# The Implications of a Net Zero Transformation of Society for Product Safety within the Home

3S Report

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May 2024

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# Acknowledgments

## Introduction to UKERC

The UK Energy Research Centre (UKERC) carries out world-class, interdisciplinary research into sustainable future energy systems.

It is a focal point of the UK energy research and a gateway between the UK and the international energy research communities.

Our whole systems research informs UK policy development and research strategy.

UKERC is funded by the UK Research and Innovation, Energy Programme.

## About Energy SHINES

The report is an output for Energy SHINES (Energy social siences and Humanities Insights for Non-Energy Sectors) – a project devlivered through UKERC's Whole Systems Networking Fund.

Energy SHINES was set up to facilitate partnerships between women Early Career Researchers from energy social science and humanities backgrounds and organisations in key non-energy sectors undertaking work towards net zero.

## Acknowledgements

I would like to firstly thank UKERC and the Energy SHINES team at the Global Sustainability Institute at Anglia Ruskin University.

Thank you to Dr Helen Pallett and Professor Jason Chilvers for their advice and input into this report.

I would also like to extend my gratitude to the team at the Department for Business and Trade's Office for Product Safety and Standards, particularly to those who have contributed to this project including Geoffrey Brown, Brendan Garrett, Michael Gentry, Rebecca Sheridan and Nick Summers.

Finally, a very big thank you to my placement supervisors Jake Barber and Mel Rohse for their guidance and invaluable help throughout the project.

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## Abstract:

This report was prepared for the EnergySHINES (Energy Social sciences and Humanities Insights for Non-Energy Sectors) placement series for early career researchers which aims to transfer valuable insights from energy social sciences and humanities to the complex challenge of energy transitions in 'non-energy' organisations, particularly emphasising the insights and expertise of women who remain underrepresented in the sector.

Current UK policy and legislation fails to adequately consider the impact that a net zero transformation of society may have on construction and consumer product safety within the home. As a result of this transformation, new products, or ways of manufacturing existing products may emerge and societal values and perceptions around sustainability and lifestyle may also evolve, along with changes in the ways that energy needs are met. This report explores the implications that a net zero transformation of society may have for product safety within the home and beyond and provides social science and humanities reflexions for policy makers to consider.

**Keywords:** Net zero; transformation; product safety; city; community; home; construction.

**Suggested citation:** Thompson, O., Rohse, M. & Barber, J. (2024). *The implications of a net zero transformation of society for product safety within the home.* 3S Report 2024 - 1. Science, Society and Sustainability Research Group, University of East Anglia, Norwich.

# I. Introduction

## 1. Background to the report

The UK government introduced their Net Zero Strategy in October 2021 which provides a pathway to the decarbonisation of all sectors of the UK economy through policy to meet the target of net zero by 2050 (UK Gov, 2021). The *Building for 2050* (2022) strategy lays out policy recommendations to meet these targets, however, recent scientific reports and political think pieces state that this may be too little, too late, for both the environment and society as we know it (IPCC, 2023; Laybourn et al, 2023).

According to the UK Energy Research Council, current policy fails to consider the impact of societal engagement with energy and climate change and a systemic approach to monitoring and understanding this engagement on a continual basis is needed (2020). Beyond a simple 'technological fix' and recognising that meeting net zero targets will *also* involve a transformation of society; it is also necessary to engage with broader systemic changes that will arise through a net zero transformation of society. For example, even as the way that energy needs are met, new products - or ways of manufacturing existing products - may emerge and societal values and perceptions around sustainability and lifestyle may also take place. For policy makers, this means that the relationships between market structures, people, and products are likely to change.

## 2. Aims

This report will seek to address what it means to regulate product safety within the home and the wider built environment in a world adapting to climate change and its environmental, political and social consequences. This report will do so by exploring a series of case studies that aim to highlight the changing relationships between people and products, changes to existing market structures and the possible consequences of these changes for policy makers. Understanding how people consume, interact with and respond to products is essential for regulators of product safety and a net zero transformation of society is likely to change these interactions between people, products and the wider built environment.

This report summarises some trends in academic literature around product safety (for both construction materials and consumer products) and net zero for a policy-making audience. It looks to social science theory to reframe issues associated with a net zero transformation of society on product safety through various case studies. These case studies range from examples within the built environment at the community level to examples of individual construction and consumer products. It suggests areas of future research for future policy recommendations to ensure that regulations are ready to meet the changing needs and demands of the building and consumer product sectors in the face of this new systemic transformation to achieve net zero.

This report will draw upon the concept of 'reflexive governance' to make policy recommendations that are flexible and responsive to ongoing changes in the sector and draw upon a wide knowledge base. The wide range of case studies below with be framed by actor network theory, ecologies of participation and material participation, which gives importance to the networks that exist between objects, people and the environment, to address the spontaneous and complex challenges emerging around construction and consumer product safety. More information on these social science theories can be found in the accompanying report: Social science approaches to understanding the implications of a net zero transformation of society (Thompson, Rohse and Barber, 2024).

## 3. Methods

To explore the implications of a net zero transformation of society on the regulations of construction and consumer product safety and standards, a literature review was carried out to capture the wider trends in academic literature through google scholar, web of science and scopus[1].

Although this literature review did not provide a wider view of issues emerging due to societal changes in values and perspectives around net zero, it did provide context as to why net zero was an important challenge to respond to. The review also highlighted the technical implications of responding to climate change and shed light on some of the technologies most associated with a net zero transition at the product and buildings level. Some of these technologies include net zero buildings and the incorporation of the passivhaus standard in building construction.

Other topics of interest which appear in the case studies of this brief emerged organically through conversations with the placement host, the author's participation in a whole-team project prioritisation workshop for construction products research and through wider informal discussions with supervisory teams at Anglia Ruskin University and the University of East Anglia. Research into these topics was then approached through more targeted searches of academic literature through google scholar, web of science and scopus.

These preliminary investigations led to a reframing of the topic and led the author to consider how the relationships between products, end users and wider society may change due to a net zero transformation of society. A common theme which emerged in answer to this question was that a net zero transformation of society places emphasis on communities of people living and acting together and systems of products working

[1] Search terms can be found in Annex 1 to this report.

together. This, in turn, led to questions around the definition of a consumer product or construction material in a net zero society.

The concepts of community and system therefore provide the context for understanding the changes to product safety that may arise through a net zero transformation of society. Placing emphasis on people, products and things being linked together through communities, systems or networks led to an examination of two social science theories that would provide a theoretical framing of the question: Actor Network Theory and Material Participation. More information regarding how policy makers may engage with social science theories can be found in the supporting brief “Social Science approaches to understanding the implications of a net zero transformation of society” (Thompson, Rohse and Barber, 2024).

This policy brief follows a funnelled, top-down approach, beginning with a community perspective to explore the implications of a net-zero transition for both products and people within the broader built environment. This approach then gradually narrows its focus to examine the individual construction material and consumer product level.

This funnelled approach allows for a comprehensive analysis of the complex implications that a net zero transformation of society may entail for policy makers. By approaching this topic from the broad perspective of the community level, through to the home as system level, the construction material and finally down to the individual product level, this method enables policymakers to gain a wider and more in-depth understanding of the issue at hand and develop targeted solutions that take into account the complex relationships that exist at all levels and between all human and non-human actors.

