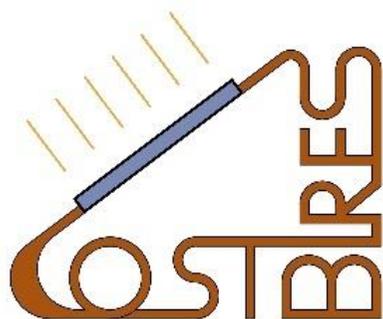


First International Conference on Building Integrated Renewable Energy Systems

Conference organized in collaboration
with COST Action TU 1205-BISTS



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Dublin Institute of Technology (DIT) Ireland
DIT Grangegorman



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BOOKS OF ABSTRACTS

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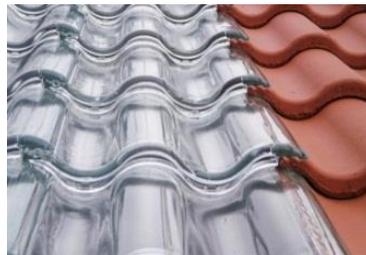


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- Thermal Storage (TS)
- Hybrid systems (HS)
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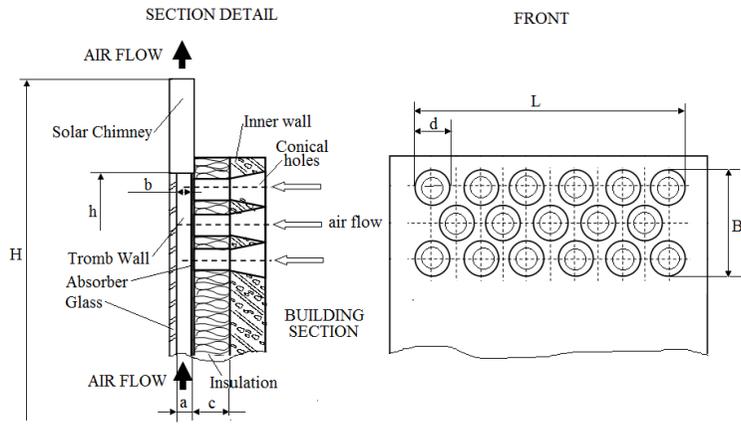
A natural ventilation system by using Trombe walls and solar chimney for reducing the impact of sick building syndrome

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Abstract

Trombe walls and solar chimneys are usually considered as passive solar heaters or components of ventilation systems for indoor cooling, relying on natural buoyancy-driven convection to produce air flow. When considering the indoor ventilation where sick building syndrome (SBS) is reported, special conditions are imposed related to air flow: humidity range between 25 and 60%, minimum outdoor ventilation rate greater than 10L/s per person, floor-to-ceiling differential temperature under 3°C, average particulate concentration less than 10 µg/m³, exposure to odor concentration between 0.3 and 3 mg/m³ etc. Also, it is mandatory to control the average air velocity in the occupied zone both for the winter period (less than 0.15 m/s) and summer (less than 0.25 m/s), the position of the persons at the desk according to air motion direction, the arrangement and shape of the in/out grid holes in the inner wall for air circulation etc. The paper presents a simplified design tool for a natural ventilation system (NVS) comprised of Trombe walls and solar chimney, in order to assess if imposed conditions could be fulfilled. Sizing of solar chimney was provided by calculating the thermal pressure which causes a displacement of the air mass according to the active surface of the tromb walls. The mean air velocity value throughout the solar chimney was verified under the condition of ensuring the minimum indoor air flow for an ordinary building section. The suction pressure i.e. the pressure gap between the building section and the solar chimney section was computed by considering the special grid holes on the inner wall. The conical holes of the wall grid were shaped and positioned for avoiding back flow when counterpressure occur in the solar chimney due to outdoor wind motion. This type of grid is more efficient than classical dumpers since aerodynamic losses are lower and reversing air flow is avoided at high velocities. The results highlighted that for an office building floor - covering an area of 300 m² where concrete wall thickness was 0.25 m, chimney width/height of 0.6/3 m and solar irradiation of 700W/m² (see the figure)– the maximum recommended number of working persons is 25-30 when considering air flow constrain. Also, if solar irradiation is lower then 380 W/m², SBS occurs hence fans must be used. The proposed design tool is using results from the literature concerning the optimum dimensions for the solar chimney – increased ratio between the height of the absorber and the gap between glass and absorber – efficient air flow pattern between input and output sections, i.e. better position of the holes in the inner wall, and also indoor air quality conditions. By using the proposed method for some existing office buildings one can conclude that natural ventilation is not be a solution and other options have to be considered since in such large buildings, the already existing systems for heating, ventilating and air conditioning actually transports micro-organisms from the place of contamination to the vicinity of the occupants.



A review of new materials used for building integrated systems

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Abstract

Solar energy has a significant impact on the environment, so the development of new technologies in this field is very important for many reasons and is subject of many researches nowadays. Incorporation of phase change materials (PCMs) into building structures has been found as useful for reduction of temperature fluctuations, while maintaining the thermal comfort. Numerous methods were developed by previous researchers using this type of materials. This paper reviews some latest publications on the use of new materials in buildings, covering PCMs, nanomaterials and nanofluids, current building applications and their thermal performance analyses. These materials have predictable applications in buildings for effective use of solar energy. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications. Also, nanofluid technology has been developed in the past decade. Nanofluids have a great potential for solar thermal applications, especially because of their specific heat and thermal conductivity increasing. Uses of hybrid nanofluids for solar thermal collectors are expected to give excellent performance improvement. This paper also investigates the feasibility of using PCMs for thermal management of Building Integrated Solar Thermal /Photovoltaic systems (BIST/PV systems).

Keywords: *Phase change materials, Nanomaterials, Nanofluids, Building Integrated Systems*

Investigating the potential for flexible demand in an office building with a BIPV façade and a PV roof system

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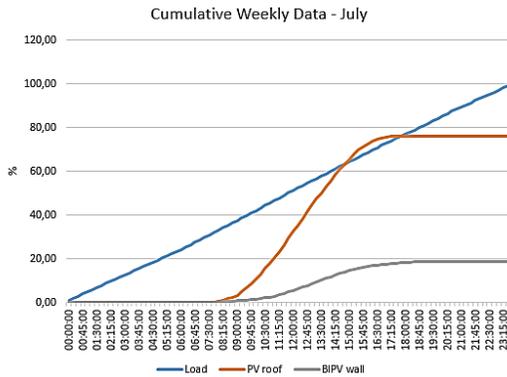
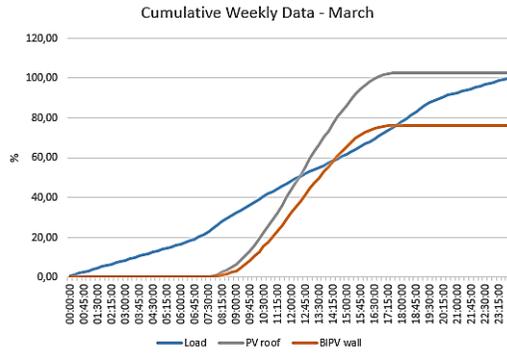
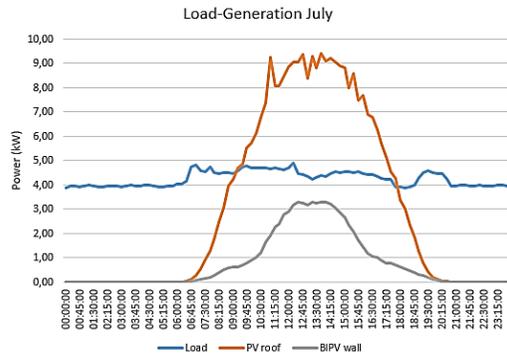
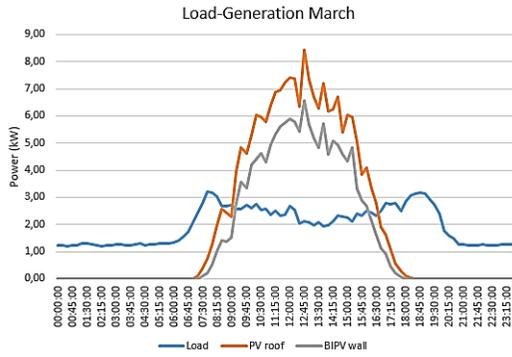
Abstract

Building Integrated Photovoltaics or BIPV are becoming an attractive solution in the context of high penetration of photovoltaics in buildings caused by the strive to achieve net or nearly zero energy status. In addition of harvesting solar radiation to produce electricity, BIPV also offers aesthetical advantages because of its architectural feature. However, when integrated in vertical façades, the angle of the PV modules may considerably affect the efficiency of BIPV when compared with horizontal orientation in the same location and altitude.

This paper reports on the electric energy performance of an office building, Solar XXI, located in Lisbon, Portugal, which has installed on the South façade a BIPV (12 kWp) and an additional photovoltaic roof system in the car park facility in the nearby (12 kWp) for electricity generation.

In this paper, the objective is to investigate the possibilities of introducing a flexible demand side response to satisfy the local energy demand with the energy generated locally. Results are reported in terms of *Load match index* for different scenarios which are developed from monitoring data obtained during March 2016 (winter period) and July 2016 (summer period). The electricity energy consumption and PV production data with a temporal resolution of 15 minutes is shown in Figures below as cumulative data.

The figures below represent respectively from the left to the right, the building *Load Match Index* and *Cumulative weekly data* of energy consumption and generation for the winter period (March) and summer period (July).



Experimental assessment of the energy performance of an advanced responsive BIPV/T-PCM system

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Abstract

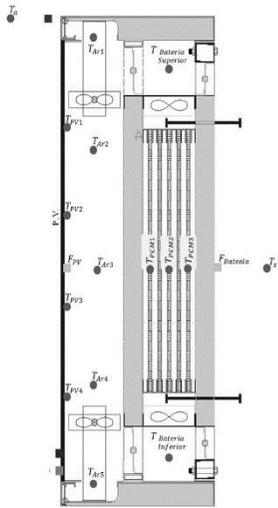
The introduction of photovoltaic (PV) panels in buildings for electricity production is a way to reduce energy consumption from fossil fuels, but by itself is not enough, only about 16% of the incident solar energy in the PV is converted into electricity the rest is absorbed and converted into heat, leading to PV overheating, which reduces its solar energy conversion efficiency. A more efficient alternative is to introduce a *Building Integrated Photovoltaic/Thermal* system (BIPV/T).

The building integration of the PV systems is becoming an attractive solution in the context of high penetration of photovoltaics in buildings caused by the strive to achieve net or nearly zero energy status. This scenario poses great challenges on where and how RES can be exploited in a building. Moreover, due to the typical mismatch existing between energy converted from RES and building demand profiles, the role of energy storage and intelligent integrated system energy management becomes essential, thinking also to other building concepts as *Interactive buildings* in the context of *Smart Cities* and *Smart grids*. A new generation of Building Integrated Photovoltaic systems start to grow interest, consisting of multifunctional and highly adaptive system (through storage or/and intelligent management control), as a physical separator between the interior and exterior environment and able to change its functions features or behaviour over time in response to transient performance requirements and boundary conditions with the aim of improving the overall building performance.

This paper aims to present the experimental results obtained with the implementation of an advanced responsive BIPV/T system with a heat storage unit obtained with the application of phase changing materials (PCM), addressed as BIPV/T-PCM, on the facade of an office in SOLAR XXI building and integrated an intelligent management control system.

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Experimental evaluation of the efficiency of photovoltaic / thermal (PV/T) modules integrated in the built environment

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Abstract

In the built environment, solar energy is largely converted into thermal energy (mainly for domestic hot water) and, with lower efficiencies into electrical energy. However, the low density of the solar energy imposes large implementation surfaces which can be a main barrier when specific renewable energy systems are to be implemented. Thus, the available area has to be intensively used and one option is represented by Photovoltaic/Thermal (PV/T) modules which produce both electrical and thermal energy.

