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Conceptualising urban density, energy demand and social practice

SPECIAL COLLECTION:
URBAN Ddensification

RESEARCH

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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 such as those of population/ha or population/km^2. A different approach is presented in this paper. Rather than evaluating the relative merits of compact or sprawling urban forms, the focus is 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, Vietnam, shows how practices of cooling, laundering and cooking (and the energy demands associated with these practices) are shaped by material arrangements that exist within the home and that also stretch far beyond. 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.

PRACTICE RELEVANCE

Energy demand is a consequence of how social practices are distributed and organised across space and time. By contrast, metrics of density can be counterproductive and tend to obscure potentially crucial questions regarding the constitution and the transformation of energy demand. A practical approach is presented to conceptualise relations between material arrangements and energy demands at different scales: from the layout of the home to more extensive infrastructures and systems of provision. The implications of these ideas can influence debates about urban density and design by focusing attention on infrastructures, appliances and the layout of the spaces that influence how they are actually used, and for the practices they accommodate and enable.

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1. INTRODUCTION

In the field of urban planning, the contrast between cities that are densely packed or sprawling is a central concern (Ewing 1997; Gordon & Richardson 1997; Dieleman & 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 such as Duany *et al*. (2001) and Dieleman & 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 & Kenworthy 1989; Boyko & Cooper 2011; UN 2017).

On the other hand, authors such as Neuman (2005) and Heinonen *et al*. (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-20th-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 (Lefebvre 1991).

Heinonen *et al*. (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) when 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 income on services that are less carbon intensive to deliver, they also acquire more personal goods and, most importantly, they 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 or not it is seen as a good thing, density is treated as an explanatory variable defined in terms of the number of people, of buildings or of businesses (Newman 2014; Boyko & Cooper 2011) packed into a given area—as if seen from above (Neuman 2005; Tonkiss 2014). Different methods can quantify 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 & 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 they exist in the real world. The present paper takes a more constructivist approach, recognising that methods and metrics are constitutive and performative. Following Hanson (1981), it is argued 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 so 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:

- treat space as a bounded container
- treat 'activities' as moments of localised performance
- focus on the relation between built form and the organisation of the 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.

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One obvious limitation has to do with the fact that energy and other resources circulate and flow through urban systems and the infrastructures on which they depend. To be more specific, conventional measures of density indicate little about how material arrangements are configured across different spatial scales (Ferrão & 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 & 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 the 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 coevolve with urban planning, building design, and related infrastructures and systems of provision (Shove & 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 indicate 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.

This paper starts 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, the themes of circulation, flow and co-constitution are addressed which relate to discourses of density. In order to bring what is an otherwise abstract discussion of spatial and material relations to life, and to learn more about how energy demands and practices are configured at different spatial scales, a single neighbourhood on the outskirts of central Hanoi, Vietnam, is used as an example. By relating discourses of density to theories of practice, and to more relational theories of geography and material culture, the experiences of two households both living in an extremely dense part of the city are described and discussed.

By starting with the details of the respondents' daily lives, and working outwards, it is possible 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 area, 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, the relevance of conceptualising urban settings is demonstrated not as containers of activity but as crossing points of intersecting relations that extend across spatial scales.

The paper is structured as follows. Section 2 gives a brief account of what a focus on social practices means for understanding the spatial organisation of energy supply and energy demand. Section 3 describes the conjunctions of objects, systems and everyday routines in two households (dwellings A and B) both located in Linh Dam, a neighbourhood of Hanoi. Section 4 discusses 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. It comments on steps that can be taken to describe and compare the spatial

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and material 'textures' that enable and which are part of contemporary configurations of social practice. These strategies do not augment methods of representing density per hectare. Instead, they depend on a substantially different method of conceptualising the spatial organisation of supply and demand.

2. SOCIAL PRACTICES AND THE SPATIAL ORGANISATION OF ENERGY DEMAND

The present authors are not the first to consider the relation between urban density and social practice. Tonkiss (2014: n.p.) 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.

Since the approach in this paper depends on what has become known as a social theory of practice, it is important to say more about what this statement means.