This methodology can be visualised in the below diagram:

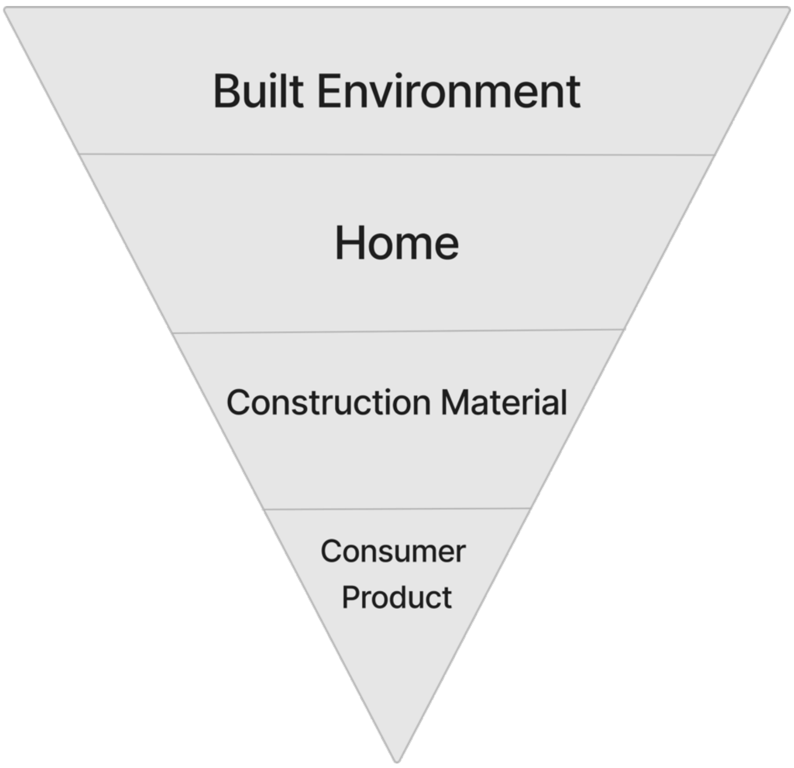

*Figure 1: A Funnelled approach to considering the implications of a net zero transformation of society.*

Reframing the issue by starting with the wider community and built environment highlights the concept of products and people being connected through a system or network and makes the relationships between apparently distinct products, people and uses more apparent.

The following questions provide the framework for this brief:

- How might the regulatory definition of a product or material change due to a net zero transformation of society?
- How might the relationships between people and products change due to a net zero transformation of society?
- How could regulatory processes and wider governance respond to the changing demands of a net zero transformation of society?
- What are the implications of these changes for product safety?

This framing allows for the consideration of products as part of a systemic whole that centres around the individual existing within a wider community and what these different levels of interaction mean for products and their lifecycles. Taking these questions and answering them at the community level, the home level, the construction product level and the consumer product level provides an overview of a system of products, people and materials emerging due to the net zero transformation of society.

Although many examples of the case studies described in this brief do exist around the world, case studies are centred around the UK or countries with similar climate, political systems or economic situations to ensure that this brief remains useful and appropriate for application in a UK context.

# II. The City Level

There is overlap between "going smart" and "going green" at the city level and characteristics of both are likely to be seen in urban planning in the future (Gazzola, Del Campo and Onyango, 2019). The products that arise from this change in how we view and use cities are likely to respond to growing demand for both convenience and comfort, and sustainability, with the view to achieving a net zero economy by 2050. There is a risk, however, that smart approaches to city planning miss the bigger picture of product and network safety, people and sustainability with green approaches to city planning proposing a less technocratic approach to achieving a net zero future.

## 1. Community led projects as a return to localised living

**An example of community energy management through community buy-out projects in Scotland (Isle of Gigha and Isle of Eigg)**

The Isle of Gigha and the Isle of Eigg in Scotland have both been the object of community-led buy-out projects and both provide examples of alternatives to current large-scale energy management.

Community-led buy-out projects are instances where a community comes together to purchase, or "buy out" an existing asset, such as land or a business, and take on ownership of that asset. In the case of the Isle of Gigha and the Isle of Eigg, both local communities bought out the islands and their infrastructure following the sale of the islands from private ownership. This resulted in a need to rethink conventional methods of energy provision and make investments to improve local building stock in innovative ways.

The Isle of Gigha and Isle of Eigg offer examples of local, community-led approaches to energy production and management. By providing examples of alternative methods of supplying and managing a community's energy needs, these examples show that policymakers and governments may have misconceptions around people's everyday energy requirements and their acceptance of living with less abundant or consistent energy supplies. The commonly held belief that energy is always readily available may not be as unquestionable as previously thought. This example of community-led energy management shows that people are willing to accept a more intermittent provision of energy supply in exchange for community owned structures and community-led governance. In other words, less consistency for greater autonomy, ownership, and control.

For example, this community has shown that with energy being provided mainly through renewable sources, there may be periods of low energy availability. This has been accepted by the community in exchange for the chance to self-manage their energy supply. At play on the Isles of Gigha and Eigg is a localised shift in people's standards around acceptable levels of energy availability and quality of energy networks, which in turn show an acceptance of communities and individuals to forego certain levels of comfort or to establish alternative methods of meeting needs which may become more common through the net zero transformation of society. While it is difficult to speculate how these small scale energy buy-out may scale, the broader movement to play a more active role in the provision of one's energy may become more common as society transitions to adapt to net zero targets in the future. While it is hard to imagine that an entire nation's population would accept a shift in energy availability if this were to be imposed by a central government, the buy-outs on the Isles of Gigha and Eigg demonstrate that when a community is empowered to make this decision for itself in exchange for some perceived benefit to the wider community, a perceived negative change, such as the shift from consistent to intermittent energy availability, may be accepted and indeed welcomed as a net positive trade-off.

Didham (2007) approaches community as a space for individuals to come together through an understanding of the social environment within which they interact. Given the flexible nature of communities and the sense of purpose that the relationships between individual within the community provides, people are most able to engage in meaningful relationships with the process of development at this local level (Didham, 2007; 12). According to this perspective, a community serves as a space for individuals to establish connections and gain insight into the social environment that surrounds them. Given the flexible nature of communities and the sense of purpose and interconnectedness that they offer, it is at the grassroots level, through community networks, where individuals can best engage in meaningful relationships with the process of development.

Community led projects, where community ownership and management are assumed, lead to proposed projects having higher rates of acceptance among local populations (Warren and McFadyen, 2010). The acceptance of intermittent energy supply was a result of design choices made by the community themselves and shows a willingness from the community to embrace alternative ways of living. Results from a 2010 study showed that residents of the Isle of Gigha were more receptive to new wind-powered energy generation than neighbouring Kintyre residents, even naming the wind turbines the 'Dancing Ladies of Gigha' (Warren and McFadyen, 2010).

The Isle of Gigha serves as an illustration of a return to traditional methods of producing goods such as the re-establishment of a traditional creamery and smokehouse and a return to traditional farming techniques. This pull of traditional ways of life may become more attractive considering growing environmental and economic concerns, however, may also have health and safety concerns through the increased need for skilled and dangerous labour. Other risks include the potential for some traditional products to have adverse health effects (such as the impact on indoor air quality and health of woodburning for a traditional smokehouse for example).

**Key messages for policy makers**

These examples illustrate a willingness of local communities to operate at the community level in areas such as energy management, sustainable housing decisions, etc. Preconceptions of acceptable standards when it comes to issues such as energy availability may shift in the future and infrastructure may adapt according to this social change in perception. This could result in more localised use of energy storage, individuals generating and managing their own energy, localised energy grids and an acceptance to living with less energy availability by adopting some “off-grid” lifestyle choices.

The example of community led buy-out projects overall shows a willingness for communities to accept trade-offs in lifestyle, comfort or convenience in exchange for independence or sustainability, for example. Although a model that may not represent the wider UK population, this example serves to challenge existing assumptions around lifestyle and, in turn, challenges existing assumptions about the types of products that non-professionals and non-specialists come into regular contact with if and where they come to a play a greater role in shaping their own energy production.

The concept of reflexive governance (more detail on which can be found in the supporting ‘social science approaches to understanding the implications of a net zero transformation of society’ brief that accompanies this report) can help to explain *why* communities may be so engaged by this kind of shift.