The paper presents the results obtained during outdoor testing of two monocrystalline Si PV/T modules, Fig. 1a. The results (for a reference area of 1 m²) are comparatively discussed with those obtained using a mono-Si PV module (of the same type), as Fig. 1b presents for June 1st, 2016.

Further on the conversion efficiency of the PV module is compared with the overall conversion efficiency of the PV/T module. The results show that the overall conversion efficiency (thus overall thermal and electric energy production) is higher than of the PV, and is significantly depending on the irradiance input and slightly influenced by the inlet temperature in the PV/T. Additionally, beyond the energy recuperating role of the “T” component in the PV/T, these systems are delivering a thermal output that can be directly used without any further conversion (e.g. for domestic hot water, DHW). Thus, for a given suitably oriented area of a building, PV/T can be installed correlated with the DHW demand and further available area (on the terraces, roofs or facades) can be filled with regular PVs allowing a high degree of coverage available for solar energy conversion.



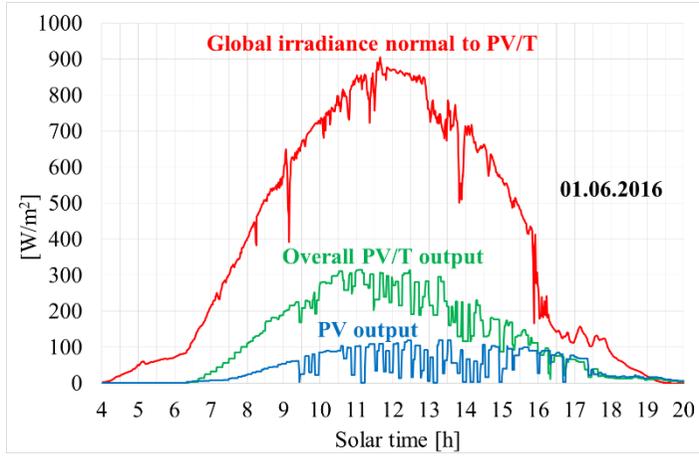


Fig. 1 Experimental PV/T system (a) and infield results (b)

Outdoor performance of a trapeze solar-thermal collector for facades intergation

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Abstract

Increasing the share of solar energy convertors installed on buildings asks for using all the suitably positioned places, including facades. However, well-known technical and acceptance barriers have to be overcome for these visible areas. Following this constraints a new solar-thermal flat plate collector was designed and developed, having rather small area (0.63 m^2) and trapeze shape; this shape allows a much higher coverage degree of the buildings' facades, in lego-type arrays; additionally, variously coloured absorber plates (red, green) will increase the architectural acceptance. A demonstrator was developed and proved a nominal efficiency of 62.38% during indoor testing on the solar simulator. Further on the demonstrator was outdoor installed, on the vertical façade of a laboratory building, in the R&D Institute of the Transilvania University of Brasov, Romania (mountain temperate climate, 45.65°N , 25.59°E at 600 m above the sea level).

The paper presents the results of a one year monitoring of the trapeze collector outdoor installed, in terms of output thermal power and efficiency. Data are compared with those obtained for two commercial collectors (with 2.1 m^2 area and nominal efficiency of 85.1%): one vertically installed on the same façade as the trapeze collector, the other one tilted (at an optimal angle of 35°) on the laboratory terrace. The data in Fig. 1 show two typical efficiency variation curves, in two days with similar radiation profile (before and after winter time), outlining that the demonstrator well preserves the conversion efficiency. These type of data are extensively discussed in the paper, considering the monthly cumulative output and the efficiency, the peak values (highest and lowest), in direct correlation with the irradiance and outdoor temperature. It is found that the irradiance values significantly and differently influence the conversion efficiency of all three collectors and this aspect is further detailed discussed.

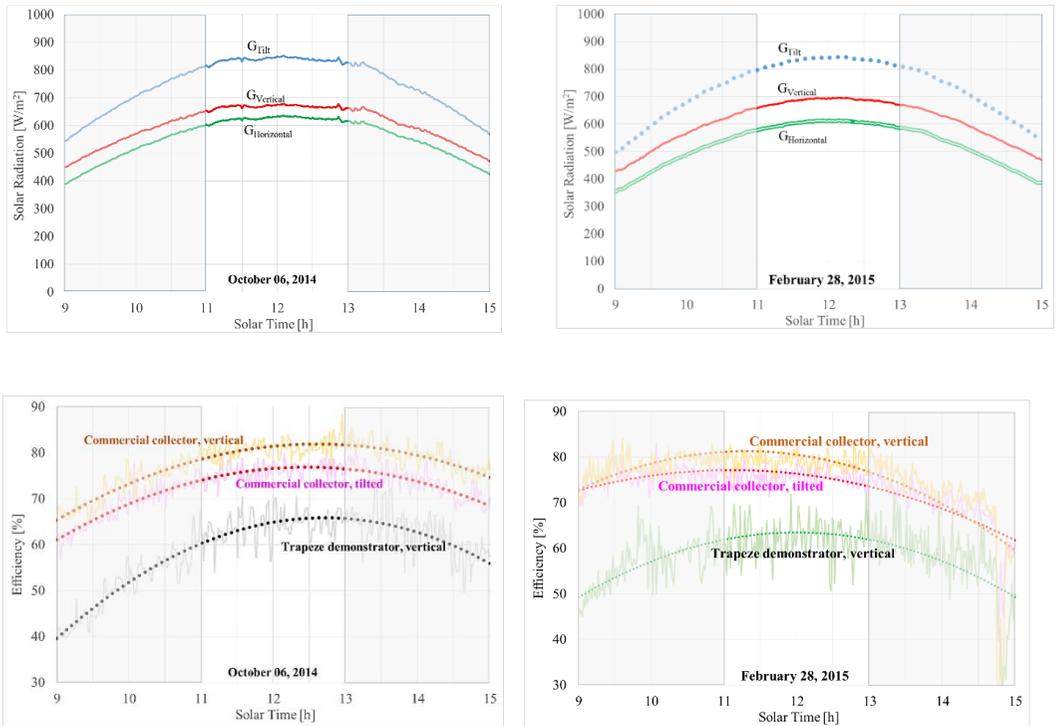


Fig. 1. Irradiance profile and efficiency of the commercial solar-thermal collectors and of the trapeze demonstrator on October 06, 2014 and February 28, 2015

Trapeze solar-thermal collectors: implementation prerequisites and solutions

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Abstract

A novel solar-thermal collector with trapeze shape and coloured absorber was designed and development as building unit for developing solar facades with increased architectural acceptance and large degree of coverage (the collector has an active area of 0.63 m²).

It was previously found that units of three trapeze collectors, interconnected in various vertical and horizontal configuration may represent an improved solution for optimal functioning, and easy mounting and maintenance. However, the actual implementation raises specific issues if the facades has rather irregular shape, as for the single-family houses in Fig. 1. Beyond the functional challenges risen by the hydraulic interconnections, another pre-requisite is imposed by the aesthetical constraints that requires minimizing the exposure of the pipes, vents, elbows, etc.

The paper discusses the main challenges faced for two types of facades: with vertically and, respectively with horizontally installed unites of three trapeze collectors; the interconnecting solutions are analysed considering both, functional and aesthetical constraints, correlated with the coverage degree and with the costs. Fig. 1 presents one typical example for facades with high coverage degree, with green-blue vertically mounted collectors and red-dark blue horizontally installed trapeze collectors, along with a possible interconnecting piping. Alternatives of these arrangements are analysed, based on a set of criteria and associated scoring and the optimal solutions are modelled in terms of thermal output, considering four typical days in the year (the solstices and the equinoxes) in a mountain temperate climate (45°N, 25.59°E). The results show, as expected, that the coverage degree will significantly influence the overall output of the facades; vertically mounted collectors have a slightly lower conversion efficiency and a lower coverage degree but the interconnecting solutions are more permissive.

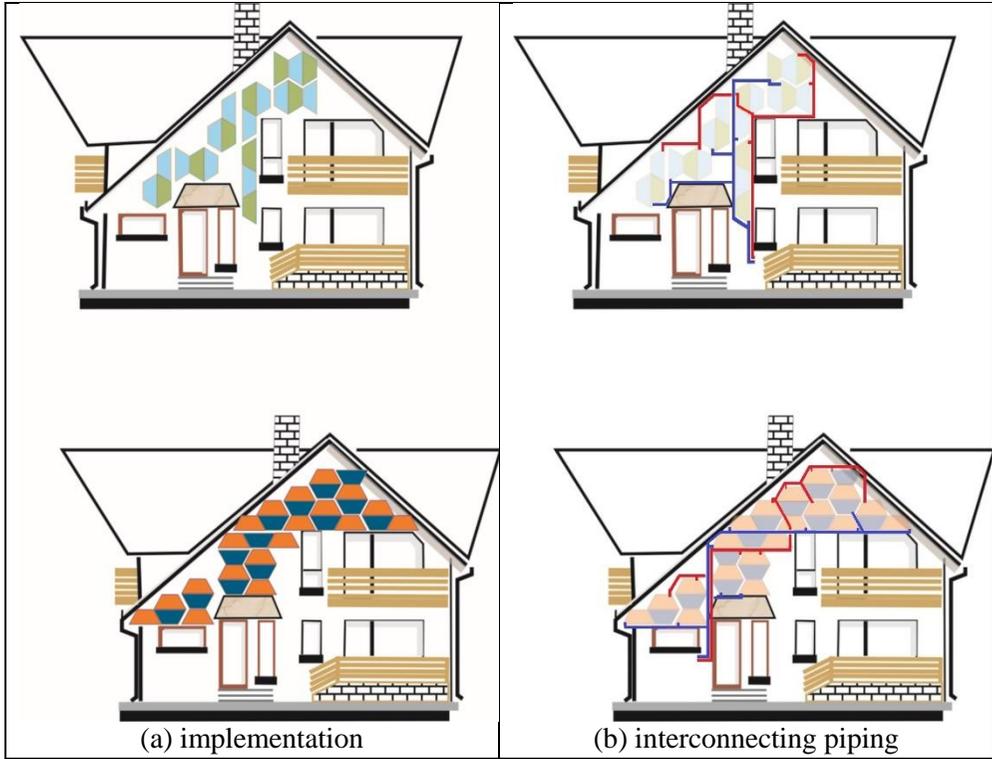


Fig. 1. Solar-thermal facades using groups of three trapeze solar-thermal collectors

Nearly Zero Energy Community – an affordable and feasible transition concept towards sustainable cities

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Abstract

The environmental challenges imposed by the greenhouse gases emissions are currently well recognized. This is why a worldwide commitment tends to be reached, on widely replacing the fossil fuels (mainly responsible for the global warming and climatic changes) with renewable based energy systems. Ambitious concepts were formulated, as the *Net Zero Energy Building*, although the current building stock mainly consists of about 97% of old buildings. Thus, significant technical and cost-related barriers are faced and transition concepts are formulated, as the *Nearly Zero Energy Buildings (nZEB)*, legally binding for the EU states, starting with 2019/2021, that may ease the transition and can be realistically met, considering the current resources.

Other ambitious concepts were formulated for communities and cities; recent literature promotes the concept of *Net Zero Energy Community*. At conceptual level this is actually the sustainability target. However, the path from the current communities, mainly relying on fossil fuels to an extensive implementation of *Net Zero Energy Community* needs to be planned, coordinated and harmonized.

This paper proposes the concept of *Nearly Zero Energy Communities (nZEC)*, as a transition phase towards *Net Zero Energy Community*. Two scenarios are analysed, Fig. 1: (1) The Transition Scenario A, where renewables implementation is scattered, following the „easy” way, thus avoiding e.g. the city centers (mostly difficult to change as they usually involve historical buildings, narrow spaces, etc.), and (2) the Transition Scenario B, where the *nZEC* concepts are involved, through a coherent approach over the entire community, with specific solutions for each neighbourhood.

The paper discusses the steps to be followed in reaching the *nZEC* status (thus a community covering at least 50% of its energy demand by using renewables); it is demonstrated that *nZEC* could even represent a more feasible and affordable concept compared to the *nZEB*, and asks for technical solutions and community involvement from the very beginning. It is also outlined that the transition from *nZEC* to *Net Zero Energy Communities* can be more cost-effective and less imposing on the inhabitants if the savings brought by implementing renewables (after the payback time) are invested to increase the sustainability degree.

