Everyday sustainability transitions through green building: Spatial perspectives on materialities, discourses and lived sustainabilities

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Affolderbach, Julia, University of Trier, affolderbach@uni-trier.de
O'Neill, Kirstie, Cardiff University, oneillk1@cardiff.ac.uk

Abstract
In 2019 governments across Europe set the goal to achieve net zero greenhouse gas emissions by 2050. Through its high share of energy use and carbon emissions, the building sector is seen as central in this endeavour. While EU and national regulation and incentive schemes provide an important context, how green building is realized often plays out at subnational spatial scales, including how green buildings are designed and embedded in existing regional and local (infra)structures. More localised scales become even more important when we consider the sustainability of buildings-in-operation. In contrast to the design and construction phase of green buildings, very little attention has been paid to post-occupancy studies and the role of building users in enabling or constraining sustainability transitions. These actors are, however, crucial in reducing carbon emissions as a fabric-only or technologically-focused approach will be insufficient. This paper seeks to contribute to a better understanding of the role of building users and the impact of green buildings once in operation through the frame of lived sustainabilities. It focuses on changes which are shaped by interdependences between discourses on green buildings including expectations, framings and understandings, activities as associated with living and working in buildings as well as materialities of green buildings. We present a research agenda which highlights the entangled spatial dimensions of sustainability transitions which define different contexts and bring to the fore the role and importance of spatial scales in terms of the impact green buildings might have on broader changes to wider everyday practices.

Keywords: green buildings, sustainability transitions, lived sustainability, practices, social change, scale

1. Introduction

Climate change has led to manifold changes in policy and practice, as the global community attempts to reduce greenhouse gas emissions and plans adaptation measures. Amongst these policy approaches, in 2019, the European Union (EU) announced its commitment to reach carbon neutrality by 2050. Member states like Sweden and Germany, have since pledged to become climate neutral by 2045, Austria by 2040 and Finland by 2035. To reach these net zero targets, a 'deep transition' (Schot and Kanger, 2018) or even a 'radical transition' (Loorbach, 2022) is needed, involving significant institutional, structural and social changes across all sectors and aspects of life simultaneously. Through its high share of energy use and carbon emissions, the building sector is seen as central to achieving these goals. For example, the EU Green Deal considers buildings and power generation to potentially make "the largest and most cost-efficient emissions reductions" (Fleming and Mauger, 2021). While significant effort focuses on the design and construction of new buildings, much less is known about the performance and role of green buildings once they are in use, including how users contribute to, or

undermine, sustainability targets, and how the green buildings they occupy influence their daily lives, within and beyond the space of the building. Furthermore, buildings will be a critical component of adapting to climatic changes, including hotter summers, wetter winters, and general variability and unpredictability. User-building interactions are becoming increasingly important as climate actions focused on the design and construction phase have so far proven insufficient to accomplish the fundamental changes that are needed to achieve carbon neutrality in the building sector. Rather than adopt a fabric-only approach that has dominated in the past, we argue that a focus on users' lived sustainabilities is critical, for the functioning of green buildings, and adapting to climate change more widely (Devine-Wright et al., 2022). We need to better understand social norms, values and lifestyles but also the way users construct and use knowledge, and the role of discourses and narratives in shaping sustainability transitions or resistance to them. Martek et al. (2019) identify the role of the user as a conspicuous gap in the academic literature on sustainable buildings.

Within this context, the paper focuses on the relationships between processes of designing, construction, retrofitting and discourses of green buildings and users' lived experiences in these buildings which we refer to as 'lived sustainabilities' to better understand the role of people, place, social practices, and climate politics. These lived sustainabilities, we argue, can be revealed and understood through examining the practices of those working and living in green buildings.

Green buildings are variously referred to as low carbon, zero carbon, low energy, eco, and sustainable, and within the green building movement there are different ideologies and approaches surrounding what it means to build 'green' (Boschmann and Gabriel, 2013, Gibbs and O'Neill, 2014). These terms are used interchangeably yet have nuanced differences. Boschmann and Gabriel (2013) further refract this term by suggesting that 'green' can be differentiated by 'light' and 'deep' green buildings. Light green buildings employ visible technologies such as innovative heat-capture system, solar panels and cutting-edge windows. This aligns with what Guy and Farmer (2001) describe as an eco-technic logic that sees technology as the best way to respond to environmental problems. Deep green buildings, in contrast, place emphasis on low-level 'technologies' adapted to regional characteristics, designed to be sensitive to local conditions, respecting vernacular practices, and utilizing more 'natural' or passive systems, representing an eco-cultural or eco-centric logic. Pickerill (2015: 1) suggests that '[e]co-homes are houses designed, built and occupied to have less environmental impact than conventional homes.'

