Written evidence submitted by Professor Aoife Houlihan Wiberg in a personal capacity

1. Executive Summary

- Need for a clear, harmonised national UK definition framework for (net) zero GHG emission buildings (and neighbourhoods) with ambition levels for both retrofit and new build.
- Need for consideration of embodied emissions of materials and the need for a robust, reliable, harmonised national standard – UK Embodied Carbon calculation methodology and development of a national open source embodied carbon database (including EPDs)
- Need for (net) Zero GHG Emission Pilot projects showcasing design drivers for reduced GHG emissions
- Need for integrating life cycle analysis (LCA) early and throughout the design process – Need for a dynamic and visual LCA approach to visually communicate and make it easier to understand key environmental impacts from design and material choices.
- Need for the use of visualisation and immersive technologies for improving stakeholder engagement in (net) zero GHG emission-built environment

2. Background

This evidence is submitted to this enquiry to help contribute knowledge for the UK development of (net) zero GHG emission and sustainable built environment as a key climate mitigation pathway and decarbonisation of the built environment. Government, policy makers, industry, architects, researchers, citizens have a tremendous potential to shift the entire industry towards zero carbon architecture and built environment. Architects play an important role particularly in the early design phase when he/she has the greatest opportunity to make design decisions that directly lead to a reduction in the GHG emissions. However, it is not easy for architects to easily understand and visualise how their design contributes to the overall GHG emissions for the built environment. This lack of fundamental knowledge is a result of the lack of integration of sustainability in the mainstream and in architectural practice and education. In response to our current climate emergency and urgent need to decarbonise the built environment, this paper highlights key areas to be developed to drive a net zero pathway and proposes key action points for the committee to consider decarbonising the built environment.

By way of background, Aoife Houlihan Wiberg is a Professor in Architecture and chartered member of the Royal institute of British Architects (RIBA). She is UK national participant and leading research in the Energy in Buildings and Communities (EBC) International Energy Agency (IEA) Annex 72 – *Assessing Life Cycle Related Environmental Impacts Caused by Buildings 2016-2022* (https://annex72.iea-ebc.org/) . Prior to this she was Norwegian national participant in the EBC IEA Annex 57 - *Evaluation of Embodied Energy and CO_{2eq} Emissions for Building Construction* 2012-2016 (https://www.iea-ebc.org/projects/project?AnnexID=57). She sits in several international conference scientific committees, invited guest speaker in USA, South Korea, Japan and Singapore. She is a regular reviewer for several leading peer reviewed journals in her field of research in (net) zero, she is founding Editorial Board member of a newly launched journal, *Environmental Research: Infrastructure and Sustainability* (ERIS) and invited guest editor for *Energies* for a special issue on *'Advances in zero energy (and emissions) buildings'.* She has been an expert reviewer in The Government and Expert Review of the Second Order Draft of the Working Group III contribution to the IPCC Sixth Assessment Report. (Chapter on Buildings) and recently has been an EPSRC grant reviewer.

In 2019, she returned to live in the UK (Bath) after a decade working at The Research Centre for Zero Emission Buildings (http://zeb.no/index.php/en/) and *The Research Centre for Zero Emission Neighbourhoods in Smart Citie*s (https://fmezen.no/) hosted by Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. In 2017-8, she was a Visiting Research Scholar at The Centre for the Built Environment (CBE) (https://cbe.berkeley.edu/) and The Lawrence Berkeley

National Laboratory (https://eta.lbl.gov/), University of California, UC Berkeley, USA. She received her M.Phil. *Environmental Design in Architecture* and PhD *Architecture* Degrees in Architecture from the Department of Architecture, University of Cambridge, UK. She has worked in architectural practice in the UK, Ireland and The Bahamas. She is currently Professor of Architecture at The Belfast School of Architecture and the Built Environment, Director of the Architectural Research Group and Lead of the (net) zero GHG emission buildings research cluster. She currently leads an innovative vertical super studio (B.Arch./M. Arch.) and a M. Arch. technical module on (net) zero GHG emissions buildings and neighbourhood. She is lead PI in a research project called 'Architects of Change', an academic-industry collaboration which is student led in the form of a 'train the trainer' project with the aim to transfer key net zero knowledge to key stakeholders in the city. She is supervising three PhD researchers in the field of (net) zero emission-built environment and immersive technologies for ZEN.