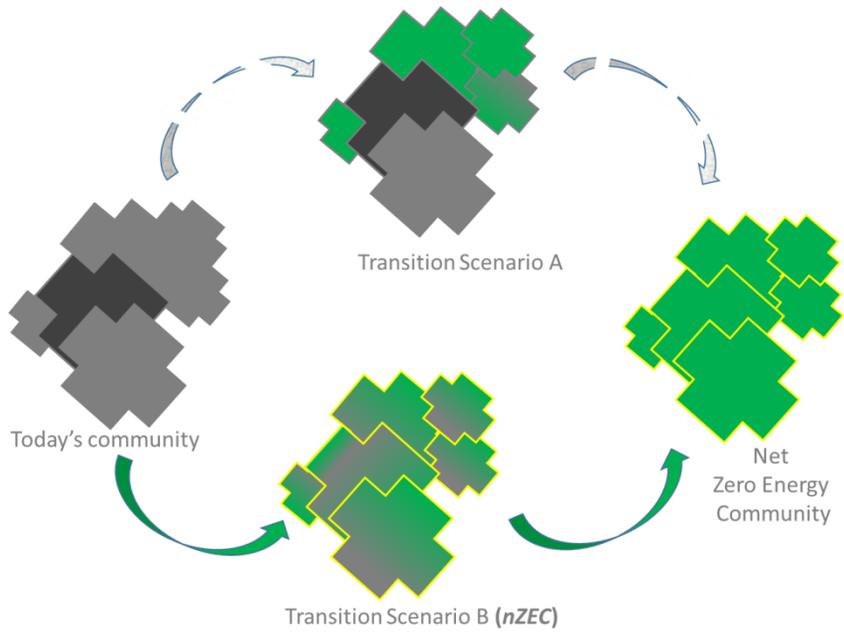


Fig. 1. Transition scenarios from the Today's communities to the *Net Zero Energy Community*

Single-axis mechanisms with limited stroke for tracking solar thermal collectors integrated in building façades

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Abstract

In line with the European strategy on nearly zero-energy buildings implementation, the solution of flat plate solar thermal collectors (FPSTCs) installed on façades can be used as an additional measure to meet the domestic hot water demand in buildings. However, the variability of the solar radiation leads for vertically mounted facades to low thermal output during the cold and transient seasons, while overproduction or stagnation (thus accelerated deterioration) can be expected during summer.

This is why, this paper proposes a solution to control the thermal output, based on controlled limited tracking. Two options are considered: forward tracking (to increase the solar energy input) and inverse tracking to decrease this input. Maximum strokes of $+15^\circ$, respectively -15° are considered acceptable having as reference the vertical mounting.

The results in Fig. 1a show the maximum incident solar energy simulated one year for the three variants (vertical – V, $+15^\circ$ noted as Max, and -15° noted as Min), while Fig. 1b outlines the energy gain (red) and the energy loss (blue) considering the traditional vertical mounting as reference. These results outline the significant role of inverse tracking (thus overheating protection) during the warm season (May – August). Although not large, the gain also contributes to meeting the target of 100% solar DHW in the built environment. These results are validated based on infield data, on the outdoor testing rig in Fig. 1c. Possible single axis mechanisms able to be implemented for facades are further presented and comparatively analysed considering the prerequisites: accurate tracking, small size, reliability, etc.

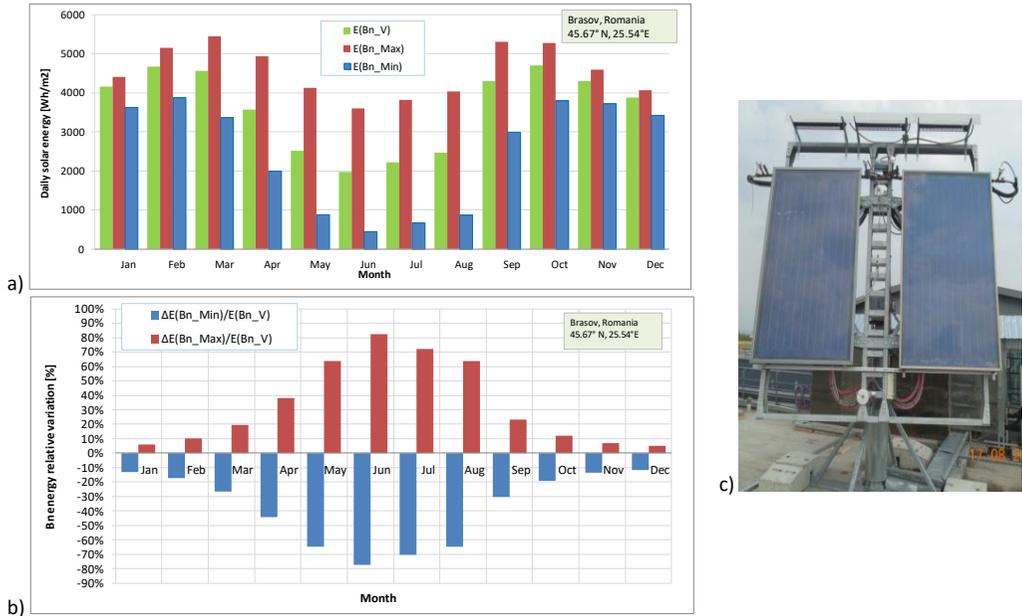


Fig. 1: Simulation results for a South-facing façade mounted FSTC: a) collected daily beam energy over one year in the vertical plane (V), on a plane limited oriented ($\pm 15^\circ$) for increasing/decreasing the solar energy gain (Max/Min), b) relative variation of the collected solar energy on Max/Min oriented plane vs. fixed vertical plane V; c) experimental outdoor testing rig

Performance and stability of semitransparent OPVs for building integration: A benchmarking analysis

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Abstract

The research presents the experimental performance of three different building-integrated organic semitransparent photovoltaic technologies (A: developed in the present study; B and C: commercial modules). Spectral transmittance and electrical measurements have been conducted in order to determine the characteristics of the modules for building integration and electric generation purposes. Continuous monitoring of the modules working at maximum power point has been performed over sunny days, whereas in other conditions, the modules were kept in open-circuit. Regarding the transmittance, technology A outperforms B and C, but concerning electrical efficiency, C is the one registering the best results in terms of degradation, B is the one achieving the highest efficiencies and A is in the middle (it presents similar efficiency results to C and similar efficiency reduction to B).

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A building integrated photovoltaic (BIPV) demonstration building in Belgium with new fibre reinforced solar technology PV modules: analysis with simulation and monitoring data

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Abstract

New more flexible and lightweight photovoltaic (PV) modules based on a novel encapsulation technology with glass fibre reinforced composite materials are installed in a residential building in Mons, Belgium which is used as a demonstration building. The tested modules are named roofing shingles (RS) and they are installed on the south part of the building's roof with inclination angle 40°. The installation comprises of 54 RS modules of 32 monocrystalline Silicon cells each. The total installed power of the system is 7.01 kWp. The BIPV system installed on the Belgian demo site is monitored to observe its performance and optimise the installation in case of efficiency loss due to natural parameters e.g. overheating. Various equipment like temperature, humidity, radiation sensors, data loggers etc., are installed on the building for the monitoring. Prior to the installation, a simulation model in TRNSYS simulation software is carried out using weather data for Belgium from a Typical Meteorological Year (TMY) file, to predict the performance of the system as well as other various parameters such as the developed temperature on the PVs surface, air gap temperature etc. The aim of this study is to present the performance of the BIPV system on the demo site and compare the monitoring data with the simulation results. It is concluded that the results from the simulation agree with the monitoring results measured on site.

Keywords: Building integrated PV, Fibre Reinforced Solar Technology PV, simulation, monitoring

Modelling of synthetic natural gas production via biomass gasification for renewable gas grid injection

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Abstract

Ireland relies heavily on imported natural gas, which is used for electricity generation, heating and cooking. Therefore, grid injection of renewable gas is very attractive. Replacing heat from fossil fuels with heat from renewable sources is a significant challenge. Due to Ireland's favourable growth climate, bioenergy is expected to play a major role in meeting renewable heat (and transport) targets; however, to date its uptake has been very low. Barriers include: low efficiency of conversion technologies; high capital and biomass fuel costs; absence of large heat loads (no district heating networks). Synthetic natural gas production via biomass gasification (BG-SNG) with subsequent grid injection can overcome these barriers. A BG-SNG plant comprises a gasifier followed by gas cleaning (removal/conversion of impurities) and upgrading (methanation and inert gas removal) steps. Development of these plants is at an early stage; 1 MW_{SNG} (SNG output) pilot plant tested in Austria and 20 MW_{SNG} demonstration plant operating in Sweden. The main aim of this research work is to investigate the techno-economic and environmental feasibility of BG-SNG systems in Ireland.

Thermal testing of new photovoltaic (PV) modules for building integration, encapsulated with glass fibre reinforced composite materials and comparison with conventional Photovoltaic

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Abstract

The use of Photovoltaic (PV) panels for electricity generation is increased dramatically the last years. The PV panels for building integration however are not so popular yet. This is because the Building Integrated Photovoltaic (BIPV) systems play an important role on the design of the building. There are architects and designers who like the idea of PV panels integrated on the envelope of a building but there are also those who believe that the colour and flat shape of the panels reduce their creativity. BFIRST (Building Integrated Fibre Reinforced Solar Technology) project developed a new solar cells' encapsulation technology with glass fibre reinforced composite materials and real size modules are manufactured. The idea behind this technology is to produce rigid photovoltaic panels with shapes that are not flat but they are also lightweight PV modules for building integration.

The aim of this study is to compare a 'BFIRST module' with a conventional module from the market, in terms of temperature and performance under different amounts of solar radiation and inclination angles. Thus, two experimental apparatuses are constructed to represent building integration, forming an air gap between the PV and a second skin. The purpose of the air gap is to cool the PV panels and avoid the decrease of their efficiency due to overheating. In this study, the ventilation of the air gap is considered natural without any mechanical means to drive the air.

The tests are carried out in the Archimedes Solar Energy Laboratory (ASEL) at Cyprus University of Technology, Limassol, with the use of a large scale solar simulator. Although this is the first time the fibre reinforced encapsulation solar technology is tried, as the modules are produced only for research and demonstration purposes, the tests show that this technology is very promising and worth to be marketed. The maximum temperature recorded was very close with the temperature of the conventional PV panel. The temperature of the PV panel under 450 W/m² constant solar radiation for three hours is 57.5°C while the temperature of the conventional PV was 64°C. For 800 W/m² constant solar radiation the temperature of the BFIRST PV panel was 73.4°C and 73.6°C the conventional PV panel.

Keywords: BIPV, Solar Simulator, Thermal testing, BFIRST, Photovoltaic

Achievements of BFIRST EU funded project on BIPV technology

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Abstract

Building-integrated photovoltaics (BIPV) is currently an expansive market worldwide, with an estimated compound annual growth rate (CAGR) of 18.7% and a total of 5.4 GW installed between 2013 and 2019². One of the main drivers for BIPV market growth in the EU is the increasingly demanding legislation related to energy performance in buildings (EPB), in fact buildings are responsible for 40% of energy consumption and 36% of CO₂ emissions in the EU³. Thus, Europe has an urgent need to make our buildings more efficient and smart.

Despite this favorable framework, it is a fact that estimations of BIPV market growth have been subsequently overestimated in the past few years. The cause for this deviation is a series of demands from the stakeholders which have not been properly addressed by the BIPV value chain. These key requirements are mainly related to the flexibility in design and aesthetics considerations, lack of tools integrating PV and building performance, demonstration of long-term reliability of the technology, compliance with legal regulations, smart interaction with the grid and cost effectiveness.