We here define green buildings as buildings and building ensembles that are designed and built in ways intended to reduce environmental impact both during construction and, but more specifically, in operation encompassing green technologies, design, materials, and envisioned ways of living. This latter point has often been overlooked in past work and thus definitions of green buildings. It involves spatially and temporally complex processes of interactions between those involved in the designing and building (e.g. architects, engineers, suppliers, builders and self-

builders), actors visioning and regulating developments (e.g. politicians, planners, community groups) and those envisioned as occupying, and subsequently using, buildings in myriad ways (the visions of designers may vary significantly from those who eventually do occupy these buildings). Central here is how green buildings and the expectations and understandings linked to them impact on users' daily activities (e.g. energy use through lighting and heating, space used for homeworking, mobility through accessibility and availability of car or bike parking).

Users affect the environmental and climatic effects of buildings, as the practices of those within green buildings can alter the intended functioning of such buildings, in ways that can improve the functioning or weaken it. In discussing 'users' we mean the occupants and managers of different types of green buildings, from homeowners and their families, to office workers, businesses renting green office space, those responsible for managing and maintaining different types of green buildings, and the ways these are envisaged by those who designed green buildings. As Pickerill (2015) notes, users can impair the functioning of green buildings, and have been overlooked in the literature. For example, Galassi and Madlener (2018) highlight unsustainable practices such as keeping windows open over long timespans to adjust room temperatures in energy retrofitted homes and thereby offsetting intended energy savings by design. Human occupants might thus ignore, remove, tweak or modify technologies, or the intended uses and purposes of green buildings. This focus on post-occupancy practices, we argue, allows us to tease out the potential transformative power of green buildings and their specific materialities through behavioural changes and social practices as well as related social norms more generally. These social practices are critical to low-carbon transitions as technology and efficiency gains alone will not address the climate emergency but require deeper social and societal changes (Gills and Morgan, 2020, Devine-Wright et al., 2022).

The objectives of the paper are twofold. First, we draw on the discourses on sustainability transitions, green building and social practice theory to develop an analytical framework for analyzing lived sustainabilities in respect to green building (Sections 2 and 3). We then examine research implications and present a research agenda focused on spatial dimensions and entanglements as well as considerations of lived sustainabilities (Section 4). In particular, we discuss the need for multi-sited studies, the importance of the micro and local scale and the embeddedness of green buildings within existing infrastructure but also with other aspects of life (i.e. other practice domains or 'bundles') drawing on an illustrative case study. Section 5 highlights the potential of researching lived sustainabilities together with future research needs.

2. Green building transitions

The growing evidence on the climate and environmental crisis has resulted in clear recommendations for curbing greenhouse gas emissions which are now widely understood and accepted. Tackling these problems will require a *deep* transition. Markard et al. (2012: 959) define sustainability transitions as comprising "institutional, organizational, technical, social, and political aspects of far-reaching changes in existing socio-technical systems (e.g., transportation and energy supply) which are related to more sustainable or environmentally friendly modes of

production and consumption." Much research has focused on these so-called shifts and transitions towards more sustainable social and economic systems with particular interest in technological, organizational and institutional innovations while social aspects have remained relatively neglected (although see Hargreaves et al., 2013), as has the extent to which such transitions actually progress sustainability (Feola, 2020). This is problematic as progress on reductions of greenhouse gas emissions as well as other ecological goals (e. g. reforestation, biodiversity) is largely lagging behind international targets such as the EU's commitment to carbon neutrality (Stoddard et al., 2021). For example, the global development of energy demand and greenhouse gas emissions of buildings has shown an absolute growth over the past decade (International Energy Agency, 2021). The International Energy Agency (2021) reported an increase of seven percent of energy demand and nine percent of emissions between 2010 and 2019 emphasizing that the building sector is clearly "not on track" in respect to accepted climate targets. The UK's Climate Change Committee (2023) recently reiterated that expanding fossil fuel production is not in line with Net Zero and that attempts to reduce household energy demands are also not on track (CCC, 2023). During the same period, the size of buildings being constructed has increased - on average by 21 percent of total floor area (International Energy Agency, 2021). Even though buildings have become more *efficient*, an overall increase in the total building stock and the growth in building size is currently outweighing any emission reductions achieved via efficiency savings (ibid.). This does not tackle the challenge of upgrading and retrofitting the existing building stock of which 75 per cent in the EU are considered energy inefficient and 50 per cent were constructed before 1970 prior to the first introduction of thermal regulations (European Commission, 2022), low replacement rates amplify these challenges.

What is hence required are more fundamental changes to expectations and practices of designing, constructing, living and working in buildings. This involves not only occupant choices and behavior in buildings that affect energy use, but, according to the International Energy Agency (2017) also a more fine-grained understanding of how building design and characteristics influence feelings and lifestyles of occupants. One important aspect in this regard is how discourses, framings and narratives are used to shape transformation processes as they relate to green buildings (Geels 2014). Furthermore, O'Neill and Gibbs (2020) highlight how transitions can fail as policy and industry incumbents attempt to maintain their power and privilege through resisting proposed changes to regulation and legislation. There is thus a need for research on deeper change(s) in and of sociopolitical systems including consideration of lifestyles, social values and norms to break with 'business as usual' approaches (Chatterton, 2019), especially in the absence of strong policy frameworks needed to promote a deep or radical transition.