Policy makers should consider the new risks emerging from community or self-managed energy supply and usage and how this may complicate the relationship between consumers and products.

## 2. Community led projects as a return to localised living

**The Connected City**

The internet of things is expected to provide multiple and diverse benefits to society including improved service and efficiency in the healthcare sector, more efficient energy management, increased monitoring and more efficient prevention of crime, more efficient regulation of transport and improvements to urban planning, among others. However, these benefits are accompanied by growing safety concerns such as the impact on the security and resilience of the internet globally, data sensitivity and privacy concerns and multiple ethical considerations (Rose, Eldridge and Chapin, 2015). It is known that gross vulnerabilities exist within systems of products operating through the internet of things which are easily exploitable by malicious actors (Brass and Sowell, 2021).

Dangers of urban spaces built upon computational models such as the computational city also pose dangers to the ethical, fair and effective governance of a city. A computational city following a centralised model built around an abundance of dashboard-type notifications tends to miss out data that does not lend itself to “quantification and visualisation” thus missing a wealth of social nuance which can lead to poorly informed policy and regulation (Mattern, 2021: 31). Decision-making based on data of this sort can have discriminatory ethical consequences with Mattern highlighting the "legacies of racial injustices [that] are embedded in our technologies - from surveillance apparatuses, to search algorithms to imaging technologies to carceral equipment (Mattern, 2021: 15).

Considering the city as computer has dangers as it "gives rise to technical models, which inform design processes, which in turn shape knowledges and politics, not to mention material cities" (Mattern, 2021: 64). From a regulatory perspective, it is important therefore to keep sight of the value of qualitative research and data when implementing policy that relates to individual product safety. How cities are designed and used and the technologies within are not only the result of digital and technological advances but are shaped by and respond organically to the citizens within.

An example of this is the rapidly changed function of cities, public spaces and technologies that emerged during the Covid-19 pandemic. These changes showed that societal values and public interest shaped and changed the function of many parts of our cities, rendering other aspects obsolete. At the product level, individual products and technologies will necessarily be used as part of a systemic whole within the fabric of the city. It is therefore important to consider, not only the safety and standards of products themselves, but the resilience of those products within the wider network. Other important factors to consider are its relationship and interconnectedness with other components of the network and its changing function (and therefore changed use, installation and load) due to changing societal values and needs which may oftentimes only be assessed (at least in part) through the qualitative study of society by engaging the individuals and communities that live within these cities.

**Key messages for policy makers**

Policy makers should consider qualitative as well as quantitative data when designing regulations for the safety of products as part of network at the city level as changing societal needs will change the installation, use and load of the individual product.

Policy makers should seek to explore the changing relationships between people and artificial intelligence at the community and city levels.

## 3. 15-Minute Cities

**Introduction to 15-minute cities**

The concept of a '15-minute city', first proposed by Carlos Moreno in 2016, provides an alternative to urban planning centred around the private vehicle. Moreno's model reimagines the city as a series of compact neighbourhoods where essential services are accessible within a 15-minute walking or cycling distance from anywhere in the city.

The demand for soft mobility (walking or cycling) and community-based urban services (shops, healthcare, parks, social spaces, etc.) that arose during the Covid-19 pandemic has led to a change in priorities of urban planning (Moreno, Allam, Chabaud, Gall and Pratlong, 2021). The 15-minute city concept also provides a net-zero solution to urban planning by reducing reliance on private motor vehicles, for example (Allamet al, 2022).

There exist many issues with the traditional urban planning of cities which centre around the car such as 1) the heightened environmental impact of a reliance on cars, 2) the decreased efficiency of transportation networks due to bottlenecks, 3) less reliable public services due to congested transportation infrastructure and 4) the increase of inequalities such as food deserts[1] due to absent public transportation or private vehicle access. Many of these issues were made more apparent by the Covid-19 pandemic but have been an ongoing and growing problem in many cities around the world since the widespread availability of cars which changed the dynamic of urban planning.

An increase in societal demands due to increased awareness of environmental issues or as legacy to the covid-19 pandemic may see an increase in urban planning decisions of this nature. With city space redesigned around the concept of the 15-minute city, the increased proximity of amenities and the workplace may result in a change in the way that people utilise – or even own - cars, a change in how people use their homes and the products that they bring into their homes. This could impact further impact expectations on things like house and garden sizes as denizens feel better able to take advantage of community parks and centres, in turn shifting patterns of social behaviour and producing citizens who are more engaged in city life.

Products that may grow in popularity due to the 15-minute city model may be sustainable soft-mobility choices such as e-bikes, e-scooters or self-balancing scooters, as well as more traditional soft-mobility methods such as the bike, scooter or walking. An increase in the demand for these products may see an increase of private ownership and this may have safety implications for the quality of the product and how these are used. Products should be well regulated, as should the use of these products. For example, Cambridge, as well as a number of other UK cities, has introduced e-scooters available to rent throughout the city, through the company Voi. The e-scooters are rented through an application which requires a photo of the individual's driving license to be uploaded and a short road safety test to be taken. The speed of these e-scooters is then regulated and determined by the experience of the driver. An increase in privately owned soft-mobility products could impact the safety of the use, pedestrians and other road users, if the products and the people using them are not adequately regulated. Guidance surrounding the use of e-scooters exists through the Department for Transport and Active Travel England, however, this could be enhanced by considering how people's behaviours, their relationship with the wider community and needs could affect the optimum functioning of the e-scooters and more robust regulation could be implemented (Department for Trasport, 2022).

**Key message for policy makers**

More research is needed into how a move to soft mobility and 15-minute city-style planning will affect the ways we use our homes and what we choose (or choose not) to put into them. Some products that may see an increase in demand are soft mobility products such as electric scooters, e-bikes or self-balancing scooters.

Policy makers may consider how changes in urban planning may accelerate the uptake of new products, especially those associated with soft mobility, and how these products will be inserted into the already complex ecosystem of the city.

## 4. Conclusion to Part II

The examples provided of community led buy-out projects, 15-minute cities and smart cities all provide examples of shifts towards built environments becoming more sustainable and people-oriented. This means that our cities, through various factors such as the covid-19 pandemic and the net zero transition, will be increasingly shaped by the people living within them. As a result, the products within these cities and communities and the relationships people have with them, are likely to change and considering how these evolving dynamics will affect people's safety is crucial.

Echoing the findings of the supporting brief "Social science approaches to understanding the implications of a net zero transformation of society", the concept of reflexive governance may be useful to consider. Understanding the evolving dynamics of people-oriented cities will require a greater focus on collaboration and engagement with stakeholders, as well as an increased capacity for flexibility and adaptability in the face of changing circumstances. These values are intrinsic to the concept of reflexive governance. In conclusion, the regulation of product safety will need to evolve in tandem with the changing needs of society and the evolution of our cities and communities to ensure that these are safe and fit for, a host of potentially changing, purposes.

# III. The Home

Homes are becoming more complex, interconnected and increasingly present as systems, taking into account the practices of the actors (both human and non-human) within. Their construction is becoming more multifaceted and multifunctional, often aiming to combine energy efficiency and sustainability concerns with functionality and comfort. This means that the construction materials and consumer products within and of our homes are also becoming increasingly complex and responding to multiple demands and functions. These materials and products do not act within isolation and are increasingly part of intricate systems and networks, connected, or not, through the Internet of Things. Safety concerns there range from durability of construction materials in the face of the more and more extreme localised effects of climate change to the resilience of networks due to the connectivity of smart home technologies.

For policy makers, these relationships between products, materials and people are becoming more complex with increasingly complex accompanying problems and risks. Although considering the basic safety of the components of homes is vital, more than this, it is necessary to place the user at the heart of risk perception. To do this, more research is needed to assess the role that different social dynamics play on the home and the products within. Factors such as functionality, comfort, cost, sustainability and privacy all play a role in the use of products and materials within the home and present diverse associated risks.