In May 2012, a consortium of EU companies, research institutes and universities, led by TECNALIA, launched EU funded BFIRST project, which stands for building-integrated fibre-reinforced solar technology. The project, which will end in early 2017, is focused on the design, development, fabrication and demonstration of a set of standardized multifunctional PV products for building integration (BIPV) using an innovative manufacturing solution based on glass fibre-reinforced composite materials, property of TECNALIA.

By means of this new technology, complex geometries can be obtained, opening a wide range of new BIPV products with enhanced building integration possibilities. The resulting PV modules present advanced characteristics in terms of structural properties, transparency, adaptability to non-planar geometries, protection, weight and reduction of stages in the manufacturing process, as well as advantages concerning transport, manipulation, assembly and safety and security.

² Building Integrated Photovoltaics (BIPV) Market: Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 – 2019.

³ DG ENER data, European Commission.

Since the beginning of the project, the consortium has taken important steps in the project execution and is currently facing the final stretch. Up to 6 different BIPV products shown in Fig. 1: ventilated façade, canopy, balcony, roofing shingle, skylight, ventilated facade on aluminium tray, have been designed, simulated, prototyped and tested at lab scale according to PV and construction standards, with positive results. Finally, real size products have been constructed and installed in three different demo sites, in Spain, Belgium and Greece. First results on the monitoring results are being obtained and analyzed, providing excellent production results without compromising the durability of the products, showing no degradation of PV modules for the moment. Several photos of these demo constructions are shown in the following figures.



View of demo house in Mons (Belgium) after set-up of BFIRST roofing shingles, May 2016



Shading elements (canopies and balconies) already installed in Pikermi site (Greece), June 2016



Left: Skylight in the roof, Right: Ventilated Façade -Aluminum in the concrete facade of Spanish INGRID demo building

Figure 1. Photographs of the three demo sites showing the various products developed

The importance of the solar systems to achieve the nZEB level in the energy renovation of southern Europe's buildings

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Abstract

Nowadays, in the European Union the construction rate of new buildings is very low and therefore achieving the EU targets at the energy consumption level of the building sector is only possible through nearly zero energy renovation of the existing building stock. Reducing energy consumption through passive measures is a priority but this is not enough to achieve the nearly Zero Energy Building (nZEB) level. Therefore, the active systems, namely those that allow harvesting the solar energy to partially replace the use of non-renewable energy, are one of the best solutions to consider. At this level, solar thermal and photovoltaic panels play an important role, mainly in countries with high levels of solar radiation, as in the Southern European countries. Nevertheless, there are still some barriers to overcome for the broader dissemination of the implementation of these systems. One of the most important is that building owners are not fully aware of the life-cycle benefits of these systems at the economic level. As in every new different design approach, the best way to arise awareness is through the analysis of case studies, highlighting the reduced life-cycle costs and environmental impacts and other long-term benefits resulting from the integration of these active solutions. Thus, this paper is aimed at assessing the contribution of the solar systems to achieve three levels of energy performance (Basic Renovation, nZEB and Zero Energy Buildings - ZEB) in the energy renovation of a multifamily building located in Portugal. From the results it is possible to conclude that, in an annual basis, and for the Portuguese climate, it is possible to overcome, a large amount of the energy needs for acclimatization and domestic hot water preparation with the integration of these systems. The study also shows attractive cost and carbon payback times resulting from their use.

Optimization of a building integrated solar thermal system with seasonal storage

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Abstract

Buildings worldwide constitute one of the biggest energy consumers with 32% of the total final energy consumption, while in terms of primary energy consumption they represent around 40% in most countries according to the International Energy Agency. Of the various renewable energy systems that can be installed in the building sector in order to cover energy requirements (electrical and thermal loads), solar energy systems are currently the most widely used, mostly in the form of solar thermal and photovoltaic systems. Especially for locations with high annual solar radiation and temperatures, solar energy systems are already a viable alternative to fossil energy systems and are expected to become even more efficient and cost-competitive in the future. One of the problems associated with the use of solar thermal systems for space heating applications is the fact that solar potential is low during the heating period. To solve this problem solar systems that utilize Seasonal Thermal Energy Storage (STES) have been developed and are investigated for small scale applications in the current work. STES implementation concerns the storage of heat in large facilities during the summer period for later use during autumn and winter, when heating load is in high demand. To that end the TRNSYS modelling software is used to simulate a typical building integrated solar thermal system with STES. The model calculates the space heating and domestic hot water (DHW) needs of a typical single-family detached home in the city of Thessaloniki, Greece that has been built according to the latest building code. The contribution of the solar system, as well as the thermal load covered by the auxiliary conventional system is determined and the seasonal solar fraction is calculated.

A parametric analysis on the impact of various solar collector areas and types, building integration type, as well as the volume and type of STES is also presented in order to optimize system design.

Keywords: Seasonal Thermal Energy Storage, TRNSYS, Solar energy

Environmental impact and economic analysis of a LED lighting products

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Abstract

The continuous growth of the use of energy has had a very big impact in the climate change due to the vast amounts of CO₂ emissions. Electricity production is the major player in energy use and lighting consumes the biggest part of electricity. This study assesses – based on prior studies the lifecycle energy consumption of a LED lamp product as compared to incandescent lamp and compact fluorescent lamp (CFL) technologies. To provide the uniformity necessary to conduct a life-cycle energy analysis, a functional unit of “20 million lumen-hours” is selected. The results showed that during the operation period of 10,000 hours of each kind of lamp, the negative impact on the environment of the product is highest in the use phase due to electricity use.

Keywords: LCA; LED lighting products; electricity

Experimental measurement and numerical simulation of a building façade integrated concentrating PV combined with phase change material system

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Abstract:

A truncated building façade integrated asymmetric compound parabolic photovoltaic concentrator with a geometric concentration ratio of 2.0 and acceptance half angles of 0° and 55° has been designed and experimentally characterised. Subsequently, a Phase Change Material (PCM) system was integrated to the rear of the concentrating PV system to moderate the PV temperature rise and maintain good solar to electrical conversion efficiency. The experimental results showed that the concentrating PV system has the potential to increase the power output per unit solar cell area by a factor of 2, when compared with a non-concentrating PV system. The electrical conversion efficiency for the concentrating PV coupled PCM system was increased by over 5% compared with a similar system with no PCM integrated at the rear, when the incident solar radiation intensity was 280W/m². This value increased by over 10% for an incident solar radiation intensity of 670W/m². Finally, a numerical model has been developed to further analyse the system performances.

Experimental and numerical analysis of overheating in test houses with PCM in Latvian climate conditions

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Abstract

Phase change materials' (PCM) efficiency is being studied experimentally and numerically. Five test houses have been built in Riga, Latvia and monitoring data (temperature, humidity, air velocity, etc.) have been collected every minute since winter 2012. After two seasons in two of the houses a different PCMs have been installed and during June 2016 mechanical ventilation and air conditioning is turned off to monitor room overheating. The efficiency of PCMs is calculates form experimental data acquired before and after PCMs were installed. A numerical model in *WUFI Plus* is set up to evaluate the performance of PCMs numerically. Results acquired from experimental and numerical data are mutually compared.

A new approach on corrosion tests for building materials with PCM

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Abstract

In recent years, using Phase Change Materials (PCMs) in building structure for energy saving has taken attention of researchers. Utilization of PCM in building envelope provides passive thermal energy storing. The main advantages of using PCMs in building structure are to reduce temperature fluctuation and energy demand of buildings, peak shaving and peak load shifting and contribute to keeping ambient temperature within comfort limits. However, researchers mainly focused on thermal and physical characteristic of PCMs. Depending on the chemical structure of PCM used, corrosion rates of metallic structure (rebar) embedded in concrete with PCM may be affected. This influences durability of reinforced concrete and also service life of building. The aim of this study is investigating corrosive behavior of Butyl Stearate (BS) as PCM on rebar in 3.5% NaCl medium to demonstrate long-term durability of reinforced concrete. Electrochemical impedance spectroscopy was used for the first time in our study to conduct accelerated corrosion tests. Change of open circuit potential (E_{OCP}) with time shown in Figure 1 indicated that BS had less corrosive effect on rebar compared to reference sample in the first six months of the monitoring period. The change of E_{OCP} values after six months reveals that the corrosive behavior of BS is changing. Further investigations on change of corrosive behavior with time are ongoing for longer inspection period and will be reported in our full paper.

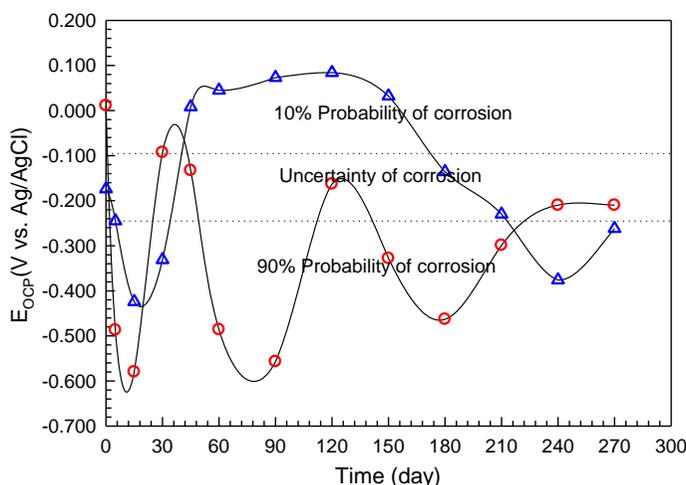


Figure 1. Open circuit potentials of rebar-Ref (O) and rebar-BS (Δ) in 3.5% wt. NaCl solution at room temperature after 270 days immersion

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Innovative pathways to thermal energy storage (INPATH- TES) project

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Abstract

Following the EC SET-Plan Education and Training Roadmap, the goal of INPATH-TES is to create a network of academia, research institutes and small and medium-sized enterprises (SME) to implement a joint PhD programme on Thermal Energy Storage (TES) technologies. The project consortium consists of 22 partners from 14 different countries consisting of 14 universities, 3 research institutes, 3 industries, and 2 SME. The final result of such a network is to educate professionals on these technologies for the European research and industry institutions.

The specific objectives of the project are:

- To establish one joint PhD programme starting year 0+2.
- To develop common at least 20 ECTS as basic common training module.
- To develop four basic common technologies PhD courses.
- To establish one annual joint workshop for PhD students.
- To aim at graduating at least 28 PhD students every year at year 0+6.
- To exchange at least 14 PhD students every year between industry and academia.

The main expected impact is the achievement of a unique joint PhD Programme on TES that will enable the qualification of professionals for the European research and industry institutions, placing on the market 28 PhDs each year. Other expected impacts comprise knowledge sharing, technology transfer between academia and industry, knowledge dissemination inside and outside the network created.

Some of the main challenges consist of the development of the programme, the implementation of the programme in each country/institution, the development of a Master degree programme (MSc) in Thermal Energy Storage, and to ensure the continuity of the programme after EU funding ends.

A total of 14 courses were proposed and defined in detail, which are currently being developed. These courses can be classified in three main groups, so that there are 5 basic common PhD courses, 4 common technology specialisation courses, and 5 research management, dissemination, and communication courses.

Keywords: thermal energy storage, PhD programme, e-learning.

Two active integrated storage systems: Double skin facade and active slab with PCM

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Abstract

The use of thermal energy storage (TES) in the building has been identified as a suitable solution to reduce energy demand for heating and cooling. TES allows the use of peak load shifting strategies and enhances the introduction of renewable energies in the sector. Hence, it is claimed that the use of TES can provide energy savings, cost reduction, and CO₂ mitigation. Passive implementation of phase change materials (PCM) in buildings has demonstrated significant energy demand reduction, but with some limitations such as the number of cycles during the year, as well as the charging availability during summer. For this reason, active implementation of PCM in buildings is becoming popular due to the high potential to be used as a storage unit as well as its capacity for providing heating and cooling supplies. The integration of these systems in the building is one of the aspects that researchers are taking into account to achieve a competitive technology for a future inclusion into the building sector.

Two innovative active systems are presented, consisting of thermal energy storage units embedded inside two different parts of building components. A double skin facade and an internal slab were filled with PCM in order to act as a storage unit and a heating and cooling supply. In this paper the potential of both technologies are presented for space heating and cooling. Moreover, some aspects found during the experimental studies are highlighted to determine required improvements and further analysis.