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

The first 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. Therefore, 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 (Rinkinen *et al.* 2020). As historical studies demonstrate, infrastructures, building designs and energy-demanding practices co-evolve, never in isolation but always recursively and always together (Trentmann & 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 television. These arrangements are, in turn, crucial for more distant flows and systems of provision (Coutard & Shove 2018). Documenting the lives of practices and showing how these develop 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 a well-known chapter entitled 'A global sense of place', Massey (1994) (see also Massey 2005) 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 does not write about urban density as such, but as McFarlane (2020: 5) 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's emphasis on circulation and flow is echoed by others who write about the spatial organisation of energy. For example, Head *et al.* (2013: 6) 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 as a bounded container in its own right; rather, it is viewed as 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 *et al.* 2015). Rooney's (2003: 61) 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.

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 term, homes are designed, and re-designed, to accommodate an influx of material goods.

Hand *et al.*'s (2007) research leads to much the same conclusion. They 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 increased. 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, multipurpose spaces and (energy-demanding) appliances, and for new patterns of provision and flow, beyond the home and behind the scenes.

In order to characterise the relations between urban form and everyday life, the following need to be considered:

- How do resources (gas, electricity, water), appliances (cookers, washing machines, *etc.*) and practices of daily life combine?
- How do they so across different urban scales, within homes and beyond?
- Are connections between practices and resource use tightly coupled (densely interwoven)?
- How do multiple relations between practice, materials and space combine in any one location?
- Do urban forms have a bearing on the types of practices, and the patterns of energy demand that follow?

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In the next section, these questions are approached not from a 'bird's-eye' point of view, and not by looking down at the structure of the urban form. Instead, the starting point is the home and at the point at which practices are enacted, at which devices and appliances are used, and at which gas and electricity are consumed. From there the approach moves *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.

3. DENSITY IN DAILY LIFE: EXPERIENCES FROM HANOI

In keeping with this approach, the experiences of two households are described, called dwelling A and 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, it is possible to 'see' connections that matter, and to identify linkages that are not visible to those who deal with standardised units (floor area, hectares, km^2); or whose analysis stops at the front door. It is only by detailing the material arrangements around which daily lives revolve that the spatial organisation of social practice can be identified as that is reproduced within homes, neighbourhoods, and more extensive infrastructures and systems of provision.

The two households are situated within Linh Dam, an area 7 km from the centre of Hanoi. A brief account of this location and its history is now presented, before discussing dwellings A and B in detail.

Hanoi, which is now home to just over 8 million people, is packed into an area of 3359 km^2 (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 (1960–85), many people were living in *khu tap* (two- to five-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, urban districts have been built on agricultural land in a deliberate effort to rebalance densities between the centre and the fringes of the city, and to meet housing demand from the emerging middle-classes (Leducq & 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 ha, including a 74 ha 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 & 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 quickly and many new apartment buildings have sprung up. The land in the centre 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 > 90% and a height of 33 floors have broken the spatial structure of this part of the city. The 5 ha of land devoted to the 'general service centre' 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 of 36–42 storeys. 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 & Town 2012).

The two households chosen for examination were both located in Linh Dam, and both were home to 'middle-class' respondents as defined by the authors' local research partners. The residents of dwellings A and B were identified and recruited via the personal and professional networks of the authors' research associates, who helped to organise and conduct semi-structured interviews with household members. These lasted for around one hour, and both took place in respondents' homes. A Vietnamese-speaking research assistant helped translate in the interviews. In both cases, the use of household appliances was discussed with a special emphasis on air-conditioning and heating, laundry, cooking and entertainment, as well as present and past routines and practices. The interviewees showed the researchers their home, therefore allowing their appliances and the layout of the rooms to be examined.

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, the aim was to discover how differently energy-intensive practices of air-conditioning and heating, laundry, cooking, and entertainment coalesce and change, and how the house, and its position in the wider infrastructure, figured in these dynamic processes.

3.1 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. First, the design of the house allows the inhabitants to keep doors and windows open and to allow the air to flow through the building. 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.

The arrangement and location of the house is important for how and when laundry, cooking and shopping are done (***Figure 1***). Although this household owns 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 traditional open space on the roof. The drying clothes provide shade from direct sunshine and 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 with gas. The open space and ready access to the front and back of the house means 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.