Her core areas of expertise in research and teaching include these interconnected strands:

- International development of harmonised (net) zero GHG emissions building frameworks to achieve global GHG emissions reductions – current research within EBC IEA Annex 72
- Development of Concepts and Strategies for (net) zero GHG emission buildings and neighbourhood for use in the Norwegian ZEB pilot buildings and for use in different climatic contexts worldwide.
- Life cycle analysis (LCA) and embodied carbon of materials calculation methodology for assessing the performance for (net) zero GHG emission buildings. She was responsible for creating and for the early development of an excel based method, The ZEB Tool, which was used by the Norwegian ZEB centre to assess the ZEB pilot buildings.
- Visual and Dynamic embodied emissions modelling – integrated LCA/Revit/BIM
- Leading research into the use of visualisation and immersive environments for improved stakeholder engagement in zero emission buildings and neighbourhoods

3. Key Areas to be addressed

3.1 Need for a clear, harmonised UK definition framework for (net) zero GHG emission buildings (and neighbourhoods)

The concept of (net) zero greenhouse gas (GHG) emission(s) buildings is gaining wide international attention for achieving global climate neutrality targets in the built environment. Countries worldwide are accelerating mitigation efforts to meet these targets resulting in an increasing plethora of differing terms, definitions, and approaches emerging worldwide. The importance and need for fostering transparency are instrumental in delivering clarity, limiting misunderstanding, and avoiding potential greenwashing critical to achieving national and global GHG emissions reductions. To better understand the current progress and differing international approaches, an overview of the results of an IEA EBC Annex 72 review of 35 international net zero building assessment approaches. The results show current progress in achieving net zero targets and find that 13 voluntary frameworks from 11 countries are characterised by net zero-carbon/CHG emissions performance targets, which are then subject to more detailed analysis. The research concludes that although there is a risk such measures will enlarge the embodied carbon contribution, and variations in the existing net zero approaches will continue to exist, certain minimum requirements for operational energy use and embodied GHG emissions need to be considered for the future development of harmonised (net) zero GHG emissions building frameworks to achieve global GHG emissions reductions.

More information and key research findings can be found in the published paper available at: https://doi.org/10.1016/j.buildenv.2021.107619, and a paper by our co-authors *'(Net-) zero-emission buildings: a typology of terms and definitions'*, available at: https://journal-buildingscities.org/articles/10.5334/bc.66/. A presentation summarising the key findings are highlighted in *'Defining (net) zero greenhouse gas emissions buildings as a key mitigation pathway'* and a parallel paper *'New mitigation solutions in construction: use case for assessment methods', both on-demand presentations* at the forthcoming Climate Expo virtual conference

(https://www.climateexp0.org/) part of the All4Climate Pre-COP programme in the lead up to 2021 UN Climate Change Conference (COP26). A recent similar talk is available on Cambridge Architectural Research Available at: https://youtu.be/8ov2YoeLdHY

3.2 Need for consideration of embodied emissions of materials and the need for a robust, reliable, harmonised national standard – UK Embodied Carbon calculation methodology and national open source embodied carbon database (including EPDs)

As stated in Kjendseth Wiik et al. (2018) *'Life cycle assessment (LCA) is a well-established methodology used for the environmental assessment of buildings [1]. Due to the long lifespan of buildings, operational energy use has traditionally been identified as the main contributor to high GHG emissions in buildings [2]. However, because of increasingly stringent energy requirements and improved energy e□ciency, the significance of emissions from operational energy has decreased. In contrast, environmental impacts from the production, construction, maintenance, replacement and demolition phases are gaining significance. This trend is even more pronounced in zero emission buildings (ZEBs), whereby the embodied emissions associated with building materials contribute to a large proportion of total greenhouse gas (GHG) emissions of a building. Consequently, there is a growing interest in addressing embodied material emissions and choosing low-carbon products when designing ZEBs.'* The full paper is available at:

Marianne Kjendseth Wiik, Selamawit Mamo Fufa, Torhildur Kristjansdottir, Inger Andresen, *Lessons learnt from embodied GHG emission calculations in zero emission buildings (ZEBs) from the Norwegian ZEB research centre,* Energy and Buildings, Volume 165, 2018 https://doi.org/10.1016/j.enbuild.2018.01.025

