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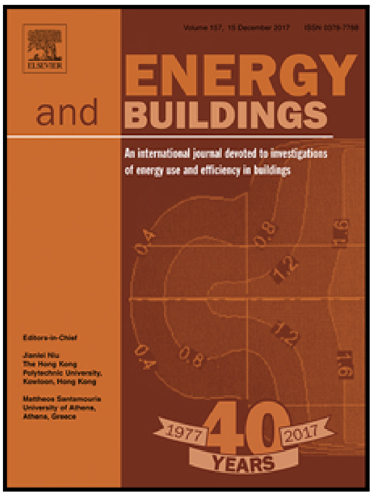

Energy poverty and indoor cooling: an overlooked issue in Europe

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Energy poverty and indoor cooling: an overlooked issue in Europe

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Abstract

Conceptually, many energy poverty studies to date have been narrowly focused on inadequate indoor heating, paying little attention to other domestic energy services. Yet there are indications that a growing number of households in Europe are struggling to achieve adequate levels of indoor cooling, with adverse consequences for their health, well-being and productivity. This situation is exacerbated by changing global weather patterns, with many countries facing increases in the frequency and intensity of extreme heatwaves. There is limited understanding of the ways in which households respond to extreme heat, and consequently how this might create greater demand for indoor space cooling and air conditioning, and the consequences for increased stress on power grids and conflicts with carbon reduction goals. Using custom-built survey data collected from 2,337 households in Gdańsk (Poland), Prague (Czech Republic), Budapest (Hungary) and Skopje (FYR Macedonia), along with in-depth qualitative fieldwork with 55 households in the same cities, this paper presents novel evidence on the issue of summertime energy poverty and space cooling difficulties. We identify the driving forces of household vulnerability to excessive indoor heat, in terms of risk of exposure, adaptive capacity, and sensitivity, and explore the implications for addressing energy poverty.

Keywords: indoor cooling; energy poverty; fuel poverty; energy vulnerability; air conditioning; heatwaves; overheating

1. Introduction

In recent years Europe's regions have been facing more extreme weather events due to climate change (European Environment Agency, 2017), and in particular many countries have experienced an increase in the frequency and intensity of heatwaves. As seen in the summer of 2003, heatwaves can have catastrophic impacts on human life, with an estimated 70,000 additional deaths in Europe due to excessive heat (Robine *et al*., 2008). These changing climate patterns can also bring about a number of urgent challenges for energy demand, energy services and domestic adaptation practices. For example, in South East Europe, a region that is particularly vulnerable to climate change (European Environment Agency, 2017), the increase in external temperatures and heatwaves is driving greater demand for indoor space cooling and air conditioning, contributing to increased stress on power grids, as well as growing household vulnerability.

Despite these shifting climate patterns - and in comparison to the advanced body of literature on summer thermal comfort and adaptive practices in non-European contexts (e.g. Bélanger *et al*., 2015; Strengers and Maller, 2017; Zhang *et al*., 2017; Indraganti, 2010; Nicholls *et al*., 2017) - research on cooling poverty in Europe is in its infancy, particularly as prevailing energy poverty discourses have tended to prioritise discussions of adequate heating (Simcock *et al*., 2016). Of the European literature that does exist on cooling in buildings and vulnerability, a large proportion of papers take a technical perspective on temperature measurement and adaption, such as a Special Issue on overheating in buildings edited by Lomas and Porritt (2016). This work establishes that overheating is a phenomenon that is already occurring in regions that were thought to be at low risk, such as within Scotland (Morgan *et al*., 2017), and that it disproportionately occurs within vulnerable households (Vellei *et al*., 2017). Within Spain, researchers have begun to propose new methods for including energy cooling needs within the definition of energy poverty (Sánchez-Guevara Sánchez *et al*., 2017) by exploring temperature thresholds specific to the Spanish context. However, much remains unknown about the particular characteristics of Europe's housing stock and demographic make-up in relation to space cooling, and the inequities around space cooling as part of a wider set of difficulties in securing adequate energy services.

Cooling has also long been underrepresented in European energy policy, especially compared to heating. While European Directive 2010/31/EU did note there had been a rise in the number of air-conditioning units in Europe, and called for measures to avoid overheating (such as shading, passive cooling, and sufficient building thermal capacity), there has been a lack of joined-up thinking in pan-EU debates on this topic. However, the European Commission recognised this gap in policy, and launched the Heating and Cooling Strategy in February 2016. This strategy recognises that space cooling is the most important aspect of thermal comfort in warmer climates, and is growing in importance across Europe. It also explicitly links excessive indoor heat to poor building quality, and notes that simple building renovations, such as insulating ceilings, walls and foundations, can improve thermal comfort (European Commission, 2016a: 4). Critically, the European Commission also draws attention to the role of nature-based solutions, such as "well-designed street vegetation, green roofs and walls providing insulation and shade to buildings" (*ibid*.). More recently, the European Commission has proposed a number of key mandates for Member States to reduce the energy consumption and emissions associated with cooling, as part of the Clean Energy for All Europeans legislative package that is in the process of being finalized (European Commission, 2016b).

Within this paper we conceptualise energy poverty as occurring when a household is incapable of securing a degree of domestic energy services (such as space heating, cooling, cooking) that would allow them to fully participate in the customs and activities that define membership in society. More specifically, we use elements of the energy vulnerability framework developed by Bouzarovski and Petrova (2015), which means examining *risk factors* – in terms of exposures, sensitivities and adaptive capacities – that contribute to the precariousness of particular spaces and groups of people. One novelty of the vulnerability framework is its emphasis on the spatial and temporal dynamics of energy poverty, which recognizes that households described as energy poor may exit the condition in the future by a change in some of their circumstances, and vice versa. By focusing on a household's inability to secure socially- and materially-necessitated levels of domestic energy services, the energy vulnerability framework allows for moving beyond space heating and including a wider range of causes and impacts associated with domestic energy deprivation. The overall aim of this paper is to introduce new varieties of energy poverty, focusing on inadequate indoor cooling among European households. In so doing, it also aims to broaden prevailing conceptualisations of energy poverty, and understandings of essential energy services.