## 1. A shift in societal values evidenced through community living

**Low impact living through the One Development Project in Wales**

In the face of increasing climate concerns, the desire for low-impact living is growing, and with it, an increase in grassroots innovations for sustainable development (Seyfang and Smith, 2007). Examples of low-impact living include off-grid living in vans, caravans, huts and boats, self-sufficient food production such as garden farming, off-grid energy management, or even community composting schemes, among others.

In 2009, the Lammas Eco Village became the first eco village to be granted planning permission in the UK. This type of sustainable living provides an example of community off-grid living and shows how radical policies, such as the One Planet Development Policy (2010), supported by The Wellbeing of Future Generations Act (2015) and other legislation in Wales are changing construction practices in rural areas (TAN6, 2010; OPD, 2006).

The Lammas eco village provides an example of a “cultural shift” in social perceptions of sustainability and how policy has risen to meet a shift in community values through grassroot innovations (Jones, 2015). For Seyfang and Smith (2007), grassroots innovations refer to the bottom-up solutions to local sustainable development put forward and actioned by networks of activists and organisations. The Lammas eco village provides a good example of this type of innovation.

Community is at the heart of this way of living; however, the home itself has also seen wide-reaching and intense change from convention in the Lammas eco-community. The homes that make up the Lammas eco village are designed and built by residents and volunteers from local and natural or recycled materials. The village is divided into a series of plots that include “dwelling-houses", covered green areas, barns and workshops depending on the needs of the residents. Resources, such as energy and water are managed collectively with residents relying on a combination of hydro, solar and wind power and a shared 27kW generator. Some biomass such as waste timber from woodland management is also used for heating.

Since the early 20th Century, the home has been predominantly a place for family life, relaxation and a safe space to recharge, however, the recent covid-19 pandemic saw a shift in the function that our homes provided. Suddenly, the home became a space for work, as well as leisure and family. In the case of the Lammas eco-village, the home’s function has diversified further to become a place for food production, energy supply, waste management, work, family, entertainment and relaxation. The way in which the Lammas home is used, and the importance given to everyday practices that are enabled through this space have undergone complete changes in function. For example, economic activities now enabled through the home include “fruit and vegetable production, livestock and bees, woodland and willow crafts, value added food production, and seed production” (lammas.org.uk, 2023).

This example provides insight into how our interactions with our homes, and the products within our homes, may change in the future due to a net zero transformation of society. Although the model of the Lammas eco village may not appeal to all just yet, this example of governance rising to meet grassroots innovation through the adaptation of planning policy shows that this way of life aligns with UK sustainability policies and may be a model adopted elsewhere in the UK in the near future.

**Key message for policy makers**

Policy makers should consider how the changing functions of the home will impact the ways our homes are built (with sustainability in mind), how the different spaces in our homes are used and what products are brought into the home as a result of these new functions and changes. The Lammas eco village provides a tangible example of this change in function whereby the home becomes construction site, homestead, workshop, marketplace, living space for socialising, recreation and family life with these various activities all undertaken by the homeowner[2]. This example of the multi-functionality of homes challenges the assumption of the conventional way of modern living whereby products are brought into the home from a central marketplace (supermarkets, online shopping, etc.) and produced by organisations both internationally and locally (farms, factories, etc.). The Lammas eco-village forces us to consider the new or changed relationships that may emerge as a result of a change in functionality of our homes.

Although the Lammas echo village presents a model that may not be accessible to all within society due to the skills, resilience and motivation required, this type of style of living is likely to increase as a form of engagement with the net zero transformation of society. Some of the risks that may emerge due to an increase of low-impact models of living may include:

- Residents building homes themselves without the necessary skills or experience,
- Construction codes (such as those ensuring fire, gas and electrical safety, etc.) not being navigable to a wider range of actors and therefore not followed correctly.
- Salvaged or reclaimed (and therefore by-passing traditional commercial marketplaces) materials introduced into homes that do not meet safety standards.

## 2. The Home as System

**Net Zero Buildings**

Net Zero Buildings are becoming more common around the world as policy adapts to the call for a net zero transition of society and consumers become more aware of environmental issues and the options available to them when it comes to designing, building or buying a home. Clarke et al (2020) also recognise the challenges for professionals in designing and constructing Net Zero Buildings that meet safety standards and call for increased research to be aimed at vocational education and training for construction practitioners involved in the repair, maintenance and improvement (RMI) of Net Zero Buildings (Clarke et al, 2020). This section will focus on examples of NZBs around the world, their commonalities and the difficulties associated with their design, build and operation.

It is often difficult to find a common definition of what it means for a home to be considered a net zero energy building. Satori et al (2012) seek to provide a consistent framework for defining NZBs and argue that these types of homes force the regulator to consider the building as a whole rather than the amalgamation of distinct construction and consumer products. For a construction and consumer product regulator, this may

[2] The Lammas eco village website provides a publicly accessible and up-to-date collection of recent research and annual monitoring reports and can be found here: https://lammas.org.uk/en/research/

mean that although products may individually meet current safety standards, together they may not be compliant with safety requirements, environmental considerations or energy efficiency. Likewise, regulations addressing the whole building may not be enough to ensure that individual components meet product safety standards.

Some of the problems identified in the design, building and operating of NZBs include:

- power stability and quality,
- meeting the demands and loads of changes in climate, energy needs or energy grid fluctuation

Some of these problems may become more or less apparent depending on the region or country where the home is located (Satori et al, 2012).

One commonality between NZBs, no matter the building type or location, is to ensure that local climates are taken into consideration. This section will explore some of these challenges within different regional contexts.

**The European context**

Santamouris (2016) explores three problems of the built environment in Europe; the energy consumption of buildings, energy poverty and localised effects of climate change. These challenges are then linked to poor thermal quality and poor ventilation systems resulting in poor air quality. This, in turn, may lead to health concerns, particularly in elderly, low income and vulnerable populations. Santamouris introduces the "zero concept world" in response to these challenges which seeks to "develop zero emission and zero waste technologies applied in zero energy and zero emission buildings and cities where advanced and innovative technologies and policies will be applied to minimize crime and diseases" (Santamouris, 2016). In this way, the increase of NZBs in local building stock may help to minimise energy consumption of buildings and eradicate energy poverty. This introduction of NZBs may result in improved building stock which, in turn, may improve thermal quality and air quality and reduce health risks due to poor insulation and ventilation (Santamouris, 2016).

**The Southern European context**

Attia et al (2017) pose five key questions to fourteen national experts from Cyprus, France, Greece, Italy, Portugal, Romania and Spain to provide an overview of current and future challenges facing nearly zero building design in Southern Europe. These questions explore national legislation around nearly zero energy buildings (nZEB) and centre around the efficiency of nZEBs in relation to local climates and local energy management and supply. Each country had a particular set of climate related and energy availability concerns which impact upon the optimal functioning of NZBs.

The questions posed in this study provide a framework to understanding the cultural and technical barriers facing NZBs in Southern Europe and include:

- "What is the minimum energy efficiency threshold for nZEB in your country?"

- “What is the heating/cooling energy needs balance for nZEB in your country?”
- “What is the thermal comfort limit for nZEB in your country?”
- “What is the minimum renewables threshold for nZEB in your country? What are the recommendations for minimum energy efficiency and renewable energy threshold onsite in your country?
- “What is the construction quality for nZEB in your country?”

Although this framework provided good insight into the requirements and barriers within each Southern European country, these questions fail to take into account changing building loads due to the localised effects of climate change. However, the case studies did demonstrate a pattern of commonality between barriers such as:

- Barriers relating to the geography and climate of Southern Europe,
- The overreliance of building professionals on simulation tools during the design and construction phases of nZEB,
- A lack of local governance and national strategies to create an infrastructure for the implementation of nZEBs.

