of urban planning, past and present.

This brings us to a third more ambitious goal which is to describe the historical (and spatial) transformation of the many practices of which urban living is composed. Flows of gas and electricity are clearly bound up with the enactment and distribution of social practices. To go further and to represent these intersections, and their combined effect on the dynamics of demand we need metrics that are capable of describing the time-space -profiles of different practices, and the urban forms to which they relate.

Which practices are enacted, and where is plainly important for the characteristics and spatial distribution of consumption, and for how those aspects change. To catch sight of these relations we need to develop ways of mapping practices and showing how they intersect and change together over time. Should such a thing exist, a hybrid 'chart-atlas of contemporary practice' might be capable of depicting 'the totality of contemporary practices in terms of related injunctions or compulsions, minutes of attention required and associated features of sequence and timing, [and] … the social-spatial distribution of specific practices' (Shove 2009: 29). There are no ready-made tools that can be adapted to this end, but there is almost certainly scope for developing techniques like those pioneered in the field of time space geography (Pred 1977). These might be used to characterize so-called 'hot' and 'cold' spots in the collective scheduling of daily life and in their spatial coordinates as well (Southerton 2003). Other more qualitative methods, including life histories could be developed to show how infrastructures and practices change together (Shove et al. 2015). And so we could go on.

As these provisional suggestions indicate, the work of developing methods and metrics that are consistent with a practice theoretically inspired account of the spatial and historical organization of energy demand is work that remains to be done. In giving a sense of what this might entail, we have sought to show that social theory, and social theories of practice in particular, provides researchers and policy makers with a means of conceptualising the recursive relations between urban design, everyday practice and energy demand. This is important in that it is only by understanding their own role within these dynamic processes that urban planners and designers will be able to understand what they can do to actively foster lower carbon ways of life.

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Data availability

Information about the data on which this article is based and conditions for access is available at the Lancaster University data archive: [add doi].

Authors' contributions

Author1 has contributed to the planning, gathering and analysis of the empirical data, literature review, framing and writing of the paper. Author2 has contributed to the framing and writing of the paper. Author3 has contributed to the planning, gathering and analysis of the empirical data, literature review, and early versions of the article.

References

Boyko, C. T. and Cooper, R. (2011). Clarifying and re-conceptualising density. *Progress in Planning* 76(1), 1-61.

Cira, D. (2011). Vietnam Urbanization Review Technical Assistance Report. *World bank, pp17-177*.

Coutard, O., & Shove, E. (2018). Infrastructures, practices and the dynamics of demand. *Infrastructures in practice: The dynamics of demand in networked societies*, 10-22.

Cowan, R. S. (1997). *A social history of American technology*. OUP Catalogue.

Dieleman, F. and Wegener, M. (2004). Compact city and urban sprawl. *Built Environment* 30(4), 308–323.

Dovey, K.and Pafka, E. (2014) 'The Urban Density Assemblage', *Urban Design International*, 19 (1):66-76

Duany, A., Plater-Zyberk, E., and Speck, J. (2001). *Suburban nation: The rise of sprawl and the decline of the American dream*. Macmillan.

Duan, S., Luo, Z., Yang, X., and Li, Y. (2019). The impact of building operations on urban heat/cool islands under urban densification: A comparison between naturally-ventilated and air-conditioned buildings. *Applied energy*, *235*, 129-138.

Ewing, R. (1997). Is Los Angeles-style sprawl desirable? *Journal of the American planning association*, *63*(1), 107-126.

Ferrão, P., and Fernández, J. E. (2013). *Sustainable urban metabolism*. MIT press.

Gordon, P., and Richardson, H. W. (1997). Are compact cities a desirable planning goal?. *Journal of the American planning association*, *63*(1), 95-106.

Graham, S., & Marvin, S. (2001). *Splintering urbanism: networked infrastructures, technological mobilities and the urban condition*. Psychology Press.

GSO (2019). *Statistical Yearbook of Vietnam 2019.* General Statistics Office of Vietnam. Available at: https://www.gso.gov.vn/default_en.aspx?tabid=515andidmid=5andItemID=19691, 18.8.2020.

Haines, V. A. (1986). Energy and urban form: a human ecological critique. *Urban Affairs Quarterly*, *21*(3), 337-353.

Hand, M., and Shove, E. (2007). Condensing practices: Ways of living with a freezer. *Journal of Consumer Culture*, *7*(1), 79-104.

Hand, M., Shove, E., and Southerton, D. (2007). Home extensions in the United Kingdom: space, time, and practice. *Environment and Planning D: Society and Space*, *25*(4), 668-681.

Hanson, N. (1981). "Observation as theory laden" in *Conceptions of Enquiry*. Brown, S., Fauvel, J. and Finnegan, R. (Eds). London: Methuen.

Head, L., Farbotko, C., Gibson, C., Gill, N., & Waitt, G. (2013). Zones of friction, zones of traction: the connected household in climate change and sustainability policy. *Australasian Journal of Environmental Management,* 20(4), 351-362.