In respect to green buildings, considerable research effort has focused on reducing greenhouse gas emissions and material consumption through innovations in building design and technical innovations including digital tools (e.g. smart meters) and green technologies (e.g. solar panels) (Li et al., 2021). Much less emphasis has been placed on understanding the sustainability of green buildings once they are in use, including broader implications for daily lives (Affolderbach and Schulz, 2018, Pellegrino et al., 2022, Thatcher and Milner, 2016). While

reducing material and energy consumption of buildings is crucial in tackling climate change, taking a fabric-only approach to sustainability in the built environment overlooks the significant impact of 'users' on energy consumption and thus emissions (Bardsley et al., 2019, Breadsell et al., 2019). Post-occupancy studies have primarily focused on user satisfaction, productivity and health (MacNaughton et al., 2017, Altomonte and Schiavon, 2013) garnered via surveys and relatively superficial qualitative data. Much less is known about users' lived experiences or what Hitchings et al. (2015: 372) describe as the "lived interplay of values and actions". A focus on *lived sustainabilities* allows us to tease out the potential transformative power of green buildings through behavioural changes, social values and practices. This also encompasses societal dimensions of how we envision, design and construct (i.e. realise) green buildings (Bahho and Vale, 2022).

Importantly, the nature of what is perceived as sustainable building, living, and working is not an end point nor universally agreed, but rather an ongoing dialogue, spatially and temporally situated, informed by (socio-)environmental problems and sociotechnical developments of the past, present and future. The progressive, cumulative and iterative processes of evolving lived sustainabilities means that transitions are never fully completed, but involve continual refinements and shifts in practices (and in the built environment and the infrastructures they intersect with): this unfinished characteristic of transitions is inevitable for they are dynamic, messy and ongoing processes. Climate change will not end or be complete by 2050, the climate will continue to change and the ways that buildings and their users respond to such changes will necessarily evolve in tandem.

Existing buildings and building traditions, materials and styles affect perceptions and lifestyles as much as societal conventions of family and work-lives. Beyond the building itself, these attitudes, practices and identities intersect with, and influence other aspects of life including health, mobility, employment and education (Bardsley et al., 2019). The Covid19 pandemic has engendered significant turmoil in lifestyles and perceptions of home life, as homes and offices were rapidly reconceptualized, repurposed and hybridized (Holmes et al., 2022).

3. Conceptualizing lived sustainabilities through social practices

Social practice theory is used by scholars to understand the stabilizing as well as transformative potential of sustainable actions (Shove et al., 2012, Hargreaves, 2011). Social practices constitute patterns of recognizable and repeated actions; routines that are taken to be part of normal, everyday life (Shove et al., 2012, Hargreaves, 2011, Reckwitz, 2003). Van Vliet et al. (2005: 17) suggest that patterns of consumption (and behaviour more generally) result from "the routine accomplishment of what people take to be the 'normal' way of life". Greene (2018) highlights how consumption practices evolve at different paces, governed by norms, values, and societal structures like planning and service delivery. She examines how consumption practices in the home are tied in to increasing energy consumption, and that the purchasing of additional technologies / appliances is self-reinforcing and cumulative. As such, social practices are often understood as stable, thus cementing *existing* ways of living.

Practices are often broken down into different dimensions: 'doings' and 'sayings' (e.g. Schatzki, 1996). Furthermore, Shove et al. (2012) argue how 'stuff' – in this case the multiple materialities of green buildings – influences and shapes doings and sayings, and vice versa. Green building practices in the post-occupancy phase consist of practices of working, cleaning, cooking, sleeping, leisure, home refurbishment, etc. which form bundles of practices (Shove et al., 2012). Practices emerge, become established and change as the links between the dimensions are established and broken (Hargreaves et al., 2013, O'Neill et al., 2019). Accordingly, "generating more sustainable practices calls for the links and elements of existing, unsustainable practice to be challenged and broken before being replaced and re-made in more sustainable ways" (Hargreaves, 2011: 83). New practices can emerge both through actor resistance to existing and new practices, as much as through new connections between dimensions and / or different (bundles of) practices. In terms of green buildings, this may happen through changes to the materialities of green buildings such as the installation or removal of design features, technologies, and materials, as well as through changes in discourses which may inform policies or other regulative or governance tools. McGuirk and Dowling (2021) draw on Foucault's concept of *dispositif* to expose the different ways that state and non-state actors seek to govern green office space in Sydney, Australia. While this approach offers a useful way to explore the ways that some actors seek to govern green buildings (through policy, ratings, certification, etc), their account leaves users out of this story, nor do they explore how the materialities of different types of buildings affect those who use them. Like social practice theories, employing 'dispositif' thinking enables a binding together of the human, technical, and material practices (McGuirk et al., 2016).