This study shows that the barriers to implementing nZEBs tend to be similar across countries with similar political and geographical characteristics. Future research may look to compare these findings with challenges within a UK setting to understand common barriers and find potential solutions to these challenges.

**The Chinese context**

Jin et al (2014) consider the social and cultural implications, as well as the environmental and sustainability implications, of the net zero building. By incorporating traditional social and cultural elements of the home region into the design of net zero buildings, this ensures that the home remains comfortable and liveable for residents and provides an example of incorporating the social into building design. In the Chinese context, this translated to a building centred around an atrium for socializing and relaxing and incorporated the principles of Feng Shui which remains an important cultural value in China today. For the UK, this may mean buildings centred around a mix of indoor and outdoor space for socialising, relaxing and working (especially in the wake of the recent covid-19 pandemic where work from home is becoming more and more accepted and expected) and which accounts for the warmer summer months and cooler winter months.

**The Australian context**

Wells et al (2018) reinforce the need for a robust definition of NZB and a standardisation of NZB practices and explore notable policies supporting energy and sustainability initiatives in Australia, Canada, the EU, the UK, New Zealand, Japan, the UN and the USA. This comparison of policy shows a lack of a universally agreed holistic definition of NZBs, inconsistent governance of energy efficiency standards worldwide, a lack of documented public acceptance and governance encouraging NZBs at the national or local levels, a lack of research into embodied energy efficiency in manufacturing building materials and a lack of discussion around the economic feasibility of NZBs at national and local levels.

For the Australian context, Wells et al conclude that “separate sets of targeted policies are required for residential and non-residential buildings” which “should advocate stronger building code and ensure much higher levels of compliance” (Wells et al, 2018).

### Key messages for policy makers

These case studies place emphasis on the importance of considering local climates, local cultures, the training and upskilling of professionals and taking into account traditional and indigenous building techniques to achieve safe and efficient NZBs. Understanding the methods used in the above case studies to accurately evaluate the challenges facing NZBs in a UK context is essential. This assessment will allow for the understanding of what new materials and technologies may become commonplace in the UK building sector in the near future and the new products that may emerge to achieve this transition to a NZB building stock. For policy makers, understanding changes in the building sector that may emerge due to the net zero transformation of society are essential to regulating the new products and materials that will emerge with these changes.

## 3. The Home as System and the Internet of Things

### Smart Home Technology

A smart home is defined by the connected and interactive technologies it contains, however, often these homes also include environmentally friendly and sustainable elements such as solar powered systems or wastewater recycling technologies (Aldrich, 2003). Smart homes are becoming more ubiquitous with growing demands for users to be able to monitor and change their environment quickly and at will to ensure comfort, energy efficiency and financial control. It is now commonplace within the home to have an AI (artificial intelligence) powered smart home hub or interface, with voice recognition technology for example. Users can dim lights, close blinds, change the thermostat, play their favourite music and add groceries to shopping lists through a simple voice command to a centralised interface such as the Amazon Echo, Google home or Samsung’s Bixby. Furthermore, these modular components connected through the Internet of Things (IoT) that comprise the smart home are devices that are often easy to install with no professional intervention required (Koshy et al, 2021).

Through the implementation of these connected technologies and interfaces, users have greater control over their energy consumption and the associated costs through the presence of smart meters within the home which show exactly how much energy is used and its associated cost. This information allows users to make informed and sustainable consumption choices. For residents with disabilities, smart home technologies such as "electronic assistive technology (EAT), including electronic aids to daily living (EADL), assistive technology for cognition (ATC), wireless connectivity and other tools" allow greater independence and can support residents' needs whilst reducing the need for caregiver support (Gentry, 2009).

Smart homes and their integrated technologies are thus important features of homes and provide autonomy, control and comfort for their occupants. However, they can also create inequalities between the primary users of these technologies and other members of the household especially around functionality and levels of privacy afforded to each resident or family member. For Koshy et al (2021) this distinction is between "those who introduce new functionality to the smart home (pilot users) from those who do not (passenger users)". These dynamics are important to consider as they shed light on how dynamics are formed around devices and products which may in turn affect the safe use of these products (Koshy et al, 2021).

Hargreaves and Wilson (2017) systematically explore "how and why people use smart home technologies, and what impact this has on different aspects of everyday domestic life", building from an earlier (2015) systematic review of academic sources focusing on smart homes technologies and their users (Hargreaves, Wilson and Hauxwell-Baldwin, 2015). Mare et al (2019) approach the question of smart home technologies from the products themselves and how various commercially available smart home products may differ, the implications of their differences and what other design alternatives exist that may improve on current commercially available models.

**Key message for policy makers**

For policy makers, although it is vital that the products within smart homes are safe, it is also important to consider how meeting safety standards may vary depending on dynamics within the home and family. This may mean considering the privacy and comfort of all users, including both pilot and passenger users, or understanding how smart home technologies interacting through the Internet of Things within a connected systemic home may influence the safe use and wider resilience of the home network. Further research is required to understand how these influences may impact regulatory needs for product safety and how policy makers can respond to the ever-growing presence of more intelligent and interconnected products within the home.

## 4. Conclusion to Part III

Considering the home as system illustrates how it is increasingly difficult to regulate the safety of individual products without taking into account the wider systems in which they are installed, connected with and operate through. For policy makers, it may be necessary to adopt a new strategy to the regulation of consumer products and construction materials. The theories of Actor Network Theory and Material Participation both consider the interconnected nature of people and things existing within vast networks of relationships. For policy makers, drawing upon these theories – themselves explained in greater detail in the supporting brief "Social science approaches to understanding the implications of a net zero transformation of society" - may highlight the need to consider the overall systems of products, materials and people as connected and influencing the safety of each other. (Thompson, Rohse and Barber, 2024).

# IV. The Construction Product

## 1. Building for the Climate

**The implications of climate change on building loads**

The impacts of climate change on building heating and cooling loads around the world has been studied extensively, particularly in the context of large Asian and American cities (for example, Tokyo, Hong Kong, Seoul, California, etc.) (Lu et al, 2009; Xu et al, 2012; Arima et al, 2016 Spandagos and Ng, 2017). These regions are among the most densely populated and most vulnerable to climate change induced natural disasters such as flooding, intense temperatures, wildfires, etc.

However, climate change induced changes in temperature and weather patterns will also impact the UK to an increasing extent if current global warming trends do not slow. The effects of climate change are already being felt locally with devastating effects such as the Summer 2020 heatwaves across the UK which caused more deaths than have been reported since the Heatwave Plan for England was introduced in 2004 (Thompson et al, 2022). Cooling efforts for indoor spaces in the UK are likely to become more energy intensive with greater energy levels required to maintain comfortable and safe indoor temperatures (Sajjadian, Lewis and Sharples, 2015).

In response to growing climate concerns and as the world is not yet on track to maintain current warming levels to under 1.5C, it is necessary to understand how the current UK building stock will respond to the localised effects of climate change in the future. Academic literature has attempted to address this issue since at least as early as the turn of the 21st century with Sanders and Philipson (2002) identifying six predicted changes in climate that affect UK building loads. These are changes in temperature, precipitation, wind speed, atmospheric humidity, solar radiation and soil moisture. These changes may in turn lead to;

- increased instances of flooding,
- negative air and thermal quality of buildings,
- negative impacts to foundation due to shrinkage and swelling of clay soils,
- Negative impacts to dynamic structural loading caused by pressure force of increasing wind speeds
- Negative impact to surrounding environment causing damage to building stock (falling trees, etc.) and damage to existing transportation infrastructure due to increasing wind speeds,
- increased instances of dry and wet rot (especially in older buildings), and,
- higher maintenance requirements to ensure that buildings remain weather tight throughout their expected life, among others (Sanders and Philipson, 2002).