The high investment cost of these systems makes mandatory an appropriate control to maximize the energy benefits during its operation. A first step was done in the double skin facade technology through an experimentally validated numerical tool used to study the effect of different control strategies on the performance of the system. Three different tested control strategies are optimized based on cost savings, energy reduction and CO₂ mitigation. The results obtained showed how optimizing based on one output can influence the other two benefits claimed by TES systems.

Keywords: thermal energy storage, phase change materials, energy savings, numerical study, reinforcement learning, building integration.

Benchmarking of energy demand of domestic and small business buildings

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Abstract

Rapid expansion of utilization of solar thermal energy for increasing energy efficiency of buildings has been adopted in short/medium and long-term energy strategies of EU countries. This enhancement of energy efficiency in buildings is in line with regional actions with the European climate energy objectives as defined in the European Union's "20-20-20" targets and in the European Commission's Energy Roadmap 2050.

Within this context, the overall objective of this work is to develop an innovative high performance and cost effective solar heat and power system, which consist in a novel flat Fresnel mirror solar concentrating collector and micro organic Rankine cycle plant combined with advanced phase change materials as thermal storage, all system managed by smart control units. The initial application is to be implemented in individual dwellings and small business residential buildings for on-site electricity and heat generation using solar thermal energy. It is estimated that the proposed technology will deliver 60% of domestic energy requirements and provide 20% reduction in energy costs and greenhouse gas emissions compared to the best existing low carbon energy technologies.

To reach the main objectives, the first step consist in providing information on features of architecture of domestic and small business residential buildings and their annual energy demands for different countries such as: Spain, France Germany, Italy and United Kingdom. This will include a detailed building information of envelopes (walls, roof, lofts, etc.), structure, fabric, and results of energy demands (domestic hot water, space heating and electricity) for the abovementioned countries. This information will be used as input data during the development of this technology as it will point out the potential benefits of the system in different countries and building typologies. This study will also highlight the technological, social and legal barriers that the system will have to overcome for its implementation in real buildings. These barriers will be related to the building integration of the concentrating solar collector, the full thermal storage system including heat pipes and heat exchangers and the micro organic Rankine cycle.

Keywords: Solar thermal energy; Micro organic Rankine cycle; Thermal energy storage; Phase change materials; Energy savings; Building integration.

Financial return of solar thermal heating with seasonal thermal energy storage - A Swedish case study

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Abstract

The solar resource in Scandinavian Maritime Climates can make a significant contribution to space heating demand given the relatively long space heating season, but is an integrated solar/STES solution economically viable? This paper reviews the actual results of a Swedish solar heating system which uses a Seasonal Thermal Energy Store (STES) for a commercial and residential Passivhaus development and provides an analysis of the economic viability of the installation.

Method A development comprising a 380m² refurbished building and a 390 m² new Passivhaus building located in Lysekil, Sweden has an integrated heating system comprising

- 50 m² solar thermal array
- 3000l domestic hot water (DHW) tank,
- 23m³ aqueous Seasonal Thermal Energy Store (STES) and
- Heat Recovery and Ventilation (HRV) system

Benchmarking of the costs of the system in Lysekil was carried out and it was found that the costs were within the normal range of combi systems as determined by the International Energy Agency task 32 study. A Net Present Value (NPV) analysis was carried out to determine the Life Cycle Cost (LCC) of providing DHW and Space Heating based on the recorded energy consumption and Solar/STES contribution on site. Scenario analysis is carried out using the key parameters of inflation, energy inflation, discount rate and terminal values when calculating the life-cycle cost.

Results & Conclusions. The costs of providing the required DHW and space heating for the development in Lysekil, Sweden are summarised. It is demonstrated it is possible to provide significant solar space heating cost effectively by integrating an STES and that there is an economic argument for the inclusion of an STES.

Harmonic heating effect of multiple electrical equipment connected to a single electrical socket

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Abstract

Under ideal circumstances, the voltage and current waveforms associated with the electricity supply should be sinusoidal. However, the increasing deployment of non-linear loads across distribution networks is causing harmonic distortion that affects the shape of both waveforms. Similarly, *harmonics* as a power quality concern is a relatively recent concern for power systems but the excessive proliferation of harmonic inducing loads in the distribution network is increasingly causing premature equipment failures, and other network failures due to harmonics [1][2][3]. Furthermore, the harmonic distortion is not taken into account within domestic installations and the associated wiring systems as the harmonic distortion potential were considered sufficiently small to be neglected.

A number of standards for example [4] were originally defined by different authorities that were to limit the harmonic manifestations in the network, but practically and increasingly in modern applications, the devices concerned – in a cumulative context – contribute (much) higher levels of harmonics than these standards specified. While these devices *individually* were not considered harmful, as the magnitude of distortion in this regard is relatively small, electrical equipment failures and insulation failures increasingly being derived from harmonic cable heating were suggesting a different story [5]. Recently attempts has been made to offer harmonic derating factors for building electrical circuit design **Error! Reference source not found.** But this lacks clarity and are better defined for large power devices only.

This work intends to simulate the harmonic heating effects caused by devices that induce harmonic frequencies in the house/building and will evaluate the possible threat derived by the cumulative contributions being created by such devices. Specifically, a case where multiple harmonic loads are connected to a single power socket through an extension board, with different combination of loads, will be considered. An aim of the work is to derive a relationship between the harmonics induced and the heating effect they create. The heating effect in this regard, will be presented in consideration of worst case scenarios arising from parametric variations. Current (*i*) waveforms consumed by these devices are recorded, and Fourier analysis is conducted to find the total harmonic distortion (THD_{iV}) caused by these devices. The results will be employed to consider precautions or the limits from which, suggestions for mitigation methods or best practices associated with such loads can be considered. This work, is also relevant in the context of *smarter networks*, where consumers are also potentially *prosumers* (customers that both consume and produce electricity). Such renewable energy system integrations are aggregable sources of harmonics as well.

Keywords: Harmonic analysis, Harmonic distortion, Ampacity cables, Non-linear loads, Harmonic content

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Adaptive solar building envelope with thermal energy storage

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Abstract

Conventional buildings are characterised by low and static thermal heat transfer coefficient, which limits their thermal response to diurnal and seasonal meteorological changes. This leads to overall increased heating and cooling demand of the building to maintain the desired levels of interior comfort. Appropriate thermal insulation strategies offer better thermal energy management and significant energy efficiency in buildings. An adaptive building shell, with flexible parameters (thermophysical/optical), that adjusts and utilises this variability to mediate indoor climates, could therefore logically address the problem. There appears to be extensive scope for further research into adaptive building envelopes to benefit energy usage and efficiency.

Hence, this paper aims to demonstrate the potential of combining dynamic heat transfer mechanisms with thermal energy storage in a novel building wall prototype. The evacuation methodologies proposed to vary the building insulation is a novel way to efficiently control the heat transfer between the interior and exterior building environment. The dynamic insulation feature of the envelope augments the heat stored in the thermal energy storage, which could be utilised to provide space heating as and when required. Overall, the proposed wall prototype is expected to exploit the solar heat gain more effectively and have improved thermal response to transient environmental conditions.

Components of prototype unit have been designed and fabricated to experimentally characterise their heat transfer characteristics. Several sample square enclosures (1m × 1m × .02m and 0.5m × 0.5m × .02m) of the component unit have been constructed. They are all built using stainless steel, set with an array of support spacers inside to prevent the units from collapsing under the influence of atmospheric pressure. Different materials and geometry of the support spacers were considered. Short term investigations of these sample units were conducted under the simulated conditions to study the effects of dynamic insulation on the thermal performance for both atmospheric and evacuated pressure conditions.

A comprehensive analysis of the results highlights the significance of the spacers used to support the enclosure under evacuated conditions. Judicious selection of the spacer material, geometry and permissible design values for the array are thus crucial to the overall system's thermal performance. Further, the study offers considerable scope to predict generalised heat transfer correlations in evacuated enclosures and develop simulation models to validate and test its accuracy.

Keywords: solar energy; building envelope; heat transfer; efficiency; thermal storage

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Financial sustainability of photovoltaic generation capacities for self-consumption in large scale commercial buildings – A case study for Rumania

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Abstract

Intensive development of large commercial buildings (LCB) in Romania, covering a range of electricity demand of 1÷10 MW, requires a new approach on electricity supply solutions especially when there are positioned in crowded urban areas. Considering the large consolidated surface of these buildings, there are suitable to become prosumers of renewable energies, since are able to fulfilling at the same time the role of a concentrated energy consumer and producer. In this paper were studied the technical and financial conditions for which a LCB becomes self - electricity producer and self - electricity consumer in a sustainable way, considering the case of a local photovoltaic network system. A LCB site – placed in the metropolitan area of Pitești city in Rumania, covering an area of 10.6 ha and an installed power of 7 MW - was scrutinized considering the solar potential of the site, the demand curve of the consumer and the balance consumption/generation. Power flows were determined by using simulations with ETAP software in order to assess the impact on the distribution network. There were identified the optimal solutions for reactive power compensation and power factor improvement within imposed limits. The impact issue was addressed by assessing various power quality parameters, along with the reactive power variation within the boundaries set by the Rumanian National Regulatory Body (ANRE). The simulations took into account the feature of modern photovoltaic power plants of generating or absorbing reactive power by using their own inverters. The technical outcomes were compared to the avoided costs by self-consumption, and have highlighted that the self-sustainability condition is fulfilled when the electricity produced by solar photovoltaic panels covers at least 90 % of the annual electricity consumption. Depending on the power demand, authors had proposed minimum values for the installed capacities, related to the electricity measurement point, where economical size was validated by practice - for LCB the installed power value was computed at minimum 3 MWp. At the same time, the paper highlights the differences that occur due to the local variation in the distribution tariffs for different service areas.

Keywords: photovoltaic system; reactive power; prosumer

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Building integration of solar thermal systems- exemple of a refurbishment of a church rectory

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Abstract

The purpose of this article is to outline some of the potential challenges and rewards that come with the solar systems integration in the buildings.

We present in this article a project falls within the framework of a European project Maritimo with different Italians partners on the subject of refurbishment. The aim is the refurbishment of Mediterranean houses. This project is situated in a Corsican village near the centre of the island.

In fact, the solar industry is relatively mature, the cost of these products is stabilized and it is likely to evolve quite slightly over the upcoming years: other than a scale effect resulting from rapid growth markets, only a technological breakthrough in the act of conception, could significantly change the economic level. The following barriers are identified (in order of importance): financial, technical and psychological (the psychological barriers are related with the aesthetics and the rigidity of the architectural codes. The problems, both technical and aesthetic, are the obvious obstacles to the development of this type of systems. For these reasons, in the frame of the present work, a new flat plate solar collector and a new solar air collector with high building integration and a prototypes of these collectors were developed. First experimental results in a Church rectory situated in Bocognano, (Corsica, France) are presented in order to show viabilities of these solar technologies.

This project is built on the objectives of contributing at the European politic on the «Building Integration of Solar Thermal Systems» (BISTS) through the COST Action «European Cooperation in Science and Technology» - TU1205

Keywords: Solar Energy, Thermal Collectors, building Integration.

Building-integrated photovoltaic/thermal (BIPVT) prototype: Environmental assessment focusing on material manufacturing

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Abstract

The study presents environmental issues about a building-integrated photovoltaic/thermal (BIPVT) configuration. The studied module is a prototype that has been developed at the Ulster University (Belfast, UK) and it has been patented. The investigation gives emphasis on the phase of material manufacturing and it includes the inputs in terms of the materials/components needed for one module. For the evaluation of the BIPVT prototype from environmental point of view, a model has been developed based on different methods: CED (cumulative energy demand), GWP (global warming potential: CO_{2,eq} emissions), ReCiPe. A comparison with the literature (table below) is also provided and in general, a good agreement is observed. Conclusively, the present study provides useful information given the fact that in the literature there are few studies which present environmental issues/LCA (life cycle assessment) about BIPVT and most of them show results in terms of embodied energy and CO_{2,eq} emissions.