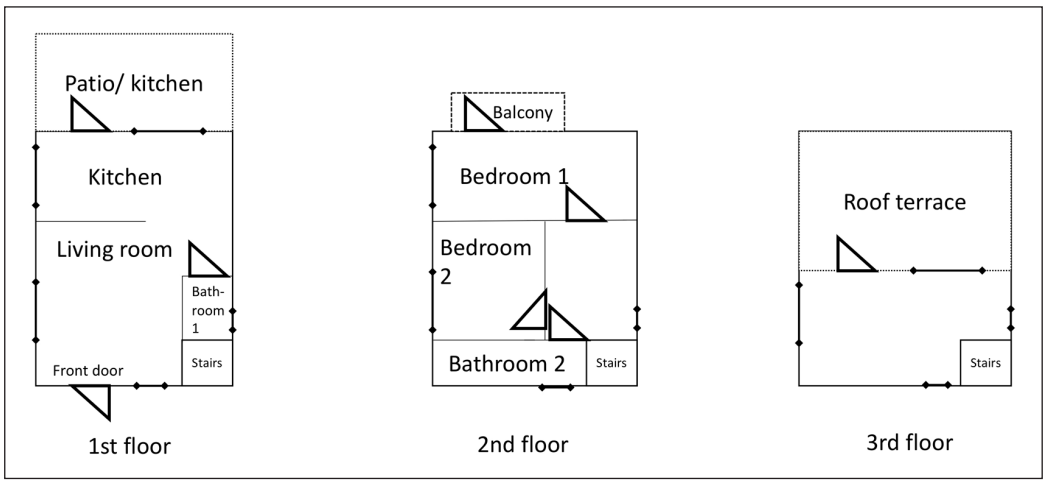

Figure 1: Floor plan of dwelling 1 (not to scale).

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.

3.2 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 (***Figure 2***). It is occupied by a brother and sister, and its total floor area is less than that of dwelling A.

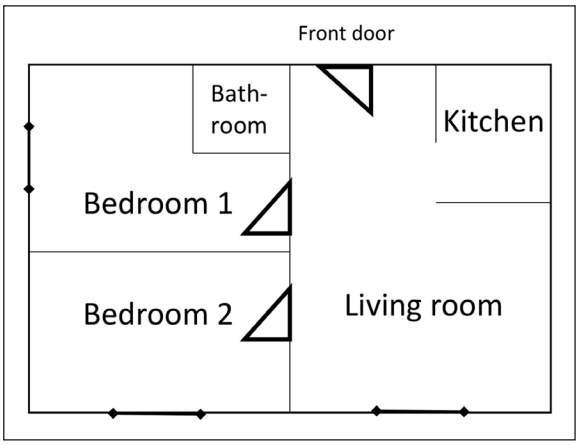

Figure 2: Floor plan of dwelling 2 (not to scale).

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 the sister 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.

A washing machine 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 dwelling an induction hob. There is a fridge freezer and most food is cooked using the microwave or the rice cooker. The occupiers shop at a big supermarket 10 km away once or twice a month. They travel 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, also has 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, a clothes dryer and an elevator.

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.

It is worth noting ways in which the domestic practices form a continuum with the wider urban environment in which they are enacted. The quantification of the energy used in dwellings A and B would be of little meaning or value since the services provided are so different. Therefore, no effort was made to quantify the energy demand. However, 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 electric sockets, enabling air-conditioners in each room. As properties such as these do not have good external sun blinds, and no natural 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 such as 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, that is, those characterised by buildings such as dwelling B, are likely to increase it, locally and in the wider neighbourhood as well.

The connections between material arrangements within the home and beyond also has implications for other forms of spatial interdependence. The use of fridge freezers requires significant floor space in the home to enable certain patterns of shopping and diet. These devices link households to a much wider 'hinterland' of food provisioning, refrigerated transportation, supermarkets and more (Shove & Southerton 2000; Hand & Shove 2007; Rinkinen *et al.* 2019). From this point of view, fridge freezers and their contents represent the endpoints of refrigerated networks which are part of a web of urban and extra-urban relations that span the globe.

It is not possible to ascertain whether those who live in densely populated environments are on average more dependent on fridge freezers than others, but it is clear that a reliance on frozen and refrigerated food is enormously important for both energy demand and 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 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 worn or the meals 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 also across the city as a whole.

