Project Call for 2022 ERBE Cohort

MaREI Supervisor	Dr. Ken Bruton
Institution	University College Cork
Co-Supervisor & Institution (if known – please note this is not a requirement at application stage):	TBC
PhD Proposal Title:	Utilising Data Driven Digital Twins to monitor and maintain Indoor Air Quality (IAQ) in a sustainable way in high occupancy buildings
Alignment with ERBE Themes: (200 words max – please specify if the project aligns with 1 or more of the ERBE Themes)	This project cuts across all three ERBE themes. Theme 1: Flexibility and resilience: This project will seek to ensure that the built environment is resilient to future needs whether they be driven by public health or cognitive performance standpoints. It will do this by ensuring ventilation is put to the forefront of indoor wellness discussions and that data is utilised to monitor and improve IAQ. Theme 2: Technology and system performance: Data driven digital twins will be utilised to drive building related mechanical system sustainable performance. Theme 3: Comfort, health and well-being: Indoor air quality (IAQ) will be monitored via IOT and analysed via advanced data analytics to offer decision support systems (DSS) to end users as well as control feedback to mechanical ventilation systems. Best in class comfortable, safe and energy efficient indoor environments will be delivered in a cross sectoral manner.

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PhD Proposal Abstract: (500 words max)	The COVID-19 pandemic has exposed areas requiring urgent development to provide healthy indoor environments [1]. The significance of the airborne transmission of SARS-CoV-2 through the exhalation of small micro-droplets has been the object of extensive discussion within the International scientific community[2]. Given that most of the documented spread of the disease has happened in indoor environments [3], control of indoor air is essential to reduce the risk of airborne pathogens [4]. Schools and educational buildings have been at the forefront of this discussion internationally as governments have strived to maintain in person education whilst mitigating the risk of viral spread. It is evident that time spent in classrooms represents a problem in this regard. Overcrowded classrooms and scarce ventilation increase the risk of exposure to pathogens. In addition studies have recently highlighted that poor air quality can negatively affect the learning performances of the students [5]. Engineering controls through heating, ventilation, and air-conditioning (HVAC) systems are considered a higher level of precaution than physical containment methods for creating healthy indoor environments [6]–[8]. Ventilation is the primary control measure for indoor transmission of airborne particles [1]. Existing ventilation systems in buildings are designed to remove heat and pollution loads in normal conditions. However, ventilation systems should also be able to eradicate the transmission of airborne particles during serious outbreaks[9]. In addition, an inadequate ventilation rate and inappropriate ventilation strategy are associated with inferior health outcomes for the occupants. Energy consumption linked with control of the indoor environment is a critical concern, given that buildings consume over 36% of energy globally. New ventilation criteria, proposed by industry professionals, have mainly focused on indoor air quality improvements to guarantee occupants' health. However, the associated energy consumption was an afterthought; this has resulted in high energy consumption as a result of increased volumes of fresh air being treated and delivered during

	the pandemic. Thus, the challenge that this project will seek to address how to balance ventilation system energy consumption with the prevention of infection risk in the indoor environment. It will seek to recommend strategies that help to deliver a healthy yet sustainable indoor environment [10]. CO2 sensors have been utilised as a proxy to viral load monitoring and have shown promise [11]. These along with other Internet of things (IOT) devices could potentially be utilised to develop digital twins of the indoor environment and its associated IAQ and offer decision support in terms of potential mitigation steps to improve it should it lapse. They could potentially offer feedback to control ventilation systems to automate this process and in doing so further ensure health, safety, comfort and energy efficiency is delivered consistently and in a controlled manner. As Europe embarks on its twin transition towards climate neutrality and digital leadership [12], the uptake of digital solutions and the use of data will help in the transition to a climate neutral, circular and more resilient economy [13]

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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)	This project will seek to address how to balance ventilation system energy consumption with the prevention of infection risk in the indoor environment. It will seek to recommend strategies that help to deliver a healthy yet sustainable indoor environment [10]. CO2 sensors have been utilised as a proxy to viral load monitoring and have shown promise [11]. These along with other Internet of things (IOT) devices could potentially be utilised to develop data driven digital twins of the indoor environment and its associated IAQ and offer decision support in terms of potential mitigation steps to improve it should it lapse. They could potentially offer feedback to control ventilation systems to automate this process and in doing so further ensure health, safety, comfort and energy efficiency is delivered consistently and in a controlled manner This project will be supervised by Dr. Ken Bruton and Dr. Dominic O' Sullivan of the Intelligent Efficiency Research Group (https://www.ucc.ie/en/ierg/description/) in UCC. UK co-supervisors will be appointed on success. The project will be undertaken in collaboration with local industrial partner companies in the Ringaskiddy area, primary and secondary schools in the Cork area and within University settings both in Ireland, the UK and the USA. Links within ASHRAE, CIBSE and REHVA will be fostered to build on best in class IAQ standards with a view to informing future policy both in Ireland and internationally.

References

[1] H. C. Burridge *et al.*, "royalsocietypublishing.org/journal/rspa Evidence synthesis The ventilation of buildings and other mitigating measures for COVID-19: a focus on wintertime."

[2] A. Di Gilio *et al.*, "CO2 concentration monitoring inside educational buildings as a strategic tool to reduce the risk of Sars-CoV-2 airborne transmission," *Environ. Res.*, vol. 202, p. 111560, Nov. 2021.

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[4] T. Lipinski, D. Ahmad, N. Serey, and H. Jouhara, "Review of ventilation strategies to reduce the risk of disease transmission in high occupancy buildings," *Int. J. Thermofluids*, vol. 7–8, p. 100045, Nov. 2020.

[5] L. Schibuola, M. Scarpa, and C. Tambani, "Natural Ventilation Level Assessment in a School Building by CO2 Concentration Measures," *Energy Procedia*, vol. 101, no. September, pp. 257–264, 2016.

[6] M. J. Risbeck, M. Z. Bazant, Z. Jiang, Y. M. Lee, K. H. Drees, and J. D. Douglas, "Quantifying the tradeoff between energy consumption and the risk of airborne disease transmission for building HVAC systems," *Sci. Technol. Built Environ.*, 2021.

[7] Y. F. Ren *et al.*, "Effects of mechanical ventilation and portable air cleaner on aerosol removal from dental treatment rooms," *J. Dent.*, vol. 105, p. 103576, Feb. 2021.

[8] M. D. Nembhard, J. Burton, and J. M. Cohen, "Ventilation use in nonmedical settings during COVID-19: Cleaning protocol, maintenance, and recommendations."

[9] W. Zheng *et al.*, "COVID-19 Impact on Operation and Energy Consumption of Heating, Ventilation and Air-Conditioning (HVAC) Systems," *Adv. Appl. Energy*, vol. 3, p. 100040, Aug. 2021.

[10] J. Ding, C. W. Yu, and S.-J. Cao, "I Indoor and and Built uilt Environment HVAC systems for environmental control to minimize the COVID-19 infection."

[11] A. Zivelonghi and M. Lai, "Mitigating aerosol infection risk in school buildings: the role of natural ventilation, volume, occupancy and CO2 monitoring," *Build. Environ.*, vol. 204, no. May, p. 108139, 2021.

[12] E. Commission, "A New Industrial Strategy for Europe," *COM(2020) 102 Final*, pp. 1–16, 2020.

[13] E. Commission, "2030 Digital Compass: the European way for the Digital Decade," *COM(2020) 102 Final*, 2020.