STUDY / TYPE OF BUILDING INTEGRATION	TYPES OF PV CELLS EXAMINED	WORKING FLUID	TYPE OF SYSTEM, APPLICATION, ETC.	ENVIRONMENTAL ISSUES STUDIED	REFERENCE AREA OF THE SYSTEM	RESULTS FOR THE PHASE OF MATERIAL MANUFACTURING
Present study / BI	Mono-crystalline silicon	Water	BIPVT for domestic water heating	CED, GWP, ReCiPe	1 m ² thermal absorber	4.92 GJ_{primary} (CED) 0.34 t CO_{2,eq} (GWP 100a)
[1] / BI	Multi-crystalline silicon	Air	PV and PVT systems for roofs	Embodied energy, CO _{2,eq} emissions	9.4 m ²	Expected values per m ² of module: 5.19 GJ LHV 0.45 t CO_{2,eq}
[2] / Building-added	Multi-crystalline silicon	Air	PV and PVT systems for roofs	Embodied energy, CO _{2,eq} emissions	30 m ² aperture area	Expected values for 1 m ² aperture area: 4.59 GJ LHV 0.41 t CO_{2,eq} (GWP 100a)
[3] / Building-added	Multi-crystalline silicon	Water	PV and PVT systems for roofs	Embodied energy, CO _{2,eq} emissions	30 m ² aperture area	Expected values for 1 m ² aperture area: 4.94 GJ LHV 0.43 t CO_{2,eq} (GWP 100a)

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Multicriterial optimization of procedures For the selection the best measures for energy performances improvement of the multifamily housing in Belgrade

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Abstract

The subject of this paper is multi-criteria analysis of the selection of the best group of measures for energy efficiency improvement of multifamily housing in the suburb Konjarnik in Belgrade. The results of all the proposed measures for energy performances improvement of the building envelope were calculated on the basis of thermodynamic simulation of 3D mathematical models in a specialized software package *TAS*, according to Serbian Regulations on energy efficiency in buildings and Regulations on terms, content and method of issuing certificates of energy performance of buildings. The results of all the proposed variants of solar thermal systems' application were calculated on the basis of simulations, carried out for all variants in the program *Polysan 4*. Selection of the optimal sets of measures for energy efficiency improvement is made on the basis of multi-criteria optimization using the method of multi-criteria compromise ranking of alternative solutions - AHP method (Hierarchical Analytical Process). AHP method is one of the most popular methods of scientific analysis of scenarios and decision-making through the process of evaluating alternatives in the hierarchy which consists of goal, criteria, sub-criteria and alternatives.

The goal of optimization is to select the best combination of measures for energy renewal of the existing building, or the best variant of a series of offered favorable variants in terms of adopted criteria and defined limitations. For the purpose of energy renewal of the existing building and according to recommendations of national regulations, 5 measures for energy efficiency improvement was adopted. The measures include the thermal performances improvement of non-transparent and transparent parts of the thermal envelope of the building and the use of renewable energy sources, respectively integration of solar thermal collectors into the building envelope. Considering that all of the proposed measures for energy efficiency improvement of the building can be simultaneously applied, which represents a significant construction and financial intervention, 8 combinations of possible measures were adopted and defined as alternatives. The combinations of the proposed measures are done on the basis of engineering experience.

For multi-criteria optimization, a set of the following 5 criteria is adopted, according to which alternatives are evaluated:

- Annual final energy consumption for heating;
- Annual primary energy consumption for heating;
- Annual CO₂ emissions;
- Investment costs for energy renovation of buildings;
- Return period of investment means.

The values of all criteria functions according to all alternatives are shown. In the process of decision-making, problem assigning weight to the criteria is solved by simulating the structure of preferences. Three scenarios were defined, and for each scenario a different combination of criteria weights. The first scenario represents the case when all criteria are of equal importance. In the second scenario, ecological interest is represented so that the greater value is given to the environmental criteria weights, and therefore to annual final and primary

energy consumption. In the third scenario, financial interest is represented so that the greater values are given to the economic criteria weights that include investment costs and payback period of investment. Finally, ranking of alternatives is done according to three selected scenarios of different combinations of criteria weight.

The aim of this study is to demonstrate the efficacy of AHP method in practice when necessary to reach an optimal decision in selecting the best measures for improving the energy performance of buildings.

Keywords: decision-making, multi-criteria optimization, measures for improving the energy performance of buildings.

Integration of PV modules into the building envelope in aim to achieve energy and environmental benefits

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Abstract

The main target on which this paper is directed is achieving energy savings and reduction of CO₂ emissions through integration of Photovoltaic (PV) modules into the building envelope. The concern of the paper is to present different models of energy efficiency improvement of the office building in Block 26, New Belgrade, Serbia, by application of active solar system to the building envelope, more exactly by integration of PV modules into the facade structure. The paper shows hypothetical models of the office building energy improvement for Belgrade climate conditions.

The building's energy efficiency is defined according energy necessary for cooling, lighting, equipments and other needs settled with electric energy. Models of PV modules integration into the facade structure are discussed by aspects of energy efficiency and reduction of CO₂. Methodological approach entails estimation of electric energy consumption of the existing building, design of hypothetical models – architectural integration of PV moduls and comparative analyses of obtained results regarding energy and enviromental benefits, discussion and conclusions.

According to analyses presented in the paper it is concluded that facades with sloped PV modules contribute to energy efficiency of building. Achievement of energy savings and reduction of CO₂ emissions are presented in the paper. New aesthetic potentials in refurbishment of the existing buildings can be obtained by application of PV modules. Office building appearance is also taken into consideration.

Keywords: Building integrated photovoltaics, Office buildings, Building appearance, Energy efficiency, CO₂ emissions.

Double skin façades integrating photovoltaics and active shadings: A case study for different climates

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Abstract

In this paper the energy potential of an innovative Double Skin Façade integrating Photovoltaics (DSF-P) for different weather conditions is investigated. The proposed system consists of semitransparent and opaque PV modules integrated in the exterior skin of the façade and active shading devices implemented within the cavity, as shown in Figure 1.

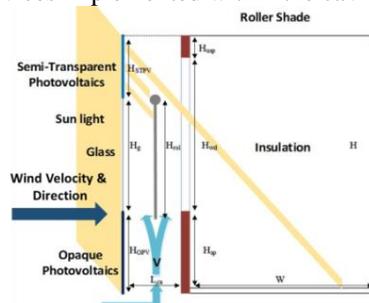


Figure 1. Sketch of the modelled DSF-P

The innovative single or multi-story proposed DSF can co-generate solar electricity and thermal energy (for space heating or other building applications). In order to effectively cool down the photovoltaics and increase their electrical efficiency, the buoyancy-driven air flow within the cavity may be assisted by a fan (natural / hybrid ventilation). Active roller blinds are taken into account in order to regulate heating and cooling loads while controlling the daylight in the corresponding adjacent indoor spaces.

In order to simulate the system performance, to predict the energy flow, temperature distribution and airflow in the DSF, as well as the active and passive effects of the DSF-P on the energy consumption of the adjacent perimeter zones, a mathematical model was developed. The simulation model is based on a detailed transient finite difference thermal network, including accurate algorithms for the calculation of the heat transfer phenomena taking place within the DSF-P. The model also allows performing sensitivity and parametric analyses, useful for pre-feasibility studies at the design phase of new buildings or for retrofit projects implementing the proposed DSF-P.

In order to determine the values of critical design and operating parameters that minimize the overall energy consumptions, while guaranteeing visual and thermal comfort of occupants, a parametric analysis is carried out. Specifically, a comprehensive case study related to a high-rise office building located in different climate zones is taken into account. Numerical results show that, by suitably optimizing the DSF-P design and operation, the energy demand of the adjacent perimeter zones can be covered by the generated PV electricity, necessary to reach the goal of net zero energy building.

Study on the energy performance of semi-transparent PV façades under continental climate

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Introduction

The use of largely transparent facades in commercial buildings has been a common practice in building design during the last two decades, mainly due to an increased appreciation of daylighting. This trend is likely to continue as more studies link daylight and a view to the outdoors with increased worker productivity, well-being [1] and reduced lighting loads [2]. Currently, highly-glazed façades maximize the incoming daylight rather than controlling it appropriately, which could lead to excessive solar gains, increased cooling loads and thermal/visual discomfort in perimeter building zones. However, this trend has the potential to have an important positive impact on building energy performance while providing a comfortable space for its occupants, if solar cells are integrated in windows [3]. Instead of using reflective coating or ceramic frits to reduce the solar gains, semi-transparent photovoltaic (STPV) could be integrated on parts of the façade [4], [5]. As a result, solar heat gains may be reduced, maintaining adequate levels of daylight, view to the outdoors [6], while generating electricity. When PV cell overheating is of concern, the window sealed cavity can be replaced with a ventilated one, turning the façade into an active STPV thermal (STPV/T) collector in addition to the electricity generation and daylight transmission [7]. The absorbed solar energy that is converted into heat is recovered either actively, using a fan or pump, or passively flowing air on the rear side of the STPV module. As the air circulates behind the PV cells, it cools down the cells through convection, reducing the temperature of the cells and increasing their electrical efficiency.

Objectives

STPV façades could have a substantial effect on the daylighting/lighting performance as well as energy and peak power demand reduction on highly-glazed office buildings. The objective of this study is to investigate the energy performance of three prevailing STPV façade configurations (Figure 1): i) curtain wall systems incorporating STPV insulated glazing units, ii) STPV/T curtain wall systems and iii) double skin façades incorporating STPV technologies on the outer skin. The study focuses on offices in a continental climate region (Northeastern United States and Southeastern Canada) and it is part of a larger effort to provide input to the design guidelines for the utilization of advance fenestration technologies that will help to achieve net-zero energy building performance targets and beyond, through energy conservation and renewable energy generation.

Approach and preliminary results

An integrated (daylight, thermal and electrical) simulation model is used to carry out an annual performance study for an archetype office building located at Toronto, Canada. The model is experimentally-verified. The analysis demonstrates that the use of STPV façades have the ability to generate enough electricity to cover the annual electricity demand of the building on electric lighting and plug loads. In the case of STPV/T or double skin façade, a significant amount of useful heat (in the form of preheated outdoor air) could be also generated. The heated air could be used to assist a solar assisted air-source heat pump that could be used to partially satisfy the heating and cooling demands of the building. Moreover, the use of

STPV/T or double skin façade reduces the heat losses through the building skin during the heating season.

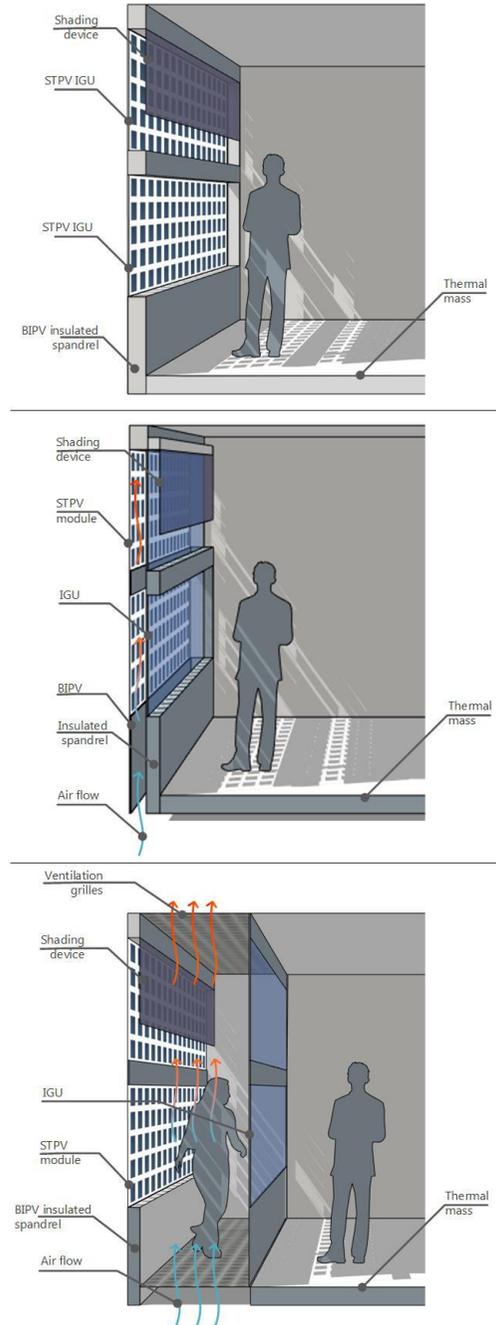


Figure 1. Schematics of the three STPV façade configurations studied: a curtain wall system incorporating STPV Insulated Glazing Units (IGU) (top), ii) STPV/T curtain wall system (middle) and iii) double skin façades incorporating STPV technologies on the outer skin (bottom).