Practices of living and working intersect with other bundles of practices such as education, leisure, and mobility. Where and how we work and live influences how we travel, consume, etc. and vice versa, with varied implications for environmental impacts and greenhouse gas emissions. For example, office buildings with changed materialities in the form of shower and bike storage facilities may change transport choices encouraging commuting by bike, and shifting expectations around presentism through the provision of hot-desking could change commuting patterns further. Building design such as spaces that allow improved interaction and exchange may lead to increased productivity and creativity, through new interactions and ideas generated in alternative and multiple work-spaces (MacNaughton et al., 2017), but also result in improved professional and personal relationships between colleagues increasing moral support and social ties (e.g. concepts of "water cooler" learning (Waring and Bishop, 2010) and corridor conversations (Thomson and Trigwell, 2018)). Lived sustainabilities of green buildings, both office, home, and hybrid, may hence provide wider impact on daily practices and lifestyles beyond the building itself, showing how buildings can act as hubs or nexuses that conjoin infrastructures and practices. Thus buildings are conceptualized here as sites of convergence, imbued with various material-spatial and affective qualities of practices that shape patterns of consumption. Rohracher and Köhler (2019) have analyzed households as infrastructure junctures using the example of meters to monitor resource use and provide consumption

feedback in Sweden. Research by Büchs et al. (2018) on the introduction of smart meters to selected UK households has shown a reduction in energy use but which in some cases led to rebound effects where households used energy (and cost) savings towards realizing activities that emitted more greenhouse gas emissions than they saved through reduced energy consumption (e.g. long-haul holiday destinations). These examples illustrated the relationships between using green buildings and other practice domains or areas of life. Social practice research thus offers an entry point to scrutinize how new sustainable, green and/or low-carbon practices emerge in the context of living and working in green buildings, which are central to low-carbon futures (Shove, 2010, Shove and Walker, 2010).

Drawing on existing work on sustainability in social practices (Shove et al., 2012, Shove and Pantzar, 2005, Schulz et al., 2019), we distinguish between three dimensions to better understand the lived sustainabilities of green buildings. These dimensions include: (1) living and working ("doings"); (2) expectations, framings and understandings ("sayings"); and (3) the built environment ("materialities"). In respect to green buildings, **'doings'** relate to the everyday practices in relation to the processes of designing, making *and using* green buildings. In terms of post occupancy practices, 'doings' encompass activities related to living and working in buildings such as cooking, sleeping, playing, cleaning, exercising, leisure, writing and reading but also including maintenance work (and future redevelopments and extensions).

'Sayings' capture the way green buildings are thought of and spoken about whether in public, political or professional discourses, in person, in print or online. This may include dominant discourses or established narratives (consisting of and shaping sayings that affect user practices) on profitability, innovations, social acceptance but also professional standards of design as well as sustainability policy. Discourses can evolve rapidly, for instance, the thermal standards in Germany which prescribe a maximum room temperature of 19°C in public buildings to reduce energy demand introduced in the context of fuel shortage as a consequence of Russia's war against the Ukraine. Discursive changes may become embedded in political discourses, like this example from Germany, and provide opportunity for social change(s) related to comfort and convenience by breaking existing links in practices (see for example Pickerill, 2015 related to thermal comfort in eco homes).

Materiality within the realm of green buildings encompasses the physical dimension of buildings (the building 'fabric') including building materials, their layout, design and eco/technological features and how they intersect within other physical (infra)structures, as well as decisions about, and uses of, home fittings and furnishings. The building fabric thus provides the stage, props, and scenery where lived sustainabilities unfold (or not). Changes to the fabric offer further opportunities for ruptures to established social practices as existing links can be broken giving room to new lived sustainabilities, but simultaneously, users can alter existing technologies or introduce new ones in ways unintended or unimagined by the building designers.