2. Methods, data, and study areas

This paper is grounded in a comparative study of energy vulnerability in Europe, based on pan-European statistical data from the European Environment Agency and the EU Statistics on Income and Living Conditions survey (EU-SILC), as well as custom data drawn from a neighborhood-level study we conducted in four cities: Gdańsk (Poland), Prague (Czechia), Budapest (Hungary) and Skopje (Macedonia). Our selection of case study cities and countries was motivated by an aim to compare cities whose recent socio-spatial transformations have received limited scholarly attention (i.e. Skopje and Gdańsk) with those that are in the scientific mainstream on the subject (Prague and Budapest). We also wished to ensure a wide geographical spread in terms of climatic conditions, building types, and urban morphologies. In each city, the research focused on two neighborhoods – a historic inner-city district containing relatively dense multi-story tenement buildings of different ages, on the one hand, and a less central area with a mix of housing estates built from the 1960s onwards (sometimes adjoining individual family homes that generally predate the socialist period), on the other. Our research thus included a variety of building typologies. In the remainder of the article, the case study neighborhoods have been assigned a three letter code that ends with “A” if the given district is in the inner city, and “B” if it is more peripheral. The first two letters of the code correspond to the study city – “GD” for Gdansk, “BU” for Budapest, “PR” for Prague and “SK” for Skopje.

A questionnaire survey, with a quasi-random and systematic sample, was conducted in the four study cities between February and April 2015, totalling 521 households in Budapest, 598 in Gdańsk, 620 in Prague, and 598 in Skopje. The survey was aimed at establishing the social, spatial and demographic underpinnings of energy vulnerability, its implications for the conduct of everyday life, as well as the nature of social attitudes towards energy and housing reforms. Further information on our survey methodology can be found in Bouzarovski and Thomson (2018). Following the surveys, we also conducted qualitative semi-structured interviews with households in Gdansk (n=23), Budapest (n=17) and Skopje (n=15) during the summer of 2016.[1] Interviews enable the collection of rich and detailed data, allowing issues to be explored thoroughly and their complexities and nuances uncovered (Valentine, 2005). The household interviews thus complemented the surveys by enabling a more detailed examination of perceptions of indoor temperatures, and the factors that determined vulnerability to excessive heat. A purposive sampling strategy (Robinson, 2014) was adopted, via which we recruited a diverse set of households in terms of their housing type and socio-demographic characteristics. Interviews were recorded and transcribed verbatim, before being coded and analysed through the 'framework analysis' approach (Gale *et al*., 2013; Ward *et al*., 2013). All interviewees gave full informed consent to participate in the interview.

3. Results

3.1. External climate context

'Cooling degree days' (CDD) provide one of the most tangible metrics of the changing external circumstances that drive associated energy services in the home. To calculate CDDs, the European Environment Agency currently uses a method originally developed by the UK's Met Office. This approach considers a combination of daily mean, minimum and maximum temperatures in relation to a baseline temperature of 22 °C, above which a building is assumed to need cooling (European Environment Agency, 2016a). In Europe, CDDs have registered a marked rise since the 1980s (see Figure 1), with the greatest absolute increase occurring in southern Europe (at latitudes below 45 °N) – particularly around the Mediterranean and in Balkan countries (European Environment Agency, 2016a; Spinoni et al., 2014). Energy demand for summertime cooling is, as a consequence, highest in such regions.

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[1] Due to unforeseen logistical difficulties, it was not possible to conduct interviews in Prague as was originally planned.