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A building integrated solar air heating thermal collector prototype: modelling, validation and case studies

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Abstract

In this paper, the thermal performance analysis of a prototype Flat-Plate Solar Thermal Collector (FPC), using air as working medium, is presented. The collector is designed to be integrated in the building envelope (Building Integrated Solar Thermal System - BISTS), Figure 1. With respect to existing commercial collectors, such prototype is characterized by low cost materials and fabrication.

In order to predict the thermal performance of the investigated system, a numerical simulation model is developed. The model, written in MatLab environment, is implemented in a suitable computer code for dynamically assessing the system energy, economic and environmental performances. Specifically, the model is capable to predict the collector active effects (e.g. air heating for ventilation purpose, etc.) and the passive ones due to the building integration on the heating and cooling loads. The prototype simulation model was validated by means of experimental data collected in Limassol (Cyprus) during experimental testing.

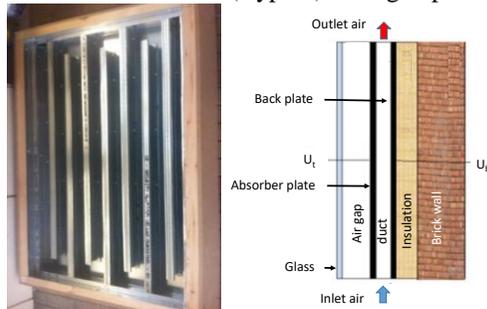


Figure 1. The modelled solar thermal collector prototype for air heating

In order to assess the system performances and to show the features of the developed simulation model, several comprehensive case studies are developed. The operation and performances of both the stand-alone and the building integrated collectors are analysed. In particular, the FPC prototype is integrated in the south facing façade of a high-rise building, characterized by diverse uses (dwelling and office buildings), located in different weather conditions (cold and warm climate zones). In addition, for comparison purposes, a building reference system layout is taken into account. With the aim at optimizing some collector design and operating parameters, a suitable parametric analysis is also carried out for the stand-alone collector layout. Simulation results show that interesting energy performances can be achieved, especially for climates with a long heating season.

Keywords: Dynamic energy performance analysis, building integrated solar thermal system, experimental analysis

Building façade integrated solar thermal collectors for water heating: simulation model and case studies

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Abstract

This paper presents a dynamic simulation model for the energy and economic performance assessment of a novel building integrated solar collector prototype, for Sanitary Hot Water (SHW) production and space heating. The investigated device is a Flat-Plate Solar Thermal Collector (FPC) with water working fluid, suitably designed to be integrated in the building envelope (Building Integrated Solar Thermal System - BISTS). The developed model was conceived for assessing the active effect of the collector as well as the influence of its building integration on the building thermal behaviour and thermal loads (i.e. overheating). The main differences of the proposed novel collector with the existing technologies consist in the system simplicity and low fabrication cost.

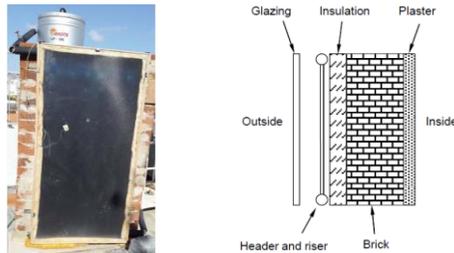


Figure 1. The modelled solar thermal collector prototype for water heating

The developed simulation model, written in MatLab environment, is implemented in a suitable computer code. Such tool is validated by taking into account the data collected through a suitable experimental analysis recently carried out in Limassol (Cyprus).

In order to assess the system performances and to show the features of the developed simulation model, several comprehensive case studies were developed. In particular, they refer to the installation of the examined FPC prototype on south facing façades of different buildings, e.g. characterized by diverse uses and envelope weights, and located in several weather zones. For each weather zone and building typology, a suitable parametric analysis, focused on several system design and operating parameters, is carried out. Suitable reference system layouts are also taken into account for comparison purposes (e.g. buildings without and with stand-alone solar collectors).

Simulation results show that interesting energy, economic and environmental advantages are always obtained through the adoption of such prototype. The energy performance and the payback periods strongly depend on the simulated weather zone.

Keywords: Building integrated flat-plate solar thermal systems, dynamic energy performance simulation, experimental analysis

Exergetic and energy-economic analysis of a building integrated photovoltaic and thermal system

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Abstract

This paper presents a detailed exergetic and energy-economic analysis of a Building Integrated PhotoVoltaic Thermal (BIPVT) system. For an optimal use of building envelope, BIPVT systems, consisting of flat-plate PVT solar collectors, are integrated in the south facing facade of a non-residential high-rise building. The BIPVT collectors produce: i) thermal energy for space heating purposes, by a radiant floor system, and Domestic Hot Water (DHW) production, and ii) electricity to satisfy the building energy demand. Electric air-to-water heat pumps/chillers and water-to-water heat pump are used as auxiliary systems for space heating / cooling and DHW preparation, respectively. In addition, with the aim to mitigate the effects of solar energy intermittency and obtain a virtually grid-independent system, an electricity energy storage system coupled to the BIPVTs system is modeled.

In order to compare the proposed BIPVT system to a traditional building, a reference building model, i.e. without BIPVTs, energy storage and radiant floor, is considered. Here, the space heating and cooling is obtained by air-to-water heat pumps (one for each floor), DHW is produced by a condensing boiler and electricity is supplied by the national grid. The comparison is performed for three thermal zones, well representative of the thermal behavior of the whole building.

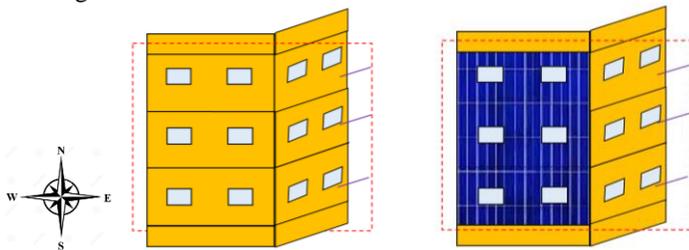


Figure 1. Reference system (left), proposed layout (right).

In this paper, a detailed simulation model implemented in TRNSYS environment, is developed in order to predict the dynamic behaviour of the BIPVT system. Energy and exergy balances are taken into account to determine, for the 1-year operation, the exergy destructions and exergetic efficiencies of each of the investigated components and of the whole system. The magnitude of the irreversibilities in the system are calculated with the aim to propose possible enhancements. In addition, the energy analysis of the proposed BIPVT system located in several European weather zones are also carried out. Such analysis aims to also assess the useful / undesired effects due to the building integration of PVTs and to the electricity storage on the building energy demands (e.g. heating / cooling and electricity). Finally, the economic viability of the proposed system is also discussed.

Keywords: Dynamic simulation, exergetic analysis, BIPVT, building Integrated Solar Thermal Systems (BISTS), electricity energy storage.

Geometrical optimization of the urban fabric in order to ensure the viability of building integration of active solar systems

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Abstract

This paper aims to determine the optimum geometry of the building blocks in order to ensure the viability of specific building integrated solar systems (BISTS, BIPV) in the current urban fabric. The proposed research starts with an analysis of the fabric's geometry and characteristics as they are defined by law, and through a literature review, explores the possibilities of building integration of active solar systems in the urban fabric, whilst similar attempts of research are reported and analyzed.

For the main body of the research, a simple set of rectangular building blocks is created, and through the configuration of some parameters the most viable geometry is determined, in order to have the most possible insolation on the buildings' roofs and facades. The parameters are the ratio between the length and the width of the building blocks, the width of the streets between them, the height of the buildings and the geometry of the buildings that can be accommodated in the proposed building blocks. The buildings' geometries are determined in ways that they could accommodate apartments in a viable way in order to create sustainable neighbourhoods. The insolation, which reflects the potential for the building integration of active solar systems, is calculated with the use of digital modelling.

The ultimate aim of this work is to present and analyse the limitations and problems of the integration in the urban fabric, and propose research-based solutions, which could establish a guide that gives guidelines for building integration of active solar systems on a neighbourhood level. Further research will determine the ratio of the building's usable area / solar system's area if the geometry of the building is optimal, and the findings will be applied to the actual urban web of Cyprus in order to be optimized. It will also be investigated whether the solar urban design reduces the ability of the existing or potentially existing urban fabric to cover the needs of the city into residential units.

Keywords: Active Solar Systems, Architectural Integration, BIPV, BISTS, Urban Solar Potential, Sustainable Urban Planning, Solar Urban Planning

Aesthetic aspects for building integrated solar and wind energy systems

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Abstract

Solar energy systems, together with other renewable energy sources and energy saving technologies, can contribute to adapt the energy targets of EC for 2020 and 2030. The changing in the energy mix that is planning for the next decade is not easy to be achieved and several difficulties should be overcome. Energy saving should be of priority and the built sector is the first one that should contribute, with most important the introduction of the nearly Zero Energy Building concept from 2020. The external surface of buildings constitutes the surface area for an effective, multifunctional building skin. Towards the design of such buildings, alternative skin designs are suggested regarding effective integration of solar thermal collectors, photovoltaics, hybrid photovoltaic/thermal collectors and small wind turbines. These systems can provide heat and electricity and combined with geothermal heat pumps and biomass boilers, can adapt energy building needs. In addition, the suitable design of building balconies and atrium spaces with the integration of curved reflectors and Fresnel lenses, could provide solar control to the interior spaces. Buildings can be designed according to bioclimatic architecture, using new heat-insulating materials and smart windows, which reduce effectively thermal losses during the winter and energy for cooling during summer. The installation of energy devices and active solar energy units is related with their cost increase and their harmonization with the architecture of the buildings. In this paper, aspects and considerations regarding the effective building integration of solar energy systems, as of solar thermal collectors, photovoltaics, hybrid photovoltaic/thermal (PV/T) systems and also of small wind turbines, are presented and discussed regarding energy, cost and aesthetic view. The solar energy and the wind energy systems are directly visible systems to everyone and their design should adapt the building architecture and surrounding environment. On the other hand, the external view of the buildings should not be covered by same solar and wind energy systems, as monotony in shape and color is not a concept of beauty. Therefore, the solar and wind energy system designers, the architects, engineers, physicists and other contributors to building energy covering, should consider the holistic concept, where the buildings are part of the new formed social human environment, in a very closed relation with the natural environment. The built sector, together with the other energy consumption sectors (industry, agriculture and transportation) has to be seen as a new field for aesthetic creation, forming a new urban landscape. Developed designs for building integrated solar and wind energy systems are included in this work and can be considered examples for application to new buildings.