4. Spatial dimensions of lived sustainabilities in and around green buildings

From a geographic perspective, a focus on post-occupancy aspects of green buildings and the role of users has implications for spatial scales of analysis and conceptualization. Social practices are contextual as people adapt, improvise and experiment with established practices which are situated, spatially and temporally (Warde, 2005, O'Neill et al., 2019). Critically, space has more recently been recognized as a central element in social practice theory (Schäfer and Everts, 2019). According to Schatzki (2015: unpaginated) "practices are inherently spatial phenomena. Moreover, the spaces pertinent to social life are ever increasingly the product of practices. The social practices that make spaces themselves are and have spaces." Space, then, determines specific variations of social practices as physical, political, socio-cultural, economic and institutional contexts vary, and co-constitute living and working practices at multiple and intersecting spatial scales: from the international and national scale to the local neighbourhood, to the living and working space, and the body (e.g. how different people experience thermal comfort or noise pollution in different places in, surrounding and beyond the immediate building). As argued above, buildings are the critical stages and spaces for many of these social practices. At the same time, space is constituted through practices (Geiselhart et al., 2019), again at different spatial scales drawing attention to the regional (e.g. city-scale, regional building vernaculars), local (e.g. neighbourhood or building complexes) and micro-scale (i.e. the body incl. subjective perceptions of heat, cold, interactions with materials and spaces as well as the emotional affects of being in and using green buildings in conjunction with others). Moving from the construction and design stage of green buildings to post-occupancy realities of those buildings being used and lived in has implications for these spatial entanglements.

Table 1 provides an overview over examples of these spatial scales of analysis in respect to the three practice dimensions outlined above. What becomes evident is that the focus on lived sustainabilities of building users shifts the scale of analysis towards the neighbourhood, the building and the scale of the body, whereas much sustainability transitions research focuses primarily on the (inter)national and regional but also urban scale, thus eliding important lessons about how sustainability transitions occur in everyday lives and spaces. These more localized scales become tangible through the materialities of (green) buildings and the daily activities of diverse building users, but also through sayings in the form of social norms, micropolitics, local culture, place identity and imaginaries. At the same time, lived sustainabilities are shaped by, and reshape, sayings, doings and materialities at other spatial scales. In the following, we discuss the various scales and entanglements of lived sustainabilities proposing a research agenda to inform future work on sustainability transitions, focusing on communities of practices and micro-scales. We use the Energy and Technical Park in Trier, Germany as an illustrative example drawing on site visits, observations and interviews to complement existing research and to highlight some of the aspects further.

Table 1: Examples of spatial and practice dimensions for green buildings

Spatial dimensions / scales of analysis	**Sayings**	**Doings (through central actor groups)**	**Materialities**

Supra-regional	Policies (e.g. building codes, regulations, subsidies); Scientific discourses; Popular / media discourses	Policy makers & regulators, lobbyists, business associations, NGOs, scientists	Technological innovations; Infrastructure regimes (e.g., energy supplies); Building materials
Regional	Knowledge communities; Networks and collaborations; Regulations & policies; Visions and Leitbilder	Regional scale policy makers & regulators, lobbyists, green building business community (e.g. planners, architects, contractors, investors, self-builders, etc.), NGOs, utility providers	Energy provision; Building materials (e.g. supply chain for regional sourcing); regionally-specific building designs ('vernacular')
Local / Neighbourhood	Governance, Power structures, local culture, place identity and images	Residents, community organisations, providers and business community, registered social landlords/housing associations	Connectivity & accessibility through infrastructure (e.g. roads, playgrounds, parking facilities, green spaces, retail, transport, educational and health services); Building specific design, material, technologies
Micro (e.g. body)	Social and cultural norms regarding family / home and work / self-presentation; Personal preferences and lifestyles; Work ethics and regulations; Rules, norms, guidelines regulating building uses (e.g. rental agreements, terms of use, house rules, etc.)	User interactions with and in buildings (e.g. use or not of technology, amenities); Interactions with other building users	Subjective realities of working and living spaces within buildings (e.g. furniture & equipment, facilities, safety concerns, ventilation, lighting, heating, accessibility, other aspects of comfort)

The Energy and Technical Park (ETP) in Trier is an eco-industrial and commercial site in the Northern part of the city of Trier, a city of appr. 120.000 inhabitants located close to the German-Luxembourgish border in the German state of Rhineland-Palatinate. The local utilities company Stadtwerke Trier (SWT) commenced plans to refurbish the 45.000 m^2 site including a former paper factory, as climate neutral development in 2013 (Fig. 1). Instead of new constructions, existing buildings from the paper factory were refurbished and retrofitted following circular economy and regional sourcing principles. The development has won a local and national sustainability award and has been certified at the development stage with the gold standard from the German Association for Sustainable Building (DGNB). The site houses a workyard for the municipality, city works (including a sewage plant), a data center, the department for urban parks and green spaces and the city's public theatre workshops. The first building, the

data center, went into operation in 2019 while development of the site continues including a new theatre rehearsal space. User practices and behaviour featured as part of the planning and design process.

*** Figure 1 about here ***

Figure 1: Parts of the refurbished buildings of the Energy and Technical Park in Trier featuring the refurbished buildings including sustainable wall covering and solar panels providing office space as well as technical support and utilities.