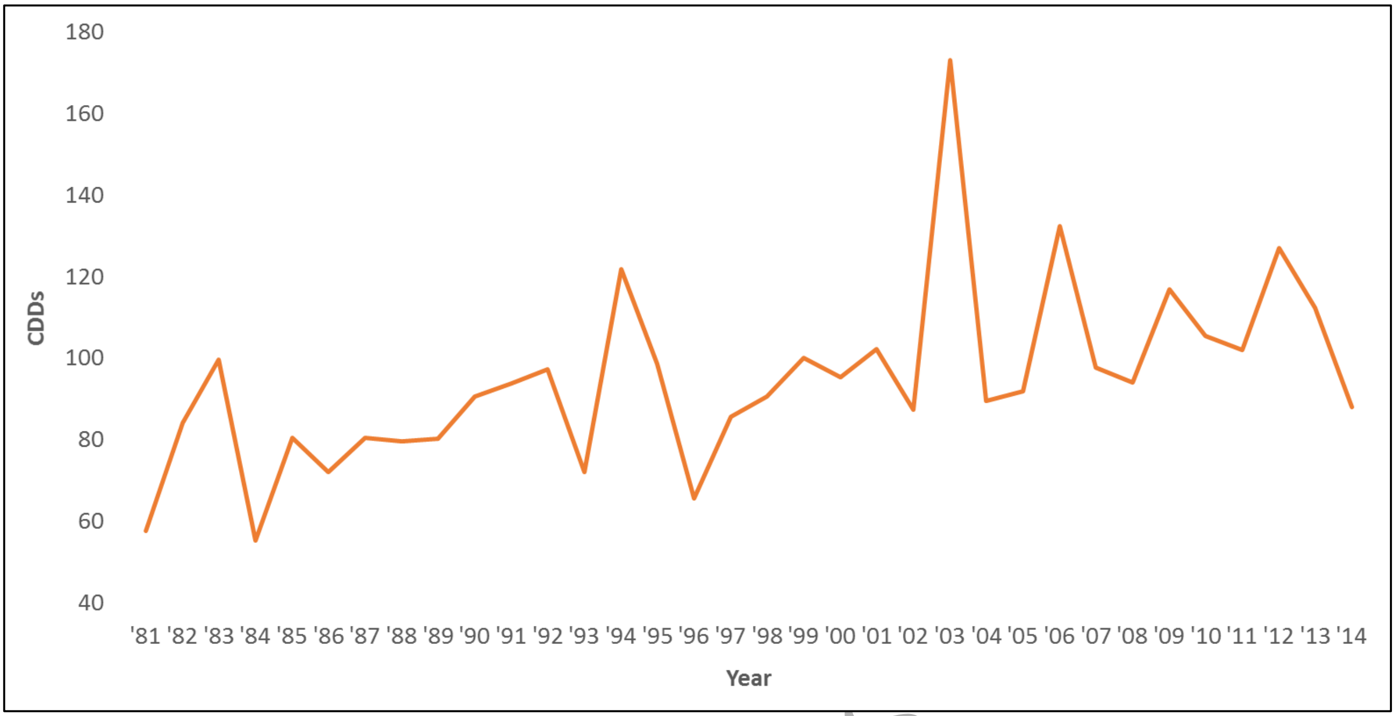


Figure 1 Cumulative population-weighted CDDs in the EU-28 (not including Cyprus but including Norway, Liechtenstein and Switzerland), 1981-2014. Data source: European Environment Agency.

In addition to the overall rise in CDDs, there has also been an increase in the frequency of extreme weather events – particularly heat waves. There is extensive evidence to suggest that such phenomena bring about a deterioration of human well-being, accompanied by increases in mortality and morbidity. This is especially true for vulnerable population groups, including older and infirm people, low-income households living in poor quality dwellings, and children. Even if the temperature thresholds for health impacts differ according to the region and season, the frequency of heat extremes has substantially increased across Europe in recent decades. As a result, it is believed that 'heat waves have caused tens of thousands of premature deaths in Europe since 2000' (European Environment Agency, 2016b). However, 'populations in regions where extremely hot weather is relatively infrequent are most vulnerable to heatwaves owing to a lack of behavioural adaptations and inappropriate housing' (Kovats and Kristie, 2006: 592). This is despite the fact that the reporting of heatwaves as 'disasters' with extreme temperatures is more common in Southern Europe and the Balkans. Research has shown that 'no population is completely acclimatized or adapted to very hot weather' (ibid) which means that hot weather-related mortality increases can be observed throughout Europe.

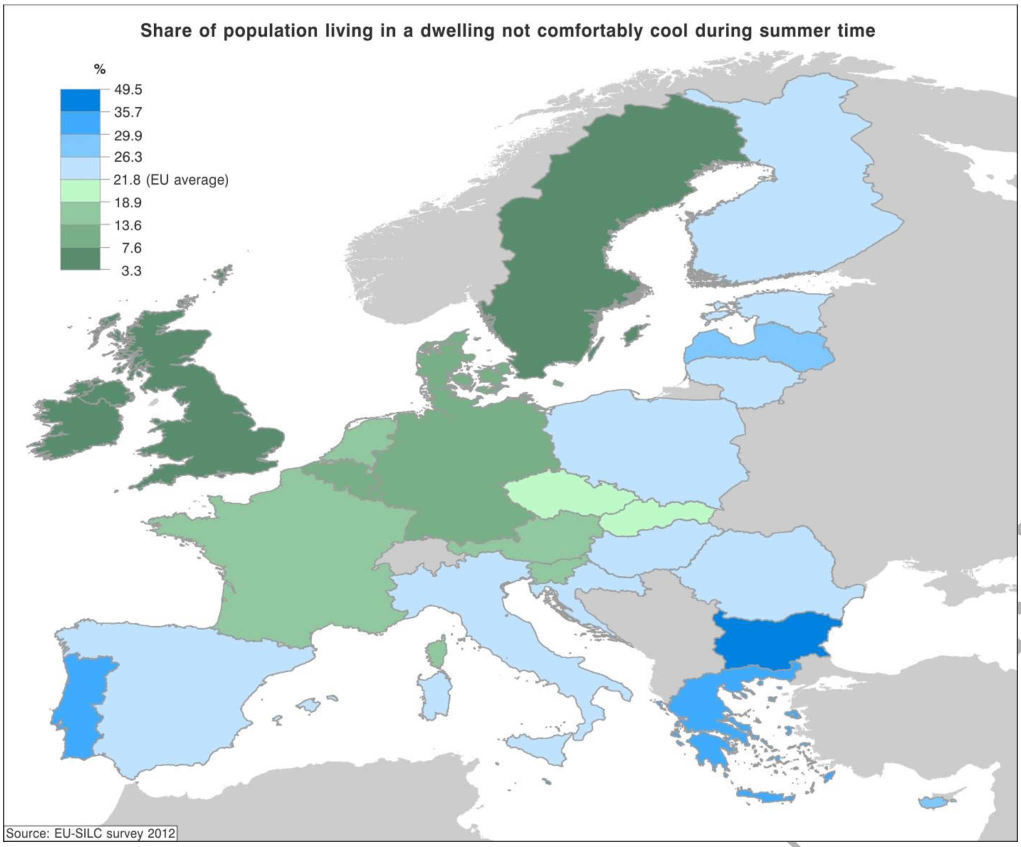
3.2. Prevalence of inadequately cooled homes in Europe

At present, the only official data on household cooling issues in Europe that exists is contained within two EU-SILC ad-hoc modules (2007 and 2012):

- Dwelling equipped with air conditioning facilities = Yes/No (2007 only)
- Dwelling comfortably cool during summer time = Yes/No (2007 and 2012)

However, collection of the air conditioning indicator stopped after the 2007 module, and from 2020, the comfortably cool indicator will no longer be collected, meaning that in the near future there will be no EU-level data relating to summertime energy poverty issues, and thus monitoring of the issue will become more difficult.