These increased pressures on building loads may also impact upon the safety of individual construction materials within the building or affect the integrity of the construction product were it to be salvaged and reclaimed, reused or recycled.

Weather files, built upon recordings of historical weather data, include daily and hourly resolution and define the external boundary conditions for a numerical building model which describes the dynamic energy behaviour of a building (Moazami et al, 2019). This is known as a Building Performance Simulation (BPS) which is used to evaluate the efficiency and safety of a proposed design under the probable climate conditions that a building will face during its lifetime. The BPS fails, however, to account for extreme weather conditions and accurately anticipate these as the localised effects of climate change become more severe (Moazami et al, 2019). Increased monitoring of extreme weather and temperature patterns will be required and partnerships between academic and governmental centres monitoring the localised effects of climate change on weather and temperature patterns may be beneficial for policy makers to foster in order to anticipate and mitigate against climate induced changes to building loads and the associated safety implications.

For policy makers, it will become necessary to take into account changes in building loads due to the changing climate and the safety of individual building materials. This may be achieved by considering the changing loads that may affect product safety and integrity[3].

It will also be necessary to understand emerging technologies that provide alternatives to traditional heating and cooling methods within homes such as alternative energy storage technologies. For example, the use of smart materials such as phase change materials - which increase thermal mass without adding weight to the building system - in construction projects may be accompanied by a specific set of risks and safety implications (Sajjadian, Lewis and Sharples, 2015).

In the face of extreme weather patterns, the way in which the home is used (for example, increased heating of small spaces due to colder temperatures or increased ventilation and cooling due to warmer temperatures) may impact the intended building load. Policy makers should consider how the intended use of construction materials and products may change in the face of the localised effects of climate change and the safety implications that this may entail.

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[3] These loads may include temperature variation, rain, snow, wind, solar radiation, barometric pressure, soil and water pressure, soil organisms, soil PH, alkalinity contaminants, gas, moisture, earthquake vibration, industrial loads and salty sea air. Other human induced loads may also increase as a result of climate change, these loads include moisture, noise, live loads, fire and smoke, impact (static or dynamic) and electrical or mechanical loads affected by people such as stack effect, vibration or heat emission.

**Key message for policy makers**

Changing weather and temperature patterns may have serious safety implications for buildings and their components. Policy makers should consider the different risks associated with changing building loads which may be affected by human activity, greater energy expenditure or exacerbated by affected construction material integrity. One approach to achieve this might be to consider how existing testing could be adapted to account for more extreme weather and temperature variations.

## 2. Reuse, Remanufacture, Recycle

**How to assure safety as standard in reused construction materials?**

The built environment makes up 25% of all carbon emissions in the UK (UKGBC, 2021). Industrial waste reclaimed as a potential resource can present valuable opportunities where waste from one activity or project can become input for another. This circular resource flow can be hugely beneficial for the environment, industrial producers and consumers as an often cost effective and lower carbon alternative to the use of new construction materials within homes and other building projects. As consumers become more aware of the environmental impact of non-sustainable building practices and materials, the use of reclaimed construction materials is likely to increase in the near future (Balador, Gjerde and Isaacs, 2020).

It is necessary to understand the public's perception of environmental issues and tackling the increasing volumes of waste is an important part of this understanding. For example, Dursun et al (2016) identified that the positive influences associated with personal health and the environment were more influential factors than financial reasoning for individuals engaging with green buying behaviour.

For Policy makers, understanding the social aspects of construction material waste; including the public's understanding of environmental issues linked to waste products, the availability of reclaimed materials and broader trends in the purchasing behaviour of customers, is an integral part of assessing the risks associated with the use of reclaimed, reused and recycled construction materials. Further to the public's general understanding of the issues associated with construction waste and the wider environment, other stakeholders, such as architects, designers, manufacturers and suppliers, builders and organisations across the supply chain and their understanding of the issues are also vital (Balador, Gjerde and Isaacs, 2020).

A recent (2023) report published by the Office for Product Safety and Standards (OPSS) identifies and evaluates emerging risks associated with the use of recycled materials and potential chemical safety concerns in specific consumer products. This report focuses mainly on the chemical thresholds for the use of recycled materials and how aware selected businesses are of these risks, the sources of support and guidance available to them and the impact that use, or not, of recycled products may have (OPSS, 2023).

Future research investigating the impacts of reclaimed construction materials could seek to explore and develop an evidence basis for the size of the reclaimed construction materials market, supply chain structures, tiered information flows in relation to the reclaimed construction product and an estimate of the proportions for "reused, recycled and reclaimed" materials within the supply chain. Such future research may also focus on providing definitions around the product lifecyle and compare the lifecycle of the new product and its waste with the lifecycle of the reclaimed and recycled product. Understanding academic and non-academic literature pertaining to sustainability within supply chain management of construction material will be an important area to consider in understanding circular supply chains of construction products (Carter and Rogers, 2008).

Further to this, future work could develop methodology that may be deployed for different construction product sectors to evaluate critical regulatory factors of interests (such as risks and hazards) in relation to reclaimed, recycled and reused products in the construction industry. These factors of interest may include the information pertaining to the product lifecycle, the development of definitions and standards on the safety and performance of reclaimed products, finance and economic consequences of reclaimed material and the monitoring and traceability of reclaimed materials.

Understanding the safety implications of the individual construction or consumer product requires a wider systemic understanding of supply chains (including alternative routes to market or consumers) and the wider systems in which recycled or reclaimed materials will be used. These proposed areas of research also highlight the importance of considering the safety implications of product systems (such as cladding, glazing, etc.) which may be installed directly into buildings rather than focusing solely on their individual components.

Through the key issues highlighted by the various case studies of this report, areas of future could include a reframing of the issues through a social science lens and with a consideration of the implications that a net zero transformation of society may entail. This may mean placing more importance upon understanding the relationships between material and consumer, material and professional and professionals and consumers, through questions like:

- how and by whom these construction materials will be sourced and installed,
- how available reclaimed materials are currently and how may that change in the future,
- how safety regulations will be understood and adhered to through DIY installation, and,
- how policy makers may account for the increased risk of reused materials in DIY projects

Important to consider in the regulation of construction material safety is the difference between intended product function and actual product use, including the control functions[5] of materials or products used within the home may be, support functions[6] and the function of distribution products may include building services and utilities. Should reclaimed materials be used for a function other than their intended purpose this may have safety implications on the product's integrity and the integrity of other products within the system or home.

With reclaimed materials often offering a cheaper and more sustainable alternative to conventional construction materials, the ways in which these materials are sourced and installed may also evolve. The Covid 19 pandemic provides a good example of a boom in DIY which was accompanied by a particular set of safety concerns with cases of ocular injury up to 3.33 times higher due to increased instances of DIY home-improvement projects (Hamroush, Qureshi and Shah, 2020; Stedman, Jefferis and Tan, 2021).

With a wealth of how-to guides on popular social media and streaming platforms, the practice of DIY home-improvement is more accessible than ever. However, how products are installed and used by non-professionals may not meet optimum safety standards and many health and safety guidelines and regulations may be ignored or overlooked.

## 3. Repair, Maintenance and Improvement

**How professionals may respond to retrofit within the home**

New energy efficient and smart technologies are emerging that can be retrofitted to existing buildings. These products and materials can range from the relatively simple-to-install such as low wattage lightbulbs to the more complex, requiring professional intervention, such as heat pumps. With an increase of smart and energy efficient alternatives technologies becoming more readily available and affordable[7] there is a growing need and desire to retrofit existing buildings with energy saving and environmentally conscious alternatives. However, to guarantee the safety and efficiency of these products or materials, current professionals must ensure that they have the adequate skillset to perform these (often highly technical) retrofitting projects (UKERC, 2020).

