Novel building Integration Designs for increased Efficiencies in Advanced climatically tunable renewable energy Systems

Background

Buildings play a significant role in the global energy balance. Typically, they account for 20–30 per cent of the total primary energy requirement of industrialised countries—40 per cent in the EU. Global buildings sector energy intensity fell by 1.3 per cent per year between 2010 and 2014, thanks to continued adoption and enforcement of building energy codes and efficiency standards. Yet progress has not been fast enough to offset growth in floor area (3 per cent per year globally) and increasing energy demand. Applying the proposed integrated renewable energy system (RES) to buildings is an important application for wider integration and deployment of renewable energy and to achieving our binding EU targets of a minimum 40 per cent reduction in greenhouse gas emissions (GHG) by 2030.

Renewable energy systems often require more space than is practicable in the urban setting. Apartment blocks and offices have restricted roof space and surrounding building footprints, which mean that traditional solar and geothermal technologies space requirements are insufficient to meet the needs of the buildings' energy needs. IDEAS brings together a number of efficiency and scale improvements to solar photovoltaics (PV), thermal and geothermal RES that will enable more energy efficiencies to be achieved using a smaller area. This will mean that buildings in urban settings will be able to have more of their energy needs met by sustainable sources.

Aim

IDEAS: Novel building Integration Designs for increased Efficiencies in Advanced climatically tunable renewable energy Systems will provide 100% renewable energy, reduce CO_2 emission by 100% with any surplus kWh generated to be used within IDEAS system operation.

The IDEAS project will combine several renewable energy technologies including solar photovoltaic, solar thermal, thermal energy storage and geothermal and air source heat pump (HP) technology coupled with underfloor heating to create an innovative building-integrated RES. This will cost-effectively exceed current RES efficiencies, generating electricity, heat and cooling, and optimised for multifamily, public, and commercial buildings in different climatic conditions.

The research aim is to create a novel low-cost building with an integrated RES, maximising the output which will be tuneable for different climatic conditions. This will be achieved through novel luminescent and geometric concentrator techniques, leading to current solar system efficiencies being exceeded electrically. Thermal enhancement will be achieved using enhanced organic phase change materials (PCM) with a passive biomimetic heat transfer mechanism to be used for heat storage and discharge. An electrically driven multi-source HP system will then use the main energy sources at building

scale (waste heat from the system, air and ground), to provide the input to an integrated underfloor heating and hot water system. It will also manage the thermal energy storage. This building-integrated RES will use advanced control techniques to maximise performance together with electrical and thermal/ cooling self-sufficiency in the building. The technology will be optimised and demonstrated for use in multifamily residential buildings, commercial and public buildings.

With enhanced solar capture, the temperature of PV cells increases, having a detrimental effect on solar cell efficiency. This will be resolved through the use of PCM which regulates PV cell temperature, maintaining the high efficiency of the cells. The PCM heat sink will be designed biomimetically for enhanced heat management. This novel system will be upscaled and coupled to a heat pump for underfloor heating and hot water demand in the building. The project will deliver breakthroughs not only in solar PV efficiencies and thermal storage but also produce a unique building-integrated solution which can be tailored to different building functions and climatic regions.