4.1 Supra-regional dimensions

The construction of green buildings is strongly dependent on political support through regulation, incentive schemes and different forms of facilitation and empowerment (O'Neill and Gibbs, 2020, Gibbs and O'Neill, 2015) which are frequently influenced by processes at the international and national scale. This includes sayings and doings of policy makers and regulators, business associations, non-governmental organizations as well as other lobby groups. It also considers how (scientific) knowledge is produced and reproduced, and how problems and solutions are framed, reproduced and reflected in the media and scientific discourses.

In terms of regulation and political support, green buildings in EU member states are implemented at the national scale through a range of policy vehicles which are strongly influenced by EU politics. For example, building codes are often set at a national scale as are the adoption of green building certification schemes, like the DGNB certification scheme in the case of the ETP, that prescribe specific standards which may accelerate but can also hinder green building transitions (Affolderbach and Schulz, 2018). In Spring 2023, the German government proposed a Bill to change the national building energy regulations to realize the national target to achieve carbon neutrality by 2045. The Bill, referred to in public discourses as "heating law," has been contested in parliament and negotiations are ongoing. From 2024 it requires that all new heating systems will have to use a minimum of 65% renewable energy. The Bill does not propose specific technologies, and provides flexibility for a range of different heating systems in existing buildings. The Bill foresees a phased introduction for municipalities (with over 100.000 inhabitants by 2026 and over 10.000 inhabitants by 2028) to develop energy and heating district plans at the local scale for the existing building stock.

The regulations on energy saving for buildings in Germany introduced in Sept. 2022 aim at reducing energy demand by setting the standard temperature in public buildings to 19 degrees Celsius where workers predominantly sit, while workspaces where people predominantly move around will be heated to a maximum of 18 degree Celsius. These regulations are different as they change lived experiences of building users. The regulations have been framed as a short-term measure, and need to be understood within the political climate surrounding the imminent energy crisis driven by Russia's war against Ukraine: such measures can be considered an experiment that may (need to) become more established in future. Regulations (i.e. sayings) like this have impacts on expectations of building users concerning thermal comfort (Shove et al.,

2008), that will be perceived differently by different people across places and climates. Another example which concerns changes in social norms and expectations as they concern working in buildings is the Japanese 'Cool Biz' campaign which was introduced by the Ministry of the Environment in 2005 following the damage of the Fukushima nuclear power plant through an earthquake and tsunami earlier that year (Shove, 2014). The Cool Biz campaign aims to reduce energy consumption through limiting the use of air conditioning in office buildings during the summer months. To implement the campaign, the Ministry of the Environment released a 'casual' dress code including short sleeve shirts, khakis and trainers. The campaign was an immediate response to the shortage of electricity supplies in Japan and public perception was critical, yet this initiative remains active and has changed Japanese norms and standards as they relate to work fashion. As the examples from Germany and Japan illustrate, immediate situations of crises can trigger more fundamental changes in sayings which have implications on doings and materialities. While the examples illustrate top-down initiated change, transformations can also emerge from the bottom-up. For example, energy saving technology and green building innovations in Freiburg, Germany, translated into stricter energy building regulations at the local scale that fed into national building regulations (Fastenrath and Braun, 2018).

Beyond specific building regulations, innovations and change can be inhibited by intersecting regulations. In the case of wood construction as used for the ETP, fire protection regulation makes wood construction difficult, given German building regulations, and can prevent sustainable alternatives or make these economically unviable. In general, increased market prices for building materials and other associated costs have weakened sustainability considerations within the building sector in Germany over the past few years.

4.2 Regional dimensions

How green buildings are realized frequently plays out at the subnational scale influenced by geographic variations including building traditions and practices. Moreover, historically, regions have developed specific vernacular building styles that continue to affect interpretations of what a 'good' building looks like. At the regional scale, green building practices are shaped by the role of knowledge communities and networks, available supplier and service infrastructures, know-how, policies and visioning but also discourses and accepted conventions of lifestyles. In terms of materiality, the building and construction sector has been strongly influenced by regional geographic specificities such as available building materials as well as climatic conditions which have, for example, shaped insulation standards and cooling needs. These have, however, also been affected by energy costs and the role of industry 'experts' who have, for example, promoted air conditioning (Shove, 2014). These industry recommendations have evolved into common-sense standards relating to comfort and ambient indoor temperatures. Over time, technological progress and access to alternative building materials have led to a standardization of the building sector including building design, often referred to as Modern Methods of Construction (such as brick-and-block, cavity walls, etc.)[1] that have spread

[1] See e.g. https://www.parliament.uk/globalassets/documents/post/postpn209.pdf.

throughout many countries. Regional and national differences do however prevail and there has been a revival of local building traditions in many countries, particularly drawing on natural building materials and vernacular designs (Gibbs and O'Neill, 2014).