From this limited evidence base, we find that people in all European Union countries report difficulties in maintaining comfortable levels of cooling during summer. As depicted in Figure 2, there is a large degree of spatial variation, ranging from a low of 3.3% of the population in the UK, through to a high of 49.5% of the population in Bulgaria.



Source: EU-SILC survey 2012

Figure 2 Map of indicator 'dwelling not comfortably cool during summer', with Jenks Natural Breaks classification. Data: EU-SILC 2012.

The issue of inadequate cooling in summer seems to particularly affect Eastern, Central and Southern European countries, as detailed further in Table 1. Even within typically colder countries such as Ireland and the UK, 7.8% and 10.8% of households respectively reported inadequate cooling in 2007. Perhaps reflecting the seasonal variations in the years when fieldwork was likely to have been conducted for the EU-SILC data (2006 and 2011), most countries saw the prevalence of uncomfortable indoor cooling reduce between 2007 to 2012. The exceptions are Finland and Greece, who both saw small increases in prevalence, and Malta whose rates more than doubled. Nearly half of all Bulgarian households reported that their homes were not comfortably cool in summer in 2012. In terms of air conditioning facilities, as might be expected countries located in Southern Europe have the highest rates of air conditioning units, with 77.1% of homes in Cyprus featuring air conditioning, 55.7% in Malta, and 52.8% in Greece. These high rates of air conditioning are concerning in terms of the tensions that exist with climate change mitigation and demand reduction goals. Considering that a high proportion of Bulgarian households report that their home is uncomfortably hot during summer, just 8.4% of households reported having an air conditioning unit. Overall, the EU average is 10.8%.

Examining the levels of inadequate indoor cooling among people who are classified as income poor[2] reveals a strong deprivation element, and echoes Klinenberg's (2002) findings that those in poverty are more vulnerable to excessive heat. The figures range from 4.3% of income poor people in the United Kingdom reporting inadequate cooling in 2012, through to 70.7% of the income poor population in Bulgaria. Similar trends are evident in terms of air conditioning, for example just 9.9% of income poor households in Finland reporting having air conditioning, compared to a national average of 19.2%.

	Dwelling equipped with air conditioning facilities - whole population and (income poor)	**Dwelling not comfortably cool during summer time** - whole population and (income poor)	
	2007	**2007**	**2012**
EU average	10.8 (8.2)	25.8 (31.3)	19.2 (26.3)
Austria	1.5 (0.8)	18.1 (25.7)	15.0 (22.3)
Belgium	3.1 (1.0)	14.3 (21.9)	12.7 (21.0)
Bulgaria	8.4 (1.1)	-	49.5 (70.7)
Croatia	-	-	24.2 (32.0)
Cyprus	77.1 (52.5)	40.9 (47.3)	29.6 (34.4)
Czech Republic	0.9 (0.1)	39.1 (44.4)	21.8 (27.6)
Denmark	5.7 (4.0)	17.7 (22.4)	11.6 (11.9)
Estonia	1.9 (0.6)	23.3 (22.8)	23.3 (26.3)
Finland	19.2 (9.9)	20.3 (20.3)	25.2 (27.8)

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[2] Where equivalised disposable income is below the threshold of 60% of the national equivalised median income.

France	5.2 (4.2)	29.0 (30.6)	18.9 (24.8)
Germany	1.8 (0.7)	22.7 (30.0)	13.6 (21.4)
Greece	52.8 (33.3)	29.4 (37.3)	34.0 (48.9)
Hungary	4.5 (1.5)	28.5 (27.6)	25.8 (32.8)
Ireland	0.4 (0.2)	7.8 (9.9)	4.0 (4.4)
Italy	25.1 (15.1)	33.4 (43.8)	26.3 (37.9)
Latvia	1.8 (1.4)	39.4 (46.0)	29.9 (31.7)
Lithuania	2.1 (0.7)	33.1 (22.8)	24.6 (21.4)
Luxembourg	5.2 (0.9)	17.9 (30.9)	10.2 (14.1)
Malta	55.7 (42.2)	16.0 (20.1)	35.4 (40.1)
Netherlands	6.4 (3.2)	18.2 (24.5)	17.7 (22.9)
Poland	0.9 (0.5)	41.2 (47.1)	25.3 (28.2)
Portugal	7.2 (2.6)	42.4 (51.2)	35.7 (41.4)
Romania	5.3 (0.6)	-	22.6 (21.5)
Slovakia	1.0 (1.8)	37.5 (39.1)	21.0 (23.4)
Slovenia	12.0 (5.9)	21.0 (25.1)	17.3 (21.4)
Spain	38.2 (32.7)	25.9 (31.2)	25.6 (33.1)
Sweden	15.2 (14.3)	11.1 (12.5)	7.6 (9.9)
United Kingdom	1.9 (1.8)	10.8 (11.4)	3.3 (4.3)

Table 1 Country means (%) for air conditioning and comfortably cool indicators. Data source: EU-SILC ad-hoc modules 2007 and 2012

Data from our neighbourhood survey conducted in 2015 in four Eastern and Central European cities confirms the above trend. In most case study areas, an inability to maintain adequate cooling was the most reported thermal comfort issue, rather than keeping comfortably warm, as shown in Figure 3. The highest overall incidence was reported in districts dominated by high-rise blocks of apartments – particularly in Prague and

Budapest, where around 40% or more of survey respondents stated they experienced excessive indoor heat during summer. Across all areas this is matched by a low availability of air conditioning systems.