To ensure the safety and compliance of retrofitted construction and consumer products, it is necessary to understand the capabilities of existing construction and building professionals working in repair, maintenance and improvement (RMI). Individual products or construction materials may be safe and meet regulatory requirements and standards, however, their safety is often contingent on the skills of RMI professionals. If these skills are not adequate to install and maintain these new materials and technologies then this may lead to energy inefficiency, waste and increased safety risks to a large percentage of the population as the retrofit of construction materials and consumer products becomes more popular within the home.

The literature around upskilling and retrofit particularly highlights the need to understand the capabilities of small and micro-firms that undertake RMI and who form 77% of workers in construction (Simpson, Murtagh and Owen, 2021). The knowledge and skill of these practitioners is often built upon generations of knowledge and risk is often minimised by avoiding new or unfamiliar technologies and practices (ibid). For regulators, it is vital to recognise the essential role of these professionals and understand how the need to upskill from the RMI of traditional technologies is being met within this category of practitioners (Simpson, Murtagh and Owen, 2021). In the case of the Net (or Nearly) Zero-Energy Building Clarke et al (2020) call for a need to improve the vocational education and training (which is often overlooked by regulators and policy makers) of professionals and explores education initiatives in Slovenia, Ireland, Finland and Belgium (Clarke et al, 2020).

## 4. Conclusion to Part III:

A net zero transformation of society will impact the construction materials industry and the composition of the UK building stock. Pressures such as the localised effects of climate change will force the construction sector to consider alternatives to current building methods and design as our homes and buildings contend with more extreme weather and temperature patterns which will impact upon building loads. As a result, the existing building stock in the UK will require a host of upgrades through the retrofit of materials and products into the home. These retrofit activities will require a skilled and knowledgeable work force for their repair, maintenance and improvement now and in the future. Further to this, as individuals become more aware of the negative effects of climate change, consumption behaviour patterns may change and the use of reclaimed materials in construction projects will increase. Future research may look to understand the safety implications of an increase of DIY projects in the home, broader supply chains of reclaimed materials and how the intended use and actual use of reclaimed materials differ.

# V. The Construction Product

## 1. An increase in artificial intelligence and the ethical considerations of intelligent products

**The ethical considerations of "street-testing" intelligent products (Autonomous Vehicles)**

Throughout the 20th century the safety testing of vehicles had been moving towards the laboratory setting (Leonardi, 2010), however, with the development of autonomous vehicles, street testing is becoming more necessary to account for the changing and multiple risks that these vehicles present. Autonomous vehicles, for example self-driving cars, are a technology emerging through scientific developments, the net zero transformation of society and address a growing societal demand for efficiency and comfort. These vehicles also provide a good example of the ethical considerations to be taken into account when examining the risks associated with decision making in intelligent products and their testing. Street tests introduce technology to society and are an example of experimentation in everyday settings, for example, on UK roads. These types of tests take place away from scientific laboratories and bring the laboratory and testing into the real world. As Marres (2018) posits; "street tests enable an expansion and intensification of interaction between the laboratory and the street, and not the displacement of innovation from the one to the other".

Autonomous vehicles and street testing show that it is possible to bring together different actors into the same space and are an example of a new form of partnership between the government, society and industry (Marres, 2018). However, street testing often does not account for societal contexts and concerns and does not always responsibly account for the safety and ethical implications of enlisting local people in tests. This may mean that local people are not consulted before being enlisted in the experiments and tests taking place in public, their safety not adequately ensured, and their data collected (photographs, film, reaction, etc.) without their prior consent.,

The UK has adopted a "non-regulatory approach" to autonomous vehicles so there is no legal requirement for a formal approval process to test driverless vehicles (as, in the UK, it remains legal to remove your hands from the steering wheel whilst driving) and the street trials of autonomous vehicles have been taking place on UK roads (in London, Milton-Keynes, Bristol and Coventry) since 2016 (Marres, 2018). This has ethical implications for environmental and social participation where permission or acknowledgement of trials may not have been sought prior to testing. This concept is taken further by Marres who questions if street trials do not, in fact, test society rather than the vehicles themselves (Marres, 2018; Marres, 2020). For example, Marres (2020) states that "UK driverless car trials are also poised as an occasion for road users to become familiar with these relatively new technologies" and these trials are not "just assumed to be one-way" (Marres, 2020).

Marres proposes that "driverless street tests are and can be configured to enable the elicitation of social, political and ethical aspects of new technology that are not already apparent, but that they are not on the whole already configured to do this" (Marres, 2018).

The regulatory implications of street trials of autonomous vehicles and what these trials are assessing (the cars themselves or society's reaction and acceptance of them) are a need for new forms of governance in support of "social learning" and "machine learning" of products. Although this case study has focused on autonomous vehicles as an example of in situ product testing in the UK, other intelligent products that require real world testing may be medical device trials and consumer electronics testing. This case study does not call for the exclusion of social phenomena in the testing of intelligent products, rather it calls for a regulatory awareness of the ethical implications of real-world testing or environmental participation.

**Key message for policy makers**

Product testing outside the laboratory can be an effective way to understand the risk associated with a particular product and can provide a way to understand society's acceptance of the product and these risks.

The example of the autonomous vehicle provides two key messages:

- The above example of the autonomous vehicle provides an example of decision-making power which now sits with the product and not with the human. This presents a disruption of the conventional definition of what a product is and does. The autonomous vehicle, along with other smart products links to the wider environment of products interacting within networks of smart cities (for example) interconnected through the internet of things. For policy makers, this shows a need for increased consideration around the safety and resilience of networks as-a-whole, rather than simply ensuring the safety of the individual smart or autonomous product.

The example of the autonomous vehicle also provides an example of how the testing of products may change in the future. To be deemed safe in a real environment, the autonomous vehicle must be tested in that same real-world setting. This will undoubtably prove a greater risk to the public than if testing was confined to the laboratory.

## 2. Smart products

### The implications of intelligent products within the home for regulators of product safety

For Kortuem et al (2009), smart products are physical or digital objects which are autonomous and "augmented with sensing, processing, and network capabilities". Several controversies exist around the use of smart technologies and artificial intelligence (AI) in products; namely a lack of transparency, misinformation, racism, exploitation, machine bias, physical harm, privacy invasion, data appropriation without consent, worker exploitation and high environmental costs (Shaping AI, 2023).

The Internet of Things, through which smart products are connected, emphasizes a vision of a "global infrastructure of networked physical objects" of which, a "loosely coupled and decentralised system" of smart products are the building blocks (Kortuem et al, 2009). However, as products become increasingly connected, risks may arise to the whole system or network which may affect its resilience. For policy makers, this means that there is a need to consider how regulations may adapt to consider the safety of a whole system, rather than the physical safety of a simple object. These risks may be physical, such as overheating, electrical or mechanical such as leading to power surges, or concern data and privacy of users. Further research on the safety implications of the increase of smart products is vital to understanding how regulations may adapt to ensure users safety.

A 2021 (OPSS) study examines the perceived risks of smart products by the public by asking participants of the study whether a single imaginary smart product increased or decreased the risk of injury (for example) compared to their non-smart counterparts (OPSS, 2021). Areas for further research were identified around the attribution of responsibility to smart products by people. This research considering the responsibilities or ensuring user safety of smart products assigns a degree of autonomy and intention to the product, which, in turn reflects a material participation style approach or considering the object as actor. This research could be taken further by examining the attribution of risk and blame to smart products within the wider home as system. An actor network theory framework may allow the product to be understood within the wider system of the home and the relationships between actors (products, construction materials, consumer, wider family and friends, pets and all other actors present within the home) may shed more light on the nuances of the responsibility of smart products within the home and how the attribution of risk and blame increases, decreases or changes depending on the relationships within the home as system.