In the case of the ETP, the SWT sought to refurbish the existing building stock based on circular economy principles that promote the reuse of all component materials. Parts of this was realized by retrofitting existing building walls through reusable layers that can be upcycled in the future. According to one of the leads involved in the ETP, thinking of "buildings as construction and reusable material" provides "a stock of construction material to be used indefinitely" in the sense of an "urban mine" (Interview, March 2023, own translation). This is highly relevant as the region suffers from a lack of availability of building materials. The region has rich forest resources making it an ideal area to promote regionally sourced wood products for modular and hence reusable construction. The ETP used wood sourced from just outside the city of Trier but also promoted the use of small-diameter timber to develop lower energy demanding wall construction material which were developed in collaboration with the Technical University Trier. One main emphasis was placed on sourcing regionally and "reading the region" for building materials (Interview with local architect, March 2023) even though this did not include upcycling existing material from deconstruction.

In terms of know-how and knowledge, the building sector in Germany in general but also within the Trier region is embedded within more established building paradigms. While universities have embraced novel ways of thinking about green buildings (in their own practices but also including training of engineers and architects), the majority of building companies remain hesitant towards change. The regional Chamber of Crafts seeks to promote new approaches by offering courses on green building principles but the audience of local building businesses and artisans has been described by one of the invited speakers as largely skeptical. Hjaltadóttir and Hild (2021) show how fragmented value chains and lack of political guidance paired with limited inter-firm cooperation are seen as obstacles towards more sustainable cooperation in the construction sector in Sweden and Luxembourg. Faller (2016) illustrates how regions can provide specific contexts for green practices such as decisions on investments, supportive planning frameworks, construction and daily maintenance of energy generation facilities and the foundation and running of interest groups. These may develop over time by growing expertise and know-how that is then regionally anchored and shared. This aligns with findings from Bartiaux et al. (2014) on retrofitting private homes which stress the social context for actions and the co-evolution of know-how, regulatory frameworks, institutionalized procedures, social norms and material dimensions. In the wider Trier region, SWT is currently in exchange with the Ministry of Environment in Rhineland-Palatinate and the regional Wood Building Cluster to pool existing scientific and applied expertise to develop the region as wood construction hub based on local resources availability.

4.3 Dimensions at the local and micro scale

It is at the local scale where lived sustainabilities in green buildings take place, and where users most immediately and intimately interact with green buildings. While local expressions are shaped by sayings, doings and materialities at other spatial scales, the local scale of the building and neighbourhood is tangible and direct through the built infrastructure and materialities which provide the stage and context for actions. Taking this approach places the actions of those who are using and interacting with green buildings at the centre of analysis. The neighborhood / home level is central to how living and working in green buildings intersects with other aspects of life through connectivity, land use and micro-politics (including consensus as well as conflict). How well buildings (and neighbourhoods) are connected to infrastructure, such as public transportation networks, influences how users can reach the location. In terms of connectivity, the ETP is located in the Northern part of the city and accessible via the local public bus system. But for the majority of new building occupants, the new work space involves a move from former office and service buildings located in the city center to a peripheral location. A canteen with regional green meals is part of the development plan but surroundings lack additional infrastructure of shops and restaurants. The site includes charging stations for electric cars and bike storage. But even where infrastructure and services that promote CO_2-friendly commuting are provided, low-carbon mobility may be inhibited as individuals might have 'complicated' travel patterns due to commitments such as childcare, household and other duties, combined with commuting distances that have been facilitated by social norms around use of the motor car as opposed to the bicycle (see Green, 2018). But developments might also impact on existing uses. In the case of the ETP, conflicts emerged between the developers and an adjacent Roma and Sinti community, which, according to a SWT representative, were resolved through an arrangement where the Roma and Sinti community were offered the right to run a food truck on the development site (On site conversation, May 2022).

At the scale of green buildings themselves, materialities and design features as well as building infrastructure are visible and tangible, which relates to questions of governance and power, through regulation, finance and in terms of past and future decision-making related to building usage. Interior design features of office and work spaces at the ETP include modular wood structures, open-plan workspaces and shared facilities which provide a distinctive work environment. Modular wood structures were (and are) used to refurbish existing industrial buildings and represent a less energy intensive construction approach but also offer flexibility in terms of future changes in use. The development of the ETP included early involvement of future occupants through information and interactive sessions. Particularly open-plan workspaces in office buildings can be met with resistance as they impact on relationships between different building users, deviate from past experiences, and can be compatible with some work tasks but not others. This was also experienced by the SWT during consultations with future occupants. The efforts to engage with "green working places" through user perspectives and behaviour were largely challenged by strong resistance to the new site from city administrative staff. This was seen to be primarily driven by the relative decentralized new location in a more industrial neighbourhood but also the modular and open plan interior design (Interview with ETP lead developer, March 2023).