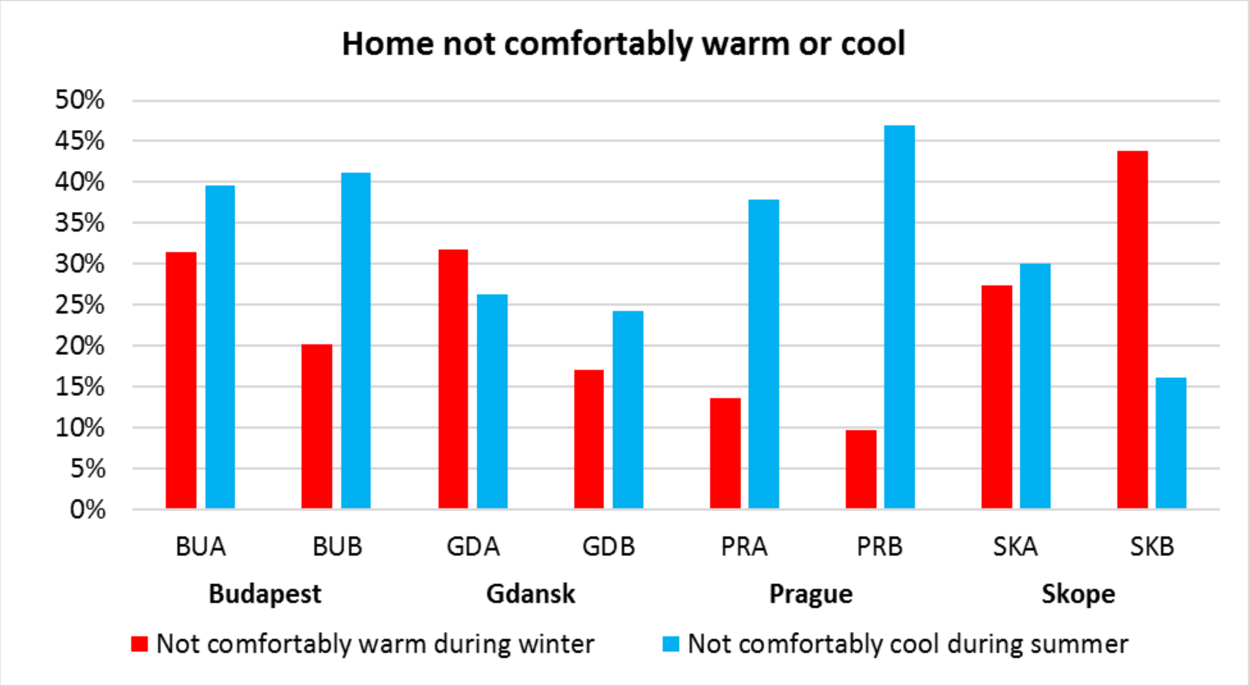

Figure 3 Thermal comfort issues reported in the neighbourhood survey

3.3. Exploring the complexities and nuances of living with excessive heat

Findings from the qualitative data collection and analysis corroborated the above quantitative results – a perceived inability to keep adequately cool in the summer was reported as a problem by many households in all of the case study cities. Notably, some of those who described such problems had *not* reported difficulties in keeping sufficiently warm during the winter, reinforcing the point that the populations affected by these two issues are not necessarily the same. The following quotes exemplify experiences of overheating:

“we mostly have a problem during the summer, because it is impossible to deal with the heat. People come and everyone is dripping with sweat.” (GD007)

“Sometimes the air fails to move in the evening and it feels like that there is no air at all, it is suffocating. You can take showers in cold water, of course not warm water just cold, but it doesn’t help” (BU005)

"It is too hot all day long. In the morning it is OK, before the sun is too high. So before 1PM it is pleasant. After that it is unacceptably hot for as long as the sun is shining" (SK033)

The severity and frequency of this problem varied between households. For some households it was an intermittent issue, occurring only on exceptionally warm days, but for others it was a frequent problem throughout the summer months. Echoing the findings of our quantitative survey, the most severe overheating experiences were reported by those living in high-rise apartment buildings, especially in Budapest and Skopje. These households also typically had limited incomes, which, as explored further in section 3.3.4, further exacerbated their vulnerability by constraining their ability to effectively respond to high indoor temperatures (see also Klinenberg, 2002 for the impact of socio-economic status on heatwave vulnerability). There was also temporal variation within days, with afternoons and early evening typically being the hottest time, and spatial variation within individual dwellings as larger homes often had at least some rooms that remained relatively cool.

3.3.1 What determines vulnerability to inadequate indoor cooling?

Drawing primarily on analysis of our qualitative data, this section examines the factors that shape a household's vulnerability to being unable to keep adequately cool during the summer. Informed by theories of vulnerability (Adger, 2006; Bouzarovski and Petrova, 2015; Lindley et al., 2011), our analysis revealed that a household's vulnerability to being unable to keep adequately cool in the summer was contingent on the interplay of three factors: (i) A household's *risk of exposure* to an overheating dwelling, and the frequency and severity of this overheating; (ii) Household members' *sensitivity* to the impact of overheating; that is, the likelihood that it would have a harmful impact on their well-being; (iii) Household members' *capacity to adapt* should their home overheat. We now discuss these in turn.