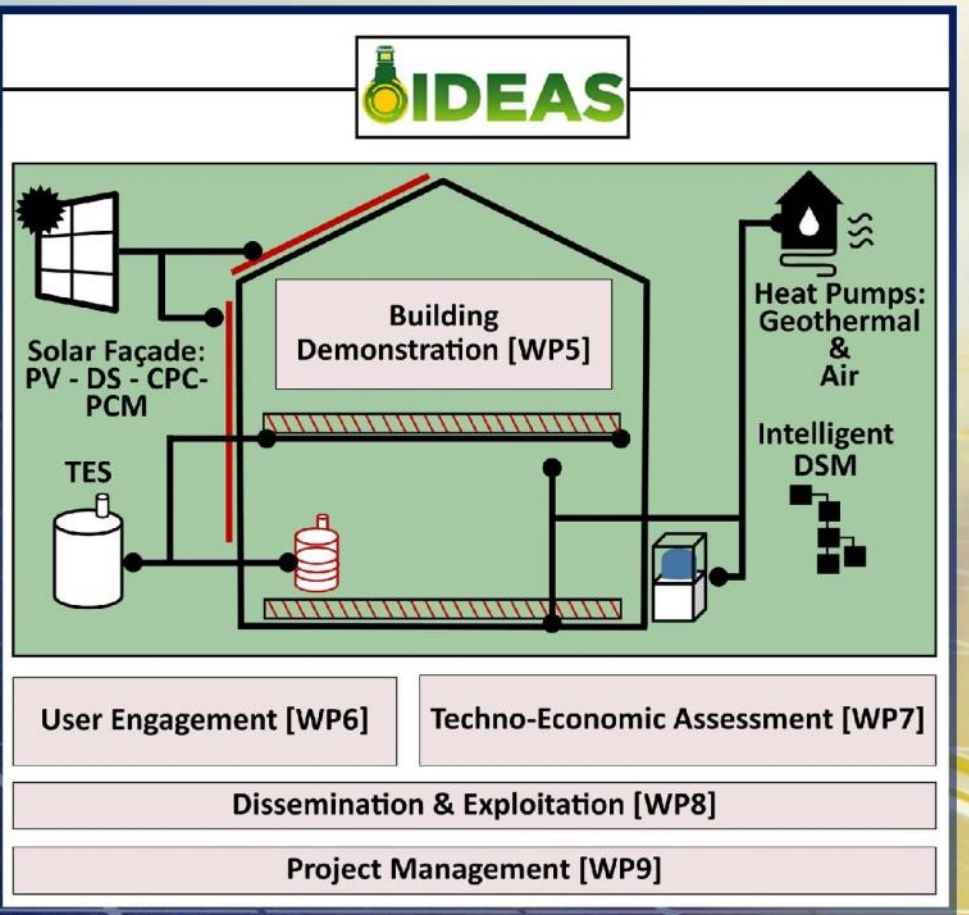

Figure 1: A conceptual view of what the IDEAS project will achieve.

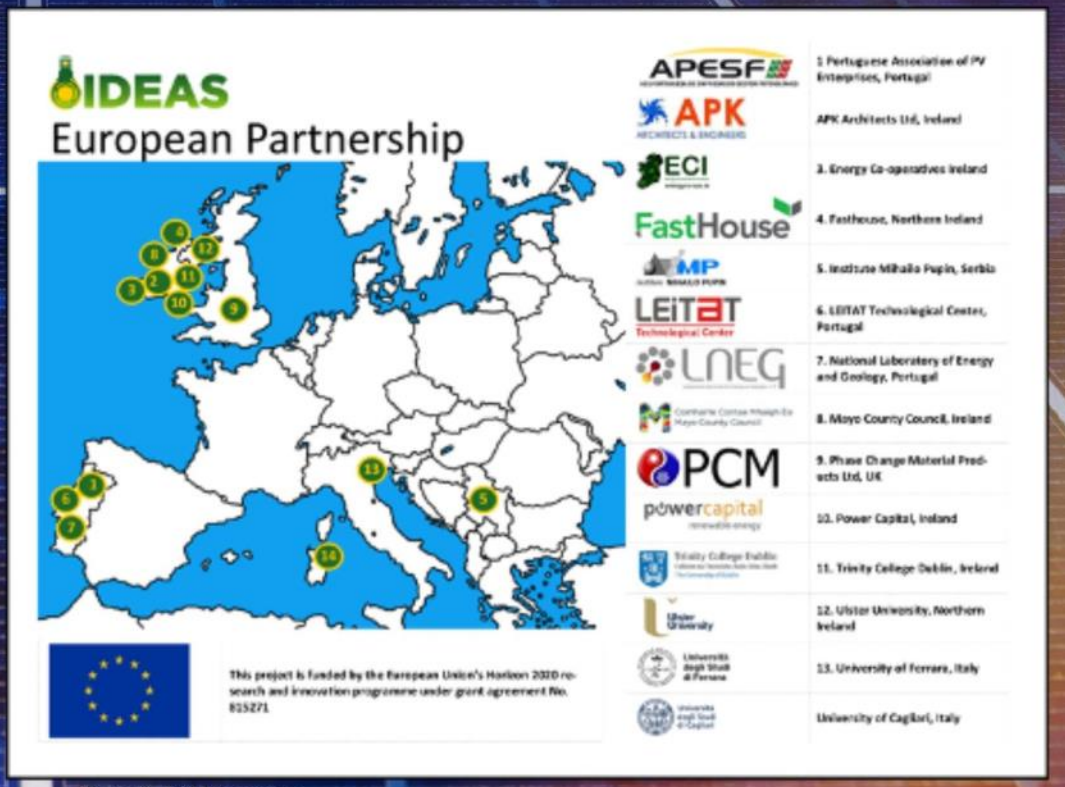

Figure 2: IDEAS partners.

IDEAS partners

The IDEAS project is led by the Department of Civil, Structural and Environmental Engineering in Trinity College Dublin. The other IDEAS partners consist of universities, public and private organisations with demonstration sites to be located in north and south Europe (specifically Ireland and Italy as shown in Figure 2).