Materialities more generally encompass green building technologies and appliances that users interact with: the nature of such relationships can affect whether envisioned benefits such as energy savings are generated. As administrative staff only moved recently, changes in day-to-day practices and engagement with new work spaces at the ETP yet have to be properly assessed. However, in her study of occupant perspectives, Westerhoff (2016) illustrates how residents of Vancouver's Olympic Village, a green neighbourhood development envisioned to demonstrate world leadership in sustainable neighbourhoods, struggled with technologies and appliances resulting in low satisfaction and perceptions of living comfort, as well as narratives that related these issues to the 'green' qualities of these buildings. In respect to the heating system, many residents struggled to comprehend the system and establish comfortable room temperatures in their apartments and found it hard to adjust to the system, with many removing passive solar shading and installing air conditioning instead (see also Galassi and Madlener, 2018). While technologies and appliances can provide ruptures to established social practices, Hargreaves' (2011) study used an in-depth observational study of a company office engaging in a workplace sustainability challenge to reduce their carbon footprint by changing daily routines and user practices. While the initiative was not overly successful in terms of reducing the carbon footprint, Hargreaves (2011: 94) shows that important changes to social practices had occurred as "new pro-environmental meanings, skills and stuff were incorporated into normal working life".

Westerhoff's (2016) work also illustrates how narratives (including framings and expectations) impact on lived sustainabilities. These are shaped at different scales by different actor groups. At the more localized scales, building uses are influenced by work and family (and neighbourly) politics, values and norms. The micro scale of the body highlights the subjective realities of building users which can be influenced by (dis-)ability, gender, ethnicity, age, health and so on (see Greene, 2018). While lived sustainabilities are influenced by sayings, doings and materialities at different spatial scales, it is the practices in and around green buildings that require more attention to better understand the transformative potential of green buildings, and / or the impacts of users in resisting changes. Future research could fruitfully address the following research questions. How do design features, technologies and appliances impact on user practices (and vice versa)? And how do narratives, and the sayings that they are constituted of, affect the kind of building designs that are perceived as socially acceptable in different locations? How do norms and narratives change to accommodate living with different spatial layouts and with changing levels of ambient inside (and outside) temperatures? What skills are needed by building designers and building users to operate new technologies? How can more cooperative approaches to lived sustainabilities be facilitated?

Considering the multiple entanglements and specificities of green buildings and their spatial contexts, these questions require in-depth insights from multiple sites and building types including office and residential buildings, self-build and standardized, buildings that are detached, terraced, or multi-unit, owned and rented units, as well as examples within and across

regions. We hence highlight the need for *spatially* sensitive, multi-sited studies on lived sustainabilities (i.e. taking different regions and countries into account) at the micro-scale to better understand and contribute to deeper green building transitions. The complexity of people's lived experiences and practices and the lack of empirical data on this matter so far requires creative theoretical and methodological frameworks to better grasp and understand processes behind sustainability transitions.

5. Conclusions

The pressing need for changes in lifestyles, values and norms has been emphasized by many (e.g., Devine-Wright et al., 2022), and the lack of progress towards internationally and nationally set targets for carbon emission reduction highlights the need for deeper transitions through social and societal change. While considerable research has focused on technical aspects of the design and construction phase of green building, much less is known about the role of green buildings towards carbon neutrality goals once they are in operation. This paper contributes to theorising post-occupancy research, presenting a perspective that shifts the focus towards the role of users, in particular their inter/actions, which are framed as lived sustainabilities. The focus on lived sustainabilities emphasizes the relationship between spatial contexts, the role of buildings designed to be green or sustainable, and user practices. It also brings into focus day-to-day routines and practices that are shaped by sayings, doings and materialities at higher spatial scales but that also highlight the relevance of the local and micro scale. Lived sustainabilities hence emphasizes individual contexts and spaces, whilst recognizing that these are always shaped by multi-scalar, socio-technical entanglements.

Buildings and green buildings act as critical junctures (or hubs) for (un)sustainability, representing strongly entangled webs of practices, across the multiple dimensions of social lives. Buildings thus represent a nexus of social practices and a critical space for considering future (sustainability) pathways. Focusing on practices of living in and using green buildings can illuminate how lived sustainabilities mesh with other bundles of practices, for instance mobility, leisure, consumption, health and education. Whether constituted as individual homes, offices or neighbourhoods, buildings are enmeshed in wider infrastructures and practices that restrict or promote the potential for transformation. It is these green building practices that require more attention to support a deep transition. Buildings offer the potential to explore and advance understanding of the dynamic nature of lived sustainabilities – how these change over time, in different places, according to the degree of 'greenness' exhibited by different buildings, in response to changing norms and new societal challenges. Such research has much to offer in relation to the unfinished nature of sustainability transitions, it is unlikely that any transition reaches an end point, rather transitions in the materialities of buildings and the sayings and doings of practices are made and remade in tandem with changes in the climate, political shifts and economic conditions. Further, insights from lived sustainabilities in green buildings also hold relevance for retrofitting and upgrading the existing building stock which is crucial for meeting the sector's, and nation's, climate targets.

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