More information and key research findings on the importance of considering embodied carbon can be found in EBC Annex 57, Subtask 4 in the published papers available at:

Birgisdottir, Harpa; moncaster, alice; Houlihan Wiberg, Aoife Anne Marie; Chae, Chang-U; Yokoyama, Keizo; Balouktsi, Maria; seo, Seongwon; oka, Tatsuo; Lutzkendorf, Thomas; Malmqvist, Tove. (2017*) IEA EBC Annex 57 'Evaluation of Embodied Energy and CO2eq for Building Construction'.* Energy and Buildings. vol. 154.

Moncaster, A. M., Rasmussen, F. N., Malmqvist, T., Houlihan Wiberg, A. A. M. & Birgisdottir, H. (2019) *Widening understanding of low embodied impact buildings: Results and recommendations from 80 multi-national quantitative and qualitative case studies.* In : Journal of Cleaner Production. 235, p. 378-393 16 p., volume 235.

Nygaard Rasmussen, Freja; Malmqvist, Tove; moncaster, alice; Houlihan Wiberg, Aoife Anne Marie; Birgirsdottir, Harpa. (2018) *Analysing methodological choices in calculations of embodied energy and GHG emissions from buildings.* Energy and Buildings. vol. 158.

3.3 Need for (net) Zero GHG Emission Pilot projects showcasing design drivers for reduced GHG emissions

Definitions and methodologies are not enough to deliver actual GHG emissions reductions from the built environment sector. The real reductions will come through the delivery and uptake of buildings and neighbourhoods that demonstrate pathways to reduced GHG emissions and showcase example of buildings as prosumers and positive energy blocks. It is recommended to draw upon existing research findings in the field, for example, from 88 international case studies showcasing key zero GHG emission design strategies from research in the IEA Annex 57 – Evaluation of Embodied Energy and CO2eq for building construction (http://www.annex57.org) including Harpa Birgisdottir (DK), Alice Moncaster (UK), Tove Malmqvist (SE), Freya Rasmussen (DK), Aoife Houlihan Wiberg (UK/Nor). Publications available: https://www.iea-ebc.org/projects/project?AnnexID=57. Draw upon existing research findings demonstrating (net) zero GHG Design Strategies from the nine Norwegian ZEB pilot buildings (http://zeb.no/index.php/en/pilot-projects) and ZEN pilot projects (https://fmezen.no/category/pilot-projects/). Key findings and results from the EBC IEA Annex 57 international case studies and nine Norwegian ZEB pilot buildings are available at showcase key design strategies and lessons learned:

Birgisdóttir, H., Houlihan-Wiberg, A., Malmqvist, T., Moncaster, A., Nygaard Rasmussen, F. ***Strategies*** Nehasilova, M., Potting, J., Soulti. E. *Evaluation of Embodied Energy and CO_{2eq} for Building Construction: Subtask 4 - Case Studies and Recommendations for the Reduction of Embodied Energy and Embodied Greenhouse Gas Emissions from Buildings.* International Energy Agency, IEA EBC Annex 57. Institute for Building Environment and Energy Conservation, Japan, 2016. ISBN: 978-4-909107-08-4

Malmqvist, Tove; nehasilova, maria; moncaster, alice; Birgisdottir, Harpa; Nygaard Rasmussen, Freja; Houlihan Wiberg, Aoife Anne Marie; Potting, Jose. (2018) *Design and construction strategies for reducing embodied impacts from buildings – Case study analysis.* Energy and Buildings. vol. 166.

Kristjansdottir, Torhildur Fjola; Houlihan Wiberg, Aoife Anne Marie; Andresen, Inger; Georges, Laurent; Heeren, Niko; Good, Clara; Brattebø, Helge. (2018) *Is a net life cycle balance for energy and materials achievable for a zero emission single-family building in Norway?.* Energy and Buildings. vol. 168.