4. 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. However, prioritising the efficiencies of a compact spatial form overlooks more fundamental questions about how resource-intensive practices are organised and how they develop and change. This paper argues that energy demand is not a consequence of the amount of activity in a given space (whether indoors or out). Instead, 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 and change.

The approach to the practices enacted in dwellings A and B, and some of the systems of provision on which they depend, reflects Kennedy *et al.*'s (2011) advice. These authors consider 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. Although this might sound as a small or semantic point, it is symptomatic of a fundamentally different way of conceptualising spatial relations. A more relational approach supposes that what appear to be readily identifiable

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'attributes' of the built environment—such as activity per m^2—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. They challenge 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. However, in the context of debates about energy and sustainability, approaches of this kind are counterproductive. They reproduce assumptions about the fixity of spatial arrangements and their importance for efficiency and supply. This can obscure potentially crucial questions regarding the constitution and also the transformation of demand. The ongoing debate about the salience of density, as it is conventionally defined, is impossible to resolve. This is 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 revealing and characterising different systems of provision and practice, alternative types of measurement are suggested. These are consistent with a more comprehensive, and also more historical, view of the spatial configuration of energy. A portfolio of approaches is identified below, aspects of which are already established in other fields.

If it is not population or activity per hectare that matters, but the form that conjunctions of infrastructures and practices take, then fresh thinking is needed on the scope for policy intervention, and what this involves. One practical consequence is that urban planners and environmentalists should be alert to the scope 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 two presented examples, there are clear differences in the extent to which energy demands are 'hard wired' into dwellings A and B. It is 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 this conjunction of infrastructures and practices is through the lens of resilience. For example, how well would a property and its inhabitants fare in the case of disruption, for example, a power cut? Are there multiple (possibly redundant, possibly inefficient) means of delivering broadly similar services or, conversely, is there only one possible option? It might be possible to appropriate already established resilience concepts and techniques and then adapt them in order to develop methods of quantifying and assessing dimensions of 'inscribed demand'.

A second feature, also highlighted in dwellings A and B, has to do with flow and circulation, and with how energy, water, waste, *etc.* move through diverse infrastructures and systems laid down at different times in the past. It is true that methods of describing and representing 'urban metabolism' overlook this historical aspect, but they do attend to the details of movement. As Ferrão & Fernández (2013: 154) 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.

There are, in addition, other methods of representing systemic interdependencies and interactions that underlie urban energy patterns and processes (Pincetl *et al.* 2012). Whilst these various traditions also emphasise supply rather than the longer term configuration of demand, they work with metrics and measures that cut through, or disregard, the spatial boundaries and units on which assessments of density usually depend.

Flows of gas and electricity are clearly bound to the enactment and distribution of social practices. To go further and represent these intersections, and their combined effect on the dynamics of demand, metrics that are capable of describing the time–space profiles of different practices are needed. Which practices are enacted, and where, is plainly important for the characteristics and spatial

distribution of consumption, and for how those aspects change. To understand these relations, new mapping practices (of revealing the spatial extent of supply chains and systems of provision) need to be developed in order to show 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 obvious precedents to draw on here, although there is almost certainly a scope for extending techniques such as those developed in the field of time–space geography (Pred 1977).

Developing methods and metrics that are consistent with a practice theory approach to the spatial and historical organisation of energy demand is work that remains to be done. In giving a sense of what this might involve, social theory, and social theories of practice in particular, provide researchers and policy-makers with a means of conceptualising the recursive relations between urban design, everyday practice and energy demand. 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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AUTHORS' CONTRIBUTIONS

J.R. contributed to the planning, gathering and analysis of the empirical data, literature review, framing and writing of the paper. E.S. contributed to the framing and writing of the paper. M.S. contributed to the planning, gathering and analysis of the empirical data, literature review, and early versions of the article.

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COMPETING INTERESTS

The authors have no competing interests to declare.

DATA AVAILABILITY

Information about the data on which this article is based and conditions for access is available at the Lancaster University data archive: *http://dx.doi.org/10.17635/lancaster/researchdata/112*.

ETHICAL APPROVAL

A statement from the research ethics committee of Lancaster University indicating approval of the research was obtained. Written informed consent was obtained from the participants of the study.

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