3.3.2 Risk of exposure

It might be expected that national and regional climate would be a key factor determining a household's risk of exposure to excessive indoor heat, with those living in warmer countries and places more likely to experience high or uncomfortable indoor temperatures. However, as noted in section 3.2, of the four cities we studied, despite having the most southerly latitude and highest average temperatures Skopje had the lowest proportion of survey respondents expressing that their home was uncomfortably hot during the summer months. This suggests that the expectation that places with 'naturally' warmer climates will necessarily have greater numbers of people experiencing uncomfortably warm indoor temperatures is over-simplistic. Rather, our analysis indicates that it was the *interaction* of 'natural' weather events with the material characteristics of (i) neighbourhoods, which influenced local air temperatures by determining the presence and severity of the 'Urban Heat Island' (UHI) effect (Stone and Rodgers, 2001) (ii) specific homes, which mediated temperatures and comfort perceptions inside an individual dwelling. Relating to this second point, we found three contingencies to be particularly important in this regard: sunlight exposure, ventilation, and building material.

The size, orientation and extent to which windows were, or could be, shaded was a key factor shaping the degree to which the inside of a dwelling was exposed to direct summer sunlight. Dwellings with large, unshaded windows with a south- or west-facing orientation frequently reported experiencing uncomfortably warm indoor temperatures during the summer months, particularly during the afternoon and early evening, due to heating caused by a 'greenhouse effect'. Having windows that were able to be shaded via shutters or awnings helped to reduce the risk of overheating, yet within our sample these were unequally prevalent between and within cities – being most common in Skopje, and least common in Gdansk. For some, shading from trees or neighbouring buildings also played a key role in keeping their homes cool by preventing the sun's rays from directly entering the house, alongside reducing localised air temperatures via evapotranspiration (Norton et al., 2015). For example, BU032 explained how window shutters and trees planted close to their apartment "*help a lot*" in keeping indoor temperatures low during summer, noting that *"Those [neighbours] who still have the old trees overshadowing their apartments say that it really makes a difference, as they catch the heat"* (BU032). Again, however, such features are not available for everyone.

In particular, several respondents living on the upper floors of apartment buildings reported that their homes and windows were too high to be shaded by trees. This factor helps explain the results of our neighbourhood surveys, which found higher rates of reported overheating in places where such dwellings are prevalent (see section 3.2).

A dwelling's degree of ventilation was a second important factor, and the orientation and number of windows were again important here. Those living in the smallest apartments with only one window, or with several windows all orientated in the same direction, reported struggling to gain sufficient ventilation to cool the home. GD008 explained *"I have got only one window, so it's impossible to refresh the air in the apartment"*, whilst BU022 similarly said "… *there's no ventilation … if there was a window [points at the opposite wall], there could be a bit of a cross wind and then there would be different air inside."* (BU022).

Finally, the materials with which a dwelling and its surrounding infrastructure were constructed also mattered. Wilhite (2008) notes that many 'modern' building practices, involving widespread usage of cement and concrete, have thermal properties unsuited for warm weather as they absorb heat before releasing this inside a dwelling. Echoing this, in our study those living in buildings with walls or roofs made of concrete or asphalt reported some of the most severe cases of excessive indoor heat: *"[The apartment building has] flat roof. In our apartment it doesn't matter but the upper floor apartment has a catastrophic room temperature in the summer"* (BU012). Importantly, insulation in the walls and/or ceiling of a dwelling could help to prevent overheating by 'keeping the heat out'. Several interviewees that had installed such measures reported a significant positive impact in terms of their ability to keep adequately cool on hot summer days. Supporting findings from previous studies (Stone and Rodgers, 2001; Mitchell and Chakraborty, 2014), the infrastructure of the wider neighbourhood also played an important role by mediating the prevalence of the UHI effect. For example: *"There is a lot of concrete in the vicinity which radiates heat"* (SK040).

3.3.3 Sensitivity

Whilst distribution of exposure to high indoor temperatures is important, to fully comprehend vulnerability it is necessary to understand how exposure interacts with an agent's sensitivity to harm (Lindley et al., 2011). Although many households in our interview sample experienced excessive indoor temperature, they were unequal in the degree to which such conditions had a negative impact on their physical health and, more broadly, their sense of wellbeing. Many respondents described issues of general discomfort, lethargy and tiredness, with potential implications in terms of restricting their ability to undertake other activities they may value. However, it was those households containing a member with a pre-existing health problem that reported the most severe consequences that extended to harms to their physical health. Previous literature has emphasised how the morbidity and mortality risks of heatwaves are exacerbated by pre-existing medical conditions, particularly those relating to the respiratory or circulatory systems (Klinenberg, 2002; Song et al., 2017), a finding echoed in our own research. For example, BU021 had a heart condition and circulatory problems, and claimed that her feet swelled and she had more trouble breathing when the home was very hot. Likewise, SK014's mother suffered from high blood pressure, and this problem was exacerbated during periods of high temperatures: "*My mother's blood pressure varies greatly because of the heat and she has constant headaches."*

A further important variable influencing sensitivity was age. Interviewees reported that young children and, especially, older people were affected more severely by high indoor temperatures. . Again, this supports previous medical research into the health implications of heatwaves, with has found strong evidence that those aged over 65 are at greater risk of heat morbidity and mortality, due to reduced capacity for thermal regulation (Sharma et al., 2018; Song et al., 2017). We further found that, in the case of older people, age and health status can in some cases combine to create particularly heightened sensitivity: *"…when I was younger … the weather did not affect my health as much. Now I am more sensitive to sudden changes in the weather … as I age the heat bothers me more and more"* (SK022).