Heinonen, J., Jalas, M., Juntunen, J. K., Ala-Mantila, S., and Junnila, S. (2013). Situated lifestyles: II. The impacts of urban density, housing type and motorization on the greenhouse gas emissions of the middle-income consumers in Finland. *Environmental Research Letters*, *8*(3), 035050.

Kennedy, C., Pincetl, S., and Bunje, P. (2011). The study of urban metabolism and its applications to urban planning and design. *Environmental pollution*, *159*(8-9), 1965-1973.

Leducq, D., and Scarwell, H. J. (2018). The new Hanoi: Opportunities and challenges for future urban development. *Cities*, *72*, 70-81.

Lefebvre, H. (1991). *The production of space*. Cambridge, MA: Blackwell.

Luan, T. D., 2014. Living In "New Urban Areas": Towards Sustainable Urban Communities In Hanoi, Vietnam. *WIT Transactions on Ecology and the Environment* 181, 333-344.

Maller, C., Horne, R., & Dalton, T. (2012). Green renovations: Intersections of daily routines, housing aspirations and narratives of environmental sustainability. *Housing, Theory and Society*, *29*(3), 255-275.

Massey, D. (1994). *Space, Place and Gender.* Minnesota: University of Minnesota Press.

Massey, D. (2005). *For space*. London: Sage.

McFarlane, C. (2020). De/re-densification: A relational geography of urban density. *City*, 1-11.

Neuman, M., (2005). The Compact City Fallacy. *Journal of Planning Education and Research* 25, 11-26.

Newman, P. G. and Kenworthy, J. R. (1989). *Cities and automobile dependence: An international sourcebook.* Brookfield, VT: Gower Publishing.

Newman, P. (2014). Density, the sustainability multiplier: Some myths and truths with application to Perth, Australia. Sustainability, 6(9), 6467-6487.

Parr, J. (1999). *Domestic goods*. Toronto: University of Toronto Press.

Phương, Q. T. L., & Town, L. D. N. (2012). Solution for The High-Density Development of New Settlements in the South-West of Hanoi. *J. Sci. & Devel*, *10*(4).

Pincetl, S., Bunje, P., and Holmes, T. (2012). An expanded urban metabolism method: Toward a systems approach for assessing urban energy processes and causes. *Landscape and urban planning*, *107*(3), 193-202.

Pred, A. (1977). "The Choreography of Existence: Comments on Hagerstrand's Time-Geography and Its Usefulness." Economic Geography 53(2): 207-221.

Reckwitz, A. (2002). Toward a theory of social practices: A development in culturalist theorizing. *European journal of social theory*, 5(2), 243-263.

Rinkinen, J., Jalas, M., and Shove, E. (2015). Object relations in accounts of everyday life. *Sociology*, *49*(5), 870-885.

Rinkinen, J., Shove, E., and Smits, M. (2019). Cold chains in Hanoi and Bangkok: Changing systems of provision and practice. *Journal of Consumer Culture*, *19*(3), 379-397.

Rinkinen, J., Shove, E., and Marsden, G. (2020). *Conceptualising Demand: A Distinctive Approach to Consumption and Practice.* London: Routledge.

Santamouris, M. (2014). On the energy impact of urban heat island and global warming on buildings. *Energy and Buildings,* 82, 100-113.

Shove, E., and Southerton, D. (2000). Defrosting the freezer: From novelty to convenience: A narrative of normalization. *Journal of Material Culture*, *5*(3), 301-319.

Shove, E. (2009). Everyday practice and the production and consumption of time. *Time, consumption and everyday life: Practice, materiality and culture*, *24*, 17-35.

Shove, E., Watson, M. and Spurling, N. (2015). "Conceptualizing connections: Energy demand, infrastructures and social practices." European journal of social theory 18(3): 274-287

Shove, E. (2017). Matters of practice. In *The nexus of practices: Connections, constellations, practitioners,* 155-168.

Shove, E., and Trentmann, F. (Eds.). (2018). *Infrastructures in practice: the dynamics of demand in networked societies.* London: Routledge.

Shove, E. (2018). "What is wrong with energy efficiency?" Building Research & Information 46(7): 779-789.

Southerton, D. (2003). "'Squeezing time' - Allocating practices, coordinating networks and scheduling society." Time & Society 12(1): 5-25.

Tạp chí Kiến trú [Architecture magazine of Vietnam association of architects). (2020) Unnamed. Undated. Available at: https://www.tapchikientruc.com.vn/chuyen-muc/thi-moi-linh-dam-tiec-cho-mot-ban-quy-hoach-khong-thanh.html, 26.11.2020.

Tonkiss, F., (2014). *Cities by design: the social life of urban form*. New Jersey: John Wiley and Sons.

Trentmann, F. (2016). *Empire of things: How we became a world of consumers, from the fifteenth century to the twenty-first*. Penguin UK.

Trentmann, F., and Carlsson-Hyslop, A. (2018). The evolution of energy demand in Britain: politics, daily life, and public housing, 1920s–1970s. *The Historical Journal*, *61*(3), 807-839.

UN (2017). Goal 11: Make cities inclusive, safe, resilient and sustainable. UN Web Services Section, Department of Public Information, United Nations, New York.