3.4 Need for integrating LCA early and throughout the design process – Need for a Dynamic and visual LCA approach to visually communicate key impacts from design

How do we make it easier for designers to assess the environmental impact of their material and design choices early and throughout the design process? We need to bridge the gap between research and design and find ways to visually communicate and make it easier for designers and decision makers to get feedback on environmental impact from different material and design choices early and throughout the design process. There is a need for a more visual and integrated approach. More information available at:

Alexander Hollberg, Benedekt Kiss, Martin Röck, Bernardette Soust-Verdaguerd, Aoife Houlihan Wiberg, Sebastien Lasvaux, Alina Galimshina, Guillaume Habert. (2021) *Review of visualising LCA results in the design process of buildings.* Building and Environment 190, 107530 Available at https://doi.org/10.1016/j.buildenv.2020.

Houlihan Wiberg, A. A. M., Wiik, M. R. K., Løkland Slåke, M., Manni, M., Ceci, G., Hofmeister, T. B., Auklend, H. & Tuncer, Z. M. (2019). *Life cycle assessment for Zero Emission Buildings – A chronology of the development of a visual, dynamic and integrated approach.*, In : IOP Conference Series: Earth and Environmental Science (EES). 352, 1, 12 p. Available at: 10.1088/1755-1315/352/1/012054

3.5 Need for visualisation and immersive technologies for improving stakeholder engagement in (net) zero GHG emission-built environment

A key area to be addressed to improve stakeholder engagement using immersive technologies and advanced visualisation of neighbourhood carbon metrics, for example, using virtual reality. address the specific challenge of increasing complexity and decreasing usability when dealing with the level of detail required to model a ZEB building. Moreover, in ZEN we will also need to handle both ‘top down’ big city level data with ‘bottom up’ building and material level data. This can quickly become overwhelming particularly when dealing with non-expert users, such as planners and architects who play a key part in the design process of future ZEN’s. Visualisation is an invaluable tool to communicate complex data in an interactive way that makes it easier for all stakeholders to understand. This research project seeks to address the key issues related to the visualisation of data from key performance indicators at different scales for both new and existing buildings in zero emission neighbourhoods. Priority should be given to build upon the robust and reliable data and methods already developed and to integrate new knowledge for the future development of citizen centred interactive dashboards and toolboxes to visualise, analyse and model the data at different scales for different sustainable key performance indicators. More information is available at:

Houlihan Wiberg A., Sondre Løvhaug, Mikael Mathisen, Benedikt Tschoerner, Eirik Resch, Marius Erdt, Ekaterina Prasolova-Førland (2021) *Advanced Visualization of Neighborhood Carbon Metrics Using Virtual Reality: Improving Stakeholder Engagement*. In: Augusto J.C. (eds) Handbook of Smart Cities. Springer, Cham. https://doi.org/10.1007/978-3-030-15145-4_64-1

Recommendations for action by the Government for the committee to consider

- **Develop a net zero (GHG) emission definition framework** with increasing ambition levels to allow for flexibility for different design scenarios for retrofit and new build and at building and neighbourhood scale. Such a framework could be further developed for use in different climate contexts and considering future climate scenarios.
- **Develop a UK national Standard for the calculation of embodied emission for materials** Prioritise a national transparent, robust and reliable calculation methodology for embodied emissions from materials including the development of a national open database for both generic and specific data (including EPDs).
- **Prioritise the coordination and alignment** of the plethora of different excellent initiatives in the UK to align to one UK common goal for (net) zero GHG emissions including the use of a harmonised embodied carbon calculation methodology and the use of a UK open source database
- **Establish a UK centre of excellence for (net) zero GHG emission-built environment** drawing upon, and aligning, the existing expertise in the field. The centre could have a physical setting, as well as, a virtual platform to function as a net zero data repository and to facilitate national and international collaboration, conferences, training workshops and education. The UK Net Zero GHG Emission Research Centre could itself to act as a lighthouse project to showcase and demonstrate strategies to reduce GHG emissions and to facilitate outreach to local citizens of all ages.
- **Need for the development of national (and interconnected international) knowledge hubs** for knowledge building and which would act as springboards into immediate local areas for the design of affordable, low tech concepts in national and international locations experiencing extreme local climate effects and climate change destruction.
- **Need for clear communication and accessibility to wider audience** and to engage diverse stakeholders at different stages of the design process i.e. infographics and design guidance, integrated dynamic LCA and energy; use of user interface and mixed reality such as AR, VR, collaborative cave etc
- **Prioritise national and international knowledge sharing and collaboration opportunities** between countries and research leaders worldwide leading the way in net zero pathways.