3.3.4 Adaptive capacity

The final dimension of vulnerability that must be considered is a household's 'adaptive capacity' (Adger, 2006) – that is, their ability to respond and adapt in order to accommodate high indoor temperatures. Indeed, none of the households in our study passively accepted overheating in their home. Rather, all made active attempts to mitigate such circumstances. Most commonly, these involved everyday 'behavioural' adaptations, such as opening windows, drawing blinds or curtains, adjusting clothing, consuming cold drinks or foods, turning on electric fans, and more frequent showering. Although such measures seemed to partly mitigate the worst experiences of high indoor temperatures, they did not remove them completely and many interviewees still reported uncomfortably warm conditions. In other words, they provided a degree of short-term and partial relief, without more fundamentally reducing exposure risk in the longer-term. It is also worth noting that research into 'cold weather' energy poverty, in which a household struggles to maintain sufficient domestic warmth during winter months, has similarly documented households making behavioural adaptations as a way of managing thermal discomfort (Anderson et al., 2012; Chard and Walker, 2016) – indicating a degree of commonality in how people cope with different forms of energy poverty.

Two other types of adaptation appeared to be more effective at reducing the incidence and impact of excessive indoor heat. First, some households we interviewed had made changes to the material structure of their home, such as installing external wall shutters and/or wall or loft insulation, and installing or running air conditioning systems. By altering the materiality of a dwelling and thus its internal climate, such measures reduced the frequency and severity of a household's *exposure* to excessive indoor heat. As noted at the end of section 3.3, several interviewees reported that overheating in their home was greatly reduced following the installation of insulation. Second, during periods of hot weather many households altered the spatial patterning and timing of their activities, seeking to spend more time in 'cool spaces'. For those in larger homes, this could mean confining themselves to the cooler rooms of a dwelling (again echoing research into cold weather energy poverty; e.g. Buzar, 2007), but a seemingly more effective approach was to leave the home and travel to a cooler area in the neighbourhood or wider city – most commonly, either air-conditioned shopping centres, or gardens and urban greenspace.

Importantly, however, our interviewees had strikingly unequal adaptive capacity, with many facing constraints on their ability to make alterations. In terms of utilising ‘cool spaces’ outside the home, for several households this was not easily accessible. Not all apartment buildings had shared gardens, and, echoing the wider environmental justice literature (Walker 2012), some neighbourhoods lacked easy access to public greenspace. The particular design and features of greenspace also mattered, by shaping its perceived quality, desirability and cooling capacity. For example, BU010 described how they avoided their apartment building garden due to vandalism and crime, whilst urban parks lacked sufficient seating, shading and drinking fountains: *“...the parks? There are no more water taps there. You know how many benches are there in this park? Just 3!”*. In terms of home renovation, such changes cost money and several interviewees noted that they lacked the required capital for such investments. For example, SK007 explained that although they would like an air-conditioning unit, they could not install one because *“It is expensive to buy and expensive to use.”* By constraining or enhancing adaptive capacity, socio-economic status is thus an important determinant of a household’s overall vulnerability to excessive indoor temperatures (Mitchell and Chakraborty, 2014). Other important factors included restrictive tenancy relations, which prevented some households making material changes to their dwelling (see also Middlemiss and Gillard 2015), whilst for others the technical constraints and physical obstacles limited a dwelling’s renovation capacity (Bouzarovski and Petrova, 2015).

4. Discussion and conclusions

From the evidence available to us, we have identified that perceived overheating during summer occurs all across Europe, including within countries that have milder climates and where this phenomenon was thought to be rare, such as the UK (Morgan *et al.*, 2017). The findings have also revealed driving forces of vulnerability to excessive indoor heat. We have argued that to fully understand vulnerability requires examining the determinants of three factors: the likelihood a home will overheat (risk of exposure); a person’s ability to respond to excessive indoor heat should it occur (their ‘adaptive capacity’), and the risk that it would have harmful consequences for their well-being (their ‘sensitivity’). It is the dynamic interaction of these three dimensions that ultimately determines vulnerability (Lindley *et al.*, 2011).

Our understanding of domestic vulnerability to excessive indoor heat is conceptualised within the diagram in Figure 4. Although this diagram necessarily simplifies a set of complex interactions, it nonetheless helps visualise the diverse range of contingencies that are at play in determining household-level energy vulnerability. Heightened risk of exposure to uncomfortably warm indoor temperatures in our study was largely caused by climatic factors combining with material features of a home that were not conducive to keeping cool – such as large windows without shutters, a lack of ventilation, and inappropriate building materials that absorb rather than reflect heat. Heightened sensitivity was due predominantly by poor physiological health, and adaptive capacity by a range of contingencies including income, tenancy relations, built structure and access to wider cool spaces outside the home. It is important to note the interaction and overlap between these different dimensions of vulnerability. For example, those who are older or in poorer health (greater sensitivity) may have reduced mobility and so be unable to easily travel to cool spaces outside the home, whilst also being at greater risk of income poverty that limits their financial capacity to make alterations to their dwelling (Snell *et al.*, 2015). Given the complexity of these interacting factors, it is clear that the dominant driving forces of vulnerability to inadequate indoor cooling will vary geographically. For example, within some Northern European countries, where summertime cooling is not as widely recognised as important, buildings are less likely to have cooling features such as shutters and tiled floors.

