Project Call for 2021 ERBE Cohort

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PhD Proposal Title:	**I**ntelligent Energy Efficient Solar Assisted HVAC system **Clean**ing **Air** for Health and Indoor Comfort **(iCleanAir)**
Alignment with ERBE Themes:	**Health and Well-being** from developing systems to quantify, deactivate, and eliminate air-borne viruses, bacteria and mould spores from circulated air in buildings. **Holistic approach** via integration with built environment with alignments included in ERBE theme 1 and 2: **Comfort** by significantly reducing indoor air pollution by controlling air quality parameters such as particle sizes, CO_2 & TVOC concentrations, relative humidity and air temperature to ensure health and improve comfort of building occupants. **Smart heating & Fuel poverty** addressed by delivering a smart low-cost net-zero solar façade system for healthy heating of fresh and recycled air for energy efficient buildings

PhD Proposal Abstract:

Motivation

Building heating and cooling represents 27% and 1% of EU energy consumption respectively. Across the EU a "renovation wave" has been initiated for existing building regulations to use less energy via increased thermal insulation and airtightness and the use of renewable energy. However, the COVID-19 pandemic revealed that buildings are not specifically designed to inhibit the transmission of very rapidly transmitting micro-organisms. Infection rates of viruses depend on transport dynamics, resistance of viruses to environmental conditions, virulence, persistence of pathogens within hosts, intra-host dynamics, evolution and spread of resistance. Viruses can be air-borne or transmitted by contact. Aerosolised viruses such as SARS-CoV-2 (causing COVID-19) travel significant distances via coughing or sneezing, so increasing ventilation removes more particles. Increased airtightness and recirculation of air to conserve energy therefore potentially promotes the growth and transmission of viruses as well as other aerosolised bacteria, fungi and spores; leading to increased risks of exposure from virus redistribution and accumulated concentrations above a critical viral load.

The Unmet Need is to develop **a low-cost, low-energy and long-life system** that:
(1) detects the type of aerosolised organisms travelling within circulated air to optimise ventilated air temperature and RH, and
(2) prevents and/or eliminates (re)-circulation of viruses and other organisms in occupants' environment while improving overall energy-efficiency for heating or cooling.

This project will design, simulate, prototype and characterise a solar façade system that;

i. provides integrated aerosolised micro-organism detection and elimination
ii. assists Heating, Ventilation and Air Conditioning (HVAC) systems reaching optimum air temperature and RH
iii. increases energy efficiency of the HVAC system, and
iv. provides clean air and comfort to meet occupants' requirements of health, comfort and cost via a controlled intelligent air heating ventilation.

Project Scope:
In this project, a prototype will be built to, in priority, detect and eliminate the SARS-CoV-2 virus causing COVID-19 but the system will be made readily extensible to detect other microorganisms using multiplexed sensors.

Viruses and most micro-organisms can be killed before entering a host via:

- **Heat**: Viruses typically die at temperatures >60ºC.
- **Radiation**: Ultraviolet (UV) light, in particular UV-B and UV-C radiations, are known to permanently damage the DNA and RNA of viruses rendering them inactive.
- **Oligodynamic** effect: Metal ions have toxic/antibacterial properties on living cells including spores, fungi and viruses. Other compounds applied with coating technologies, such as TiO_2 and pyrion compounds with polyethyleneimines have antimicrobial properties and biocidal activities eliminating a wide range of viruses (including SARS).

Methodology
To achieve these deadly conditions for micro-organisms and contribute to improving the quality of circulated air, various already enabled façade technologies that will be combined include:

- **Thin flat solid-state solar concentrators:** Dielectric compound parabolic concentrators to reach high temperatures under both sunny and cloudy conditions.
- **Luminescent species**: Solar light absorbed by species can re-emit in the UV-B and/or UV-C.
- **UV-C lamps/LEDs**: The designed solar system can be optically coupled to market-available UV-C lamps/LEDs to provide continuous operation.
- **Active coatings**: Oligodynamic coatings can be cheaply deposited.
- **Filters**: Fine filters catch large particles, HEPA filters trap particles typically down to 3 µm and electrostatic (ES) devices can charge and catch particles. Active carbon filters neutralise odours.
- **Dehumidifier**: Controlling the RH concentration in the air flow will enable to optimise the deactivation of virus while maintaining indoor comfort under various outdoor conditions.
- **Capture & Analyse**: Detection of viruses, bacteria, fungi and spores will be achieved using an **ionizer** to trap air-borne micro-organisms and implementing a particle size-based separation. Microorganisms can be collected into a test tube for rapid onsite or integrated online quantification using **a novel single-step fluorescence-based technique** based on molecular beacons for specific recognition and transduction.

A scale prototype will be built, and its efficiency tested without and with use of inactived (unharmful) viruses to characterise the operating conditions achieved in laboratory and outdoor conditions.

PhD Proposal Summary and PhD Candidate Profile:

The COVID-19 pandemic revealed that we are insufficiently prepared to fight very rapidly transmitting viruses. Aerosolised viruses such as SARS-CoV-2 can travel significant distances, first via coughing or sneezing and even further through building ventilation. In closed environments this leads to increased risks of exposure, redistribution of the micro-organisms and concentrations above a critical viral load. Current measures to mitigate risks are not enough. Pathogen transmission risk is the highest in enclosed built environments. A continuous decontamination and conditioning of the air must be achieved that is even more critical for permanently occupied buildings.
This project will prototype a solar façade system that detects and eliminate aerosolised micro-organisms, assists HVAC systems in providing a clean air, increase their energy-efficiency operation, thereby providing occupants with healthy and comfortable ambient air, and overall increase the renewable energy fraction available to a building while reducing the overall energy consumption and associated greenhouse gas emission.

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The desired candidate will have at least a 2.1 degree in Physics, Energy, Applied Sciences in HVAC, Design Engineering, Building Engineering and related topics. The candidate will have a general understanding of the built environment with skills and knowledge related to HVAC systems. Programming (e.g. Python, Matlab), model and simulation skills such as computational fluid dynamics and solar energy model exploiting dedicated or holistic software (e.g. COMSOL) are preferred. Experience in the development, testing and validation of diagnostic sensors or prototypes will be an added advantage. The candidate will be fluent in English, have a positive problem-solving attitude, demonstrate scientific rigor, excellent communication (oral and written) skills, creativity, ambition with multi-disciplinary interests and a goal oriented mind.