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Objectives

The IDEAS project goals will be achieved by integrating the physical, technical and socio-economic aspects of RESs as well as engaging with user groups and installers to design the novel system optimally. This will be achieved through a multidisciplinary consortium composed of leaders in the fields of solar energy, thermal energy storage, heat pumps, intelligent demand-side management and user engagement. The industry, county councils and energy coops involved will ensure early adoption of the developed technologies, as will engagement with stakeholder groups such as building dwellers, building users, installers, building services engineers, local authorities and architects who have expressed their support for the proposal.

Work packages

This ambitious project will be delivered using the interactive project structure (Figure 3) with a focus on technology development, demonstration, and user engagement.

Efficiency concept and ambition

IDEAS is based on an advanced concept where the highest possible share of renewable energy will be achieved, developing a truly innovative building-integrated RES beyond current state of the art. Our PV/T system (WP1 and 2) will lead to increases in system efficiency from a combined overall efficiency of 47 per cent to 72 per cent and combing the whole IDEAS system, the heat demand of the building can be covered—up to 100 per cent. With enhanced solar capture, the temperature of the PV cells increases, which has a detrimental effect on solar cell efficiency. This will be resolved using thermal regulation which will absorb the excess heat, regulating PV cell temperature and therefore maintaining the high efficiency of the cells. A heat sink incorporating PCM will be designed and modelled for enhanced heat management. A low-temperature HP will be used to maintain the PV to achieve the maximum temperature drop and to provide heat to store in the underfloor heating system for space heating. This novel system will

IDEAS Research Objectives 2019–2022	
1	To design novel luminescence downshifting (LDS) layers using high quantum efficiency (QE) over 60 per cent, luminescent dyes and quantum dots (QDs) to increase the capture of direct and diffuse solar radiation enhancing PV efficiency by over 20 per cent.
2	To design a building-integrated compound parabolic concentrator (CPC) for different climatic locations and difference acceptance angles achieving a concentration ratio of three and with LDS whereby the solar technology will provide 40 per cent of the electricity for the building.
3	To design and optimise a biomimetically modelled heat sink utilising PCM as thermal energy storage (TES), to capture the waste heat in the system to maintain higher system efficiencies and to investigate biomimetic methods of heat distribution for heat removal to achieve a 40 per cent reduction in temperature at the PV.
4	To integrate a HP with the novel PCM system to supply the underfloor heating systems and to extend HP functionality adopting a multi-source approach that integrates air and ground as secondary source/sink with TES to achieve 100 per cent efficiency in total energy utilisation for both heating and cooling in the building.
5	To design an advanced demand-side management (DSM) control system with an artificial intelligence (AI) for IDEAS system with maximised performance increased building energy self-sufficiency to communicate directly with the building and provide 100 per cent renewable energy for buildings in different climatic regions.
6	To develop a planning tool which will offer optimal sizing of the system and assess its environmental and economic impact for application in different building types (multifamily, public and commercial) in different climatic regions.
7	To engage with building owners and occupiers to get their input into the designs and modelling tools developed. To produce a guide for installers explaining the different system modes of operation. Two toolkits will be produced: one for installers, building designers and contractors, and another for homeowners, communities and building users.
8	Fabrication of the innovative building-integrated component and installation in a demonstrator building in Mayo, Ireland.

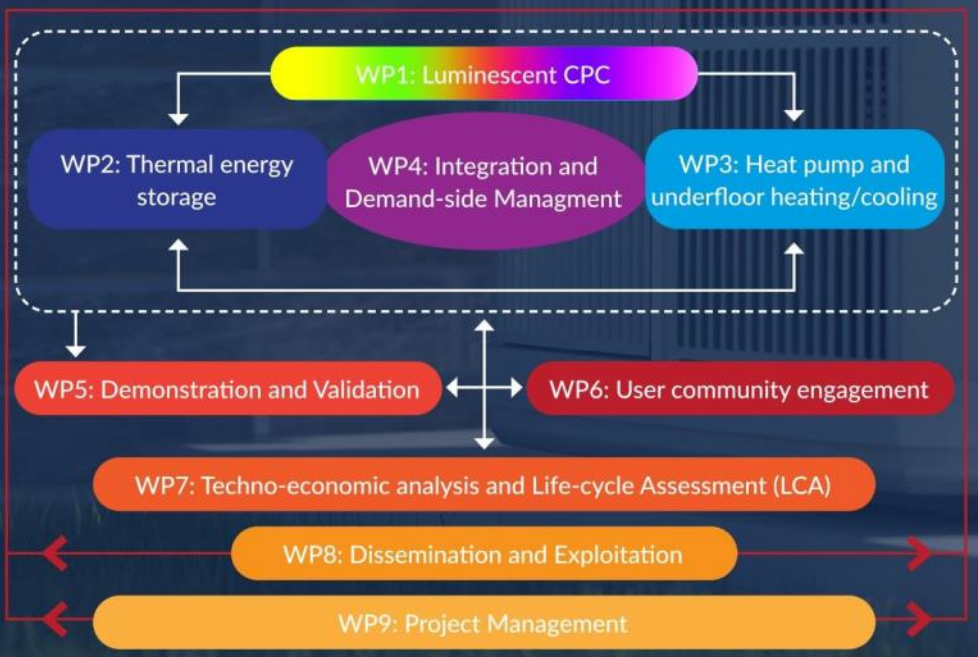

Figure 3: IDEAS project structure.