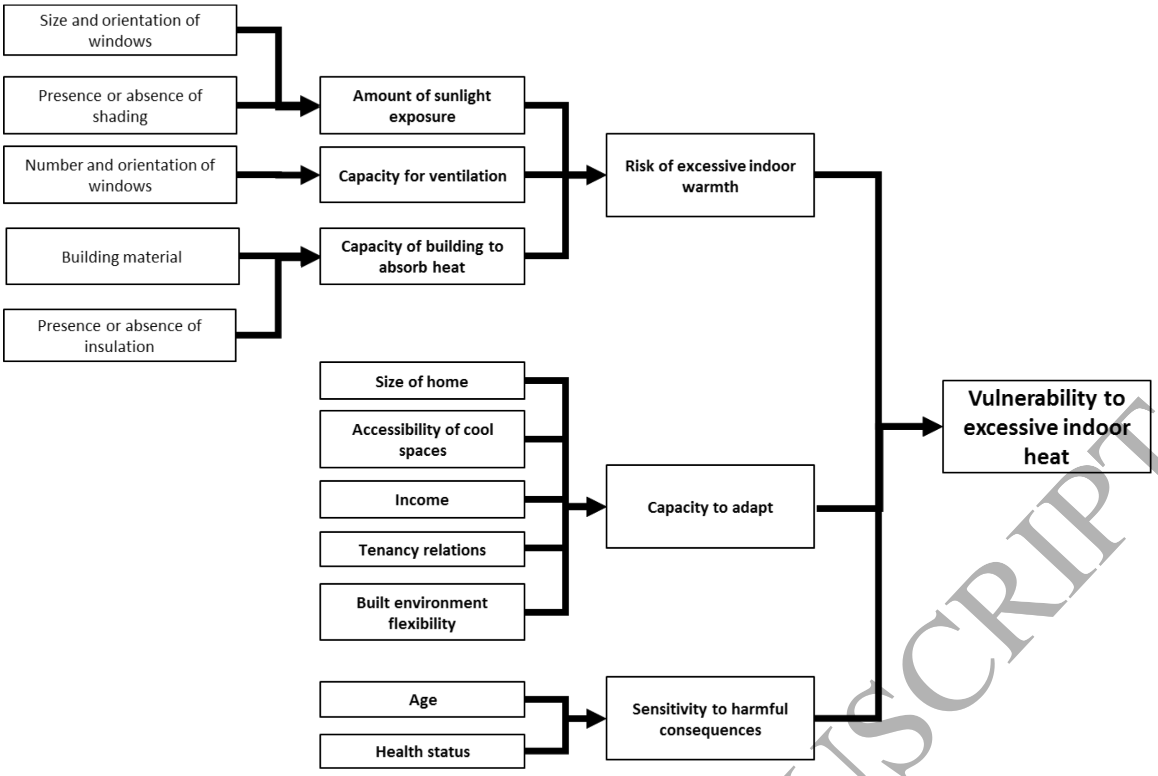

Figure 4 Conceptual diagram of vulnerability to excessive indoor heat

Unlike North America, where the relationship between inadequate summer indoor cooling and income inequality is well documented – principally focusing on the lack of air conditioning in poor urban areas, and the health effects of heat waves (Kovats and Kristie 2006, Uejio et al 2011, Mitchell and Chakraborty 2014), research on cooling poverty in Europe is in its infancy. The findings presented in this paper trace the contours of a new research agenda. First, future scholarship in the field would need to elucidate the particular characteristics of Europe's housing stock and demographic make-up in relation to space cooling: dense urban areas prone to overheating with relatively low income differentials, but with an overrepresentation of vulnerable households (pensioners, immigrants, unemployed adults, large families with children, single parents). Research of this nature should take into consideration the importance of humidity in how high temperatures are experienced (Oppermann et al., 2017), an aspect of heat that was not explored within our research. Second, it becomes necessary to take into account Europe's relative unpreparedness – with the exception of the Mediterranean region – to summer heat; our study has shown that space cooling-related energy poverty affects countries located well into the European north (such as Poland), where the notion that households may struggle to cool their homes for a considerable part of the summer is outside the focus of public attention. Third, there is a need to consider the inequities around space cooling as part of a wider set of difficulties in securing adequate energy services, among which space heating, lighting and appliance services stand out. The juxtaposition of multiple types of energy deprivation against the background of a globally unfolding climate crisis raises worrying prospects that require prompt recognition from the scientific community.

The findings in this paper also point to a number of important implications for the ways in which policymakers – at the regional, national, and supranational level – conceive of energy challenges in their domain. There is an urgent need to move beyond over-simplistic assumptions of seasonal climate needs, towards the commissioning of new research on year round vulnerability, and comprehensive climate risk assessments that include measurement of the preparedness for heat waves in the domestic sector.
This is challenged by Eurostat's decision to stop collecting EU-level data on indoor cooling issues and air conditioning, meaning that from 2020 we will have no official pan-European data. We strongly recommend that this decision be reversed, and indeed, that additional data is collected and compiled on cooling needs and responses – by bodies such as Eurostat and the EU Energy Poverty Observatory. This type of data is essential for monitoring trends in perceived thermal comfort, as well as any potential increase in the use of air conditioning units which may arise in response to the growing risk of experiencing heatwaves. The growth of domestic air conditioning as an adaptation practice is concerning for many reasons. Firstly, if it becomes more established in use this will place pressure on electricity grids during summer, which could become unmanageable when taken in combination with the cooling demands from non-domestic buildings (such as hotels and offices). The use of air conditioning also creates tensions with carbon reduction goals, and creates additional layers of potential financial vulnerability for households. It is imperative that policymakers first look to measures to avoid overheating that do not involve air conditioning, such as nature-based solutions, shading, passive cooling, and increased building thermal capacity (European Commission, 2016a). A significant amount of investment will be made to energy systems and buildings in forthcoming years in order to meet the requirements of the new Clean Energy for All Europeans legislation, which

presents a range of opportunities for policymakers to reflect on the emerging literature on space cooling as an issue of energy poverty, and engender systemic change to reduce future vulnerability.

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Declaration of interest

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