**Key message for policy makers**

Policy makers should consider how the increase of smart products may affect the safety of users, as well as overall networks. Risks may be physical, technical or ethical and may require a new strategic regulatory approach.

## 3. A return to traditional product design

**A return to low tech products and traditional product design**

This report has provided multiple examples of high-tech products, often powered by AI and connected through the Internet of Things either at the community level through computational cities, at the home level through smart home technologies or at the individual product level. However, the net zero transformation of society may also inspire a return to traditional product design methods or influence the popularisation of low-tech alternatives to smart products. This increase in the use of traditional or low-tech products presents a different form of public engagement in the context of net zero.

Some of these low-tech or traditional alternative products may be relatively easy and affordable for individuals to adopt as part of daily routines, such as reusable cloths used for household cleaning. Others may require more important levels of commitment such as the installation of appliances, for instance, composting toilets which aim to eliminate pressure on wastewater treatment systems. These forms of engagement reflect wider behaviour change in individuals which Perlaviciute et al. (2021) call low-carbon behaviour. This low-carbon behaviour relates to behaviour change around "mobility, housing and food" which can have substantial positive effects on the reduction of carbon emissions (Perlaviciute et al, 2021).

Traditional design and manufacturing processes have also seen a rise in popularity with, for example, the art of origami being implemented in the product design of everyday items. This example of traditional artisanal product design is increasingly being implemented in "state of the art" products and is celebrated for its ability to allow for the reconfiguration, flexibility, compactness, and multifunctionality of products (Morris et al, 2016). Examples of the use of this traditional art form in products include its use in product packaging (Büyükyılmaz, 2019) and in the design of deployable childcare furniture (Armes et al, 2022). Due to this increasing popularity, origami inspired product design has become more mainstream, even featuring as a topic of focus in a recent National Geographic issue (National Geographic, 2023).

**Key message for policy makers**

For policy makers, the switch to the use of traditional product design methods or low-tech products replacing single use or high-tech products reflect a change in consumer attitudes influenced by the net zero transition of society. For policy makers, this may mean that new sets of safety concerns may emerge. These concerns may range from the correct installation of low-carbon alternatives to everyday home appliances to the risks of ensuring that products designed through traditional methods are durable and secure for everyday use. Further research is needed to understand what low-carbon products may emerge in the near future and how their associated risks may differ from more conventional products such as single use products or electronic appliances that are now commonplace in the home.

## 4. Conclusion to Part V

At the individual product level, changes in consumption due to the net zero transition of society reflect a broader public awareness and engagement with the issues around climate change. There is a real need to track and understand this engagement as these changes in behaviours and consumption patterns have real impacts on climate change. The UKERC observatory for public engagement is currently addressing this question and is committed to tracking, tracing and understanding multiple and diverse forms of public engagement and participation in relation to climate change, energy and net zero. The observatory may provide a gateway for further research for policy makers by highlighting case studies reflecting the implications of a net zero transition of society (UKERC, 2023).

# VI. Conclusion

An often overlooked yet crucial aspect of the net zero transformation of society are the people at its heart. Further research is needed to account for the multiple and diverse forms of public engagement which accompany this net zero transformation and how these may change the ways in which the safety of products is regulated. Vital research is needed to further understand how differences in age, gender, racial and cultural backgrounds and access to education affect people's interaction with the products within their homes and the wider built environment.

Although efforts to address global warming and implement strategies to achieve net zero emissions have been implemented across sectors, there lacks a systematic, systemic and interconnected approach to policy making with "most observed adaptation responses [being] fragmented, incremental, sector-specific and unequally distributed across regions" (IPCC, 2023). This policy brief has aimed to address the regulatory implications that may emerge due to a net zero transformation of society. This brief has aimed to do this through a reflexive governance perspective, placing emphasis on the systemic nature of products, people, communities, the wider built environment and governance. This report has anchored its theoretical framing through actor network theory and a material participation approach – two defined theoretical frameworks supported by their own bodies of literature – that focus, variously, on the systemic participation and interactions between non-human actors and human actors of participation.

Regular nods to the Covid-19 pandemic have been made throughout this report as it represented a potential paradigm shift of how energy was consumed and how people engaged with their homes and the wider built environment. The pandemic also served to highlight how quickly seemingly set or well-established values and ingrained models of behaviours may change. Although a tragic period of recent world history, the pandemic also provides a recent example of the emergence of new ways of thinking about how we work and live in society and has provided alternatives to previously entrenched energy usage and consumption practices (UKERC, 2020). The recent Covid-19 pandemic has also highlighted weaknesses in the ways in which our cities, homes and products function and showed the importance of having spaces and products designed to meet the changing needs of people. From the 15-minute smart city to the autonomous vehicle, new products and systems are emerging to meet behaviour changes and the new demands of society. These systems and technologies not only require news ways of thinking about safety and how to regulate products but force us to reconsider what a product is, how it functions and the direct and indirect effects it has on people.

Moving away from the misconception of an ill-informed and uninterested public, people today are engaged, informed and increasingly vocal about the need for a net zero transformation of society and policy must adapt to respond to the implications of this movement. From grassroots environmental activism including groups such as Extinction Rebellion or Just Stop Oil, to everyday consumer decisions and practices, the role of people must not be overlooked in the development of net zero policy and governance. In turn, the regulation of safety as a result of this societal transformation must be informed, in the first instance, by people and their interactions with their environment. For Chilvers and Hargreaves, “this calls for new ways of seeing, doing and responding to diverse societal engagements with energy and climate change” (Chilvers and Hargreaves, 2020).

For a product regulator, the implications of a net zero transformation in construction and consumer products may be an increase in intelligent products, an increase in eco-friendly materials that will require new ways of assessing safety and environmental impact and an increase in the need to consider reuse-remanufacture-recycle as standard for product eligibility on the market. In this context, a regulator might move away from only considering safety but a framework for sustainability should be implemented to ensure that all construction and consumer products in the UK meet a certain Net Zero sustainability standard. The development of these standards should take into consideration new systemic forms of engagement with the built environment and products and should consider the role of products and materials as actors within the net zero transformation of society.

This report has shown that the behaviours and values that govern people’s relationships with product and their wider built environments cannot be taken for granted and that large-scale change is not always gradual. This report has also demonstrated that the very definition of what a product is may also evolve as products, people and their environments become more interconnected than ever. Furthermore, it is the diverse and complex relationships that exist between them that are critical to now explore.

For the regulatory of product safety and standards, the criteria for a product to be considered safe may need to be expanded upon as seen with the introduction of intelligent products and artificial intelligence based products which may have decision making capabilities of their own (such as autonomous vehicles) or the ability to influence human behaviours, decisions and choices as these products become more sophisticated (Smart watches, AI assistants within the home, etc.). Through these technologies and functionalities, these products present a host of ethical challenges that policy makers may need to address in the near future.

A key message from this report is that the implications of a net zero transformation of society will be diverse and complex, however, people, through their needs, behaviours and values will dictate how this transformation unfolds. Within this context, any work to understand those needs, behaviours, and values will offer great value to a regulator that wishes to remain effective in a changing world.

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# Annex

## Annex 1

**Further Information on the academic literature review**

An academic literature review was undertaken by the author to ascertain key areas of interest around the topic of the net zero transition, society and the implications for construction material and consumer product safety.

This literature review was undertaken in Scopus, Web of Science and Google Scholar using the below search terms.

**Search terms used in the literature review.**

TITLE.ABS.KEY(( product* AND design* ) OR ( construct* AND product* ) OR ( home* AND product* ) OR (house* AND product)) AND ( ( net AND zero ) OR ( transition* ) OR (low carbon) OR (just transition) OR (carbon neutral)) AND ( ( safe* ))

The results of this review were then manually sorted by relevance to the topic through the analysis of both title and abstract from 584 results to a final 35.