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be designed, upscaled, and a building-integrated component fabricated, with the ability not only to generate power but also provide hot water and space heating in a building. The project will deliver not only breakthroughs in solar PV efficiencies and thermal storage but also produce a unique building-integrated RES tuneable for different climatic conditions, supplying electricity and heating and cooling for buildings.

IDEAS is an ambitious yet realistic project, with clear and specific goals in scientific, engineering, and societal engagement aspects. The solutions suggested by this project will mean not only a radical improvement of RES performance, but also an ambitious body of research at the basic level with a view to industrial applications. The IDEAS concept is to develop a versatile component; a method of integrated RES improvement, lowering of thermalisation and easy implementation with affordable cost for customers at industrial level.

Progress and next steps

The project has made considerable progress in its first year's work, including:

- LDS layer optimisation, fabrication and characterisation, and optimised CPC design for different climatic regions
- integration and characterisation of the LDS with the CPC
- prototyping the CPC and testing the most efficient dyes for the light downshifting layers
- investigation of enhanced heat transfer methods for heat dissipation in PV and other energy conservation in buildings
- progressing the phase change material backings to the PV/thermal hybrid panels
- methodology design for the matching between technologies and applications (PV/T, underfloor/wall, GHE)
- design and installation of the thermal floor loop and the flat-panel geothermal and air-to-water heat pumps in Ferrara and the design of the smart climactic control system
- development of the TRNSYS model to simulate the IDEAS project system
- design of cubicle of system control unit, multi-criteria RES storage planning tool, and smart mobile app/device development for integration and DSM
- user community engagement with desktop analysis and interviews in Italy and Ireland
- dissemination via conference and presentation of peer-reviewed journal papers
- discussion of the design of the API and dashboard for a smart mobile app and development of prototype of intellicIDEA and android studio
- a public webinar on the IDEAS project to take place in the coming months
- techno-economic analysis with cost evaluation of system and behavioural modelling.

The installation of the full prototype system in Ferrara, Italy is underway in July 2020 with a large-scale demonstration of the system to be installed in Mayo, Ireland in 2021. However, due to COVID-19, there may be a slight delay in the installation at both demonstration sites.

Participatory technology development (PTD) is critical to exploring potential users and experts' perceptions, so community workshops and focus groups are planned in Ireland and Italy once international non-essential travel restrictions are lifted. The next IDEAS meeting is in Lisbon, Portugal in late October 2020, with EU partner cooperation currently via TEAMS.

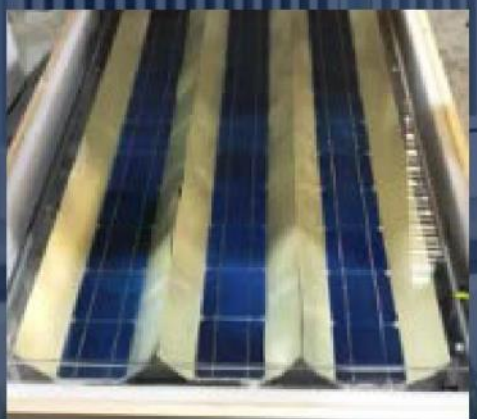

Figure 4: (Left) Prototypes leaving TCD Lab, Dublin. (Right) Illustration of demo. installation in Ferrara, Italy.

IDEAS

PROJECT SUMMARY

The IDEAS project is an innovative building-integrated renewable energy system utilising solar energy, thermal storage and heat pump technologies to generate electricity, heating and cooling. This hybrid energy efficiency application will benefit multi-purpose public and commercial buildings across a range of urban and rural climatic conditions. This will enable families, communities and businesses to contribute to creating a low carbon sustainable future.

PROJECT LEAD PROFILE

The Civil, Structural and Environmental Department of Trinity College Dublin comprises academic staff, experienced researchers and PhD students with its research internationally recognised and extensive expertise in energy efficiency in buildings, energy storage and low carbon technologies. Associate Professor Sarah McCormack, PhD with TCD staff leads and coordinates the IDEAS project.

PROJECT PARTNERS

The IDEAS project is led by the Dept. of Civil and Mechanical Engineering in TCD Dublin, utilising modern laboratory resources in close partnership with the University of Belfast. Key IDEAS partners consist of universities, public and private organisations in Ireland, UK, Portugal, Italy, Spain and Serbia with demo. sites to be located in north and south Europe.

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