Project Call for 2021 ERBE Cohort

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Institution	University College Cork
Co-Supervisor & Institution (if known – please note this is not a requirement at application stage):	**Dr Michael O'Shea**, School of Engineering & Architecture, MaREI Centre, University College Cork A further supervisor from a UK ERBE partner will be identified if successful.
PhD Proposal Title:	**Sustainable & Healthy Buildings: Optimising Indoor Environmental Quality and Building Energy Efficiency in a post COVID-19 era through Indoor Sensing and Digital Twin Capabilities**
Alignment with ERBE Themes: (200 words max – please specify if the project aligns with 1 or more of the ERBE Themes)	This project aligns with ERBE Theme 3 which is **'Comfort, Health and Well-Being'**. This project will examine sustainable and healthy buildings from an energy consumption, indoor environmental quality and occupant health and well-being perspective. The COVID-19 pandemic has led to an increased awareness of the importance of indoor environmental quality, resulting in the need for improved ventilation, air purification and building occupancy management. Such improvements could potentially result in increased energy consumption in both public and residential buildings. This research aims to quantify this potential energy increase, implement novel air quality improvement strategies through a digital twin platform while also examining energy efficiency of such strategies. The research will focus on developing solutions to mitigate the impact of airborne viruses such as influenza and COVID-19 in public buildings. The emergence of building based digital twins, which are virtual real time simulations of a building linked through live sensor data, provides an opportunity to investigate a range of strategies to improve building occupants' health and wellbeing. This research aligns with the Energy Performance of Buildings Directive (1), World Health Organisation guidelines in relation to indoor environmental health (2,3) and the United Nations 2030 Sustainable Development Goals.

PhD Proposal Abstract: (500 words max)	Limiting global warming to 1.5°C will require major energy use and greenhouse gas emissions reductions in the energy, buildings, industry, agricultural and transport sectors (4). Buildings represent a substantive proportion of energy demand, for example 40% in the EU (5) and 35% in Ireland (6) to provide Heating, Ventilation and Air Conditioning (HVAC), lighting and power. HVAC systems account for a substantial proportion of building energy consumption. As humans spend 90% of their time indoors, building environments are an extremely important contributor to health (7). Building ventilation, thermal comfort, air quality, safety, water quality, noise quality and lighting impact on occupant health (7,8). The COVID-19 pandemic has given renewed impetus to the development of healthy buildings, not least due to potential airborne SARS-CoV-2 transmission in indoor settings (9-13). Notwithstanding recent progress, a greater understanding of the interlinkages between indoor environmental metrics, occupancy, physical distancing and energy use are urgently required (14-16). Our overarching objective is to **inform evidence-based strategies for optimising building energy efficiency and indoor environmental quality for improving human health and well-being**. Following a synthesis of the global scientific literature, specific objectives will include: **Objective 1. Quantifying Energy Consumption & Indoor Environmental Quality** Energy and HVAC usage profiles in relation to indoor environmental conditions will be examined. Firstly, an indoor environmental sensing platform will be developed and deployed to monitor air quality, relative humidity, temperature, room occupancy, noise, lighting and other metrics (17). Air quality parameters will include $PM_{2.5}$ (particles less than 2.5 microns in diameter), nitrogen dioxide and carbon monoxide. Additionally, data on energy and HVAC usage and the outdoor environment will be collected. **Objective 2. Quantifying Human Exposures & Health** A smartphone application will be developed to monitor occupancy and individual human mobility patterns in high spatiotemporal resolution. Subsequently, optimal occupant distribution patterns for physical distancing and minimum energy consumption will be examined. Using methods outlined in Nyhan et al. (18-22), individual pollution exposures and self-reported health will be determined. A human respiratory tract model will predict

	individual inhaled lung doses of air pollution. Model inputs including gender, lung capacity and respiratory rates will be measured or inferred in participants. **Objective 3. Real-time Building Health Risk Management - Digital Twin** In progressing from Building Information Modelling (BIM), Digital Twins (DTs) encompassing 'physical' components, 'virtual' models and real-world data (23), will be examined for real-time building health and energy management. The 'physical' will acquire real-time data from the sensors, BMS and smartphone application, and in return, the 'virtual' will apply algorithms, statistical analyses and AI models (e.g., support vector machines) to generate building management recommendations. We will understand associations between energy use and environmental health while also optimising energy and HVAC use, occupancy, environmental quality, exposures and health. The project will utilise BIM (NavisWorks, Revit) and visual programming (Dynamo, Firefly) tools that have been successfully applied to occupant comfort, structural health monitoring and managing COVID-19 in buildings (24-26). In going beyond the state-of-the-art, the findings will have major implications for building energy management and environmental health policy.

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PhD Proposal Summary for inclusion in Student Call Document: (300 words max – please note the student will be indicating their order of preference for all submitted proposals; please ensure this summary includes a project overview & introduction to the supervisor & institution)	**Project Overview** In the post COVID-19 era, building occupant health and indoor environmental quality will be at the forefront of managing both existing and future public buildings. Achieving compliance with existing and imminent building well-being standards (27,28) will be a complex task for facility managers. There is also a potentially large energy cost for this improvement making 'Nearly Zero Energy Buildings' (28) even more difficult to achieve. This project will utilise the visualisation power of the emerging Digital Twin concept to provide solutions to the healthy building question while also optimising energy consumption. By creating real-time intuitive virtual models based on real-time building sensor data, the public health risk associated with disease transmission can be mitigated while optimising energy expenditure. The successful student will develop healthy building management solutions that will inform the design of sustainable buildings in the future. **Project Supervisors & Institution** **Dr Marguerite Nyhan** is a Senior Lecturer in Environmental Engineering in the School of Engineering & Architecture at University College Cork (UCC) and a Visiting Scientist at Harvard University's School of Public Health in the United States. At UCC, she is also a Principal Investigator at the Environmental Research Institute and a Funded Investigator at the MaREI Centre for Climate, Energy & Marine. She has held positions at Massachusetts Institute of Technology, Harvard University and the United Nations. Dr Nyhan's research includes developing data-driven solutions for carbon-neutral, sustainable, healthy and liveable urban environments. She has published widely on human exposure modelling and environmental epidemiology especially on the impacts of air pollution on human health. **Dr Michael O'Shea** is a Lecturer in Structural Engineering in the School of Engineering & Architecture, a chartered engineer and member of NSAI Technical Committee on building information modelling. His research interests include BIM sensor adaption for improved structural health and asset management.

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