Integration aspects of solar energy systems to renovated buildings

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Abstract

Building sector is the most important one for the energy consumption and every step to energy saving and energy source replacement by renewable energy sources contributes to overcome environmental and economical problems. Considering the zero energy building concept, although it is not addressed to old buildings, most of existing buildings could be improved in energy consumption and install solar thermal collectors, photovoltaics and hybrid photovoltaic/thermal (PV/T) systems. In order this solar energy prospect to be successful, improved methodologies in energy saving and operation should be used, applying smart building energy technologies, which will reduce the energy load of building. To deal with this problem, new technologies have been developed to improve the energy performance of buildings, accompanied by the use of systems which exploit the solar energy and other RES, in order to cover their energy needs. The application of solar energy technologies, alone or combined with wind energy technologies, should be analytically studied, adapting effectively the cost, energy supply and aesthetic integration of them to buildings. In this paper, integration aspects for solar energy technologies adapted to building eco-retrofitting, is presented. Considerations for energy and building eco-improvement of a typical one family Greek house and of a hotel, are presented and analyzed. Critical parameters for the effective integration of solar energy systems are the building orientation and the external surface availability. Regarding orientation, the slope and azimuth angle of the building inclined roof and of the azimuth angle of the façade, are not always the ideal by the energy point of view. A significant energy output reduction in heat and electricity is observed in most cases, due to not perfect orientation. We studied experimentally the effect of slope and azimuth angles and solar radiation incidence angle to thermal collectors and photovoltaics surface, to record the energy output. Considering external surface availability, the application of hybrid PV/T systems can be recommended, as they can provide simultaneously electricity and heat, covering smaller surface area in comparison with separately installed thermal collectors and PV panels. These systems can provide preheated fluid, which can be heated to the final temperature by an efficient solar thermal collector system. The heat from PV/T system can be also used to improve the COP of a Heat Pump, used for space heating of the building. For limited availability of building external surface to mount solar energy systems, the use of hybrid PV/T systems can be considered as an effective solution. Towards this aim, aspects for improved performance of PV/T systems, with low cost heat extraction modes, are referred as developed solar energy systems that can provide more benefits.

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Application possibilities of building integrated solar tile collectors

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Abstract

This paper is dealing with the development of a new type of shell-structured solar collector for the heat exploitation of solar energy for building use and to define its thermal efficiency. In designing of the shell-structured collector bodies it was used a proper combination of the traditional and new type of construction materials. The literature review confirms that solar collectors appreciated not only by their usefulness, but also according to their aesthetic considerations. In this paper such principles are also included. In addition to traditional solar collectors is viable to study the solutions how the structural elements of the buildings can be used to capture solar energy, when the architectural design would not change, but the required surface operates as solar collector (Fig. 1).



Fig. 1. The traditional and advanced structure design of solar collector

During the modelling and simulation of the solar system strong consideration was given to the efficiency issues. The energy balance equation of the collector includes the influencing factors especially the radiation and heat convection, which are expressed by their heat loss coefficients. The temperature distribution on the collector surface was validated by an infrared camera recording.

Finally, it has been developed an easy-to-install equipment, which is expected to be really effective in summer period along with improving the efficiency. Additionally, more accurate measurements are to be performed in order to improve heat transfer in the collector body.

It is also recommend such items to reduce the urban heat-island effect, when the heating of buildings worsens human comfort. A recommended use of such protected architectural elements designed for the renovation of buildings, along with the active utilization of solar energy in order to meet the increasingly stringent building energy standards.

The potential of concrete solar thermal collectors for energy savings

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Abstract

Solar thermal systems are amongst the most successful sustainable technologies commonly available. However, widespread uptake is still limited by the high capital cost. Solar thermal collectors manufactured from concrete offer a cheap alternative to the standard range of solar thermal collectors. Concrete is also inherently durable, maintenance free and exhibits good thermal storage qualities given its high specific heat capacity and density. Also considering the wide range of concrete, textures and surface finishes now achievable, concrete solar thermal collectors may offer greater potential as a façade integrated solar technology.

However, research by these authors into concrete solar collectors has presented the challenge in attaining the high output temperatures needed for domestic hot water (DHW) applications. Even with the optimisation of a number of parameters including concrete conductivity, absorptivity and pipe embedment depth, maximum output temperatures of 25 – 30°C for winter input water temperatures result. Similar to unglazed flat plate collectors which are also characterised low temperature outputs, supplementary heating of the water may be required to bring the water to DHW temperatures.

This study evaluates the real feasibility of concrete solar thermal collectors. Specifically it assess their potential for energy saving by reducing the energy requirement of the mechanical heating system by supplying input water at temperatures 15-20 °C above mains temperature. The relative savings for high temperature hot water radiator heating and low temperature underfloor heating are assessed. The energy payback is calculated for the maritime climate of Ireland, and extended to a selection of climates across Europe. The embodied energy of concrete solar thermal collectors relative to other collectors is also evaluated. Concrete solar thermal collectors are shown to have good potential for energy saving and should be considered amongst the range of solar thermal technologies.

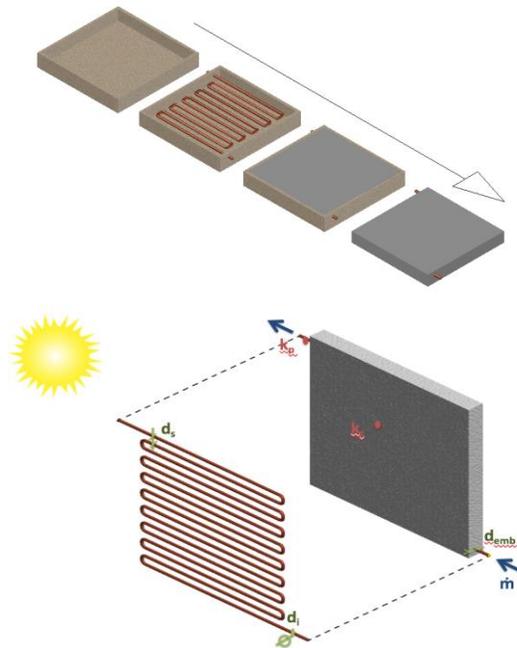


Figure 2. Concrete Solar collector

Building integrated photovoltaics in the overall building energy balance: Lithuanian case

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Abstract

The integration of PV systems into buildings becomes more and more significant in the context of increasing energy consumption and rising energy costs. The paper presents analysis of roof and walls integrated PV system performance on the overall building energy balance, based on simulations and experimental data.

The renovation of residential building, in Kaunas town, Lithuania, was chosen for the analysis. The purpose of renovation was to reduce the energy costs and the environmental impact from energy production. Energy production and efficiency of roof integrated PV system were simulated and economical assessment of the renovation was performed. An alternative case - PV integrated in the facade was analysed by different softwares.

Keywords: integrated PV system, renovation, efficiency, simulation

Case studies on Upper Austria examples of integrated solar thermal systems for buildings

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Abstract

The paper will be about the benefits of solar thermal systems. The current trend in low carbon assessment is mainly related to the production of electricity by photovoltaic systems. The cost-benefit analysis, however, comparing these systems with systems using integrated solar thermal principles shows a very challenging profile of benefit in favour of solarthermie. The parameters of these benefits will be presented and analyzed and a reference will be given in context to smart energy and buildings.

A second part will be the presentation of Austrian cases studies of relevant examples using integrated solar thermal systems. The study will focus on lessons learned and deviations from planned data.

Keywords: Integrated solar thermal systems, case studies, cost-benefit relation, Smart Energy Systems, Life cycle Assessment;

Sustainable retrofitting of existing residential buildings: a case study using a rainscreen cladding system

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Abstract

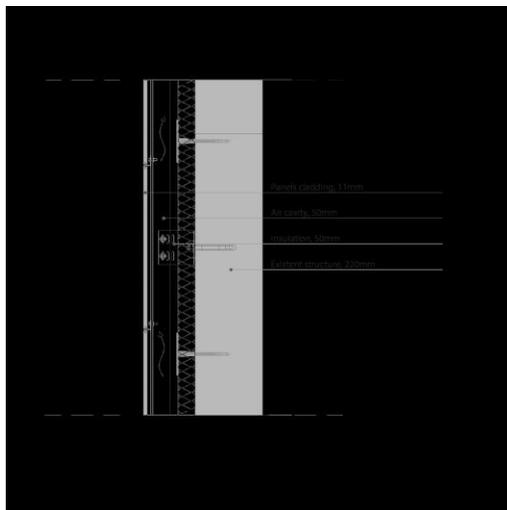
The energetic requalification of the existing buildings stock is a key question in the attainment of the ambitious program regarding the energy efficiency proposed by European Union. There are several measures taken to increase the energy efficiency, both for new buildings and for existing buildings, such as the 20 – 20 – 20 EU Policy which one give the guidelines to be followed in order to attenuate the energy consumption in this sector. However, to achieve these goals, especially considering the current stock of buildings, new redevelopment solutions are needed, which must be well adapted to the specific needs.

The Europe has a vast heritage of buildings built in precast reinforced concrete panels, realized after the Second World War, in order to solve in the fastest way, the housing deficiency, especially in Eastern Europe.

This study case takes in analysis the buildings stock of the post-war dwellings in the city of Timisoara. The research falls to a specific building model and propose a rehabilitation of the building envelope, through a particular structure of rain-screen cladding system made of prefabricated modules. The study has the goal to adopt a solution that could be a good compromise between quality, high performances, and reduced cost.

The precast module studied will be adaptable to the different morphologies and sizes of the type 744R buildings, so as to obtain a kit of second façade versatile and at affordable cost. This solution allows to adapt the new Europeans guidelines regarding on the energy performance, but also improve the socioeconomic value of the buildings.

Keywords: Retrofitting, sustainability, rainscreen cladding system, thermal analysis, collective dwellings, precast reinforced concrete panels



A review of materials science research pathways for building integrated photovoltaics

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Abstract

Buildings account for a large part of the world's usage of energy. Hence, there is a growing interest for renewable and non-polluting energy sources for utilization in buildings, both for existing and new buildings. A promising energy technology for buildings are building integrated photovoltaics (BIPV), which are part of or replace the traditional exterior building skin, e.g. roof and facades, and at the same time are being able to harvest the solar radiation and convert it to electricity in their solar cell elements.

Thereby, for BIPV the properties and requirements for both the solar cell technology and the climate protection screen will be important to address, e.g. aspects like solar cell efficiency, power output and performance ratio as well as rain tightness, robustness, durability and building physical issues such as heat and moisture transport in the building envelope. Moreover, the BIPV systems may provide savings in materials and labour in addition to the electricity generation. Several advances within the materials science of solar cells may turn out to become very advantageous for the integration part in buildings, where some keywords may be thin layers, flexibility, less solar cell material usage, solar cell concentrators, paint systems, ease of application, and snow and ice avoiding or repelling surfaces.

Thus, this work presents from a materials science perspective the possible research pathways and opportunities for the BIPV of tomorrow. These pathways include sandwich, wavelength-tuned, dye sensitized, material-embedded concentrator, flexible (e.g. copper indium gallium selenide CIGS and cadmium telluride CdTe), thin amorphous silicon, quantum dot, nanowire, brush-paint and spray-paint solar cell material technologies, different surface technologies and various combinations of these. Satisfactory durability requirements in terms of years will be dependent on the overall costs of maintenance and replacing the BIPV systems entirely, so in that respect the ease of application of e.g. thin solar cell paint layers by brush or spray may be promising for the future of BIPV.

Keywords: Building integrated photovoltaics, BIPV, Solar cell, Materials science, Review.

Large-scale laboratory wind-driven rain tightness testing of building integrated photovoltaics

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Abstract

The world's attention towards energy-efficient and zero emission buildings is increasing, where one key aspect among others is to utilize non-polluting and renewable energy sources. Building integrated photovoltaics (BIPV) represent an interesting solution both for existing and new buildings. Various research and development questions are being raised. In general, it is important to address the properties, requirements and possibilities of both the solar cell and building envelope for BIPV. The work presented herein focuses on large-scale laboratory testing of the wind-driven rain tightness of BIPV, where two specific BIPV systems have been selected as test specimen examples, where Fig.1 depicts some of these investigations.



Fig.1. Large-scale laboratory wind-driven rain tightness testing of BIPV applying a rain and wind box. Comparing BIPV tiles with normal tiles (left), inspecting for any water leakages

under a pitched BIPV roof (middle) and a detail showing a water leakage under the BIPV roof caused by protruding screw heads creating opening in the joints (right).

The main and long-term objective of this study is not, although crucial for a sound or fail-safe application of the actual BIPV product, to determine precisely the wind-driven rain tightness of the chosen BIPV system, neither the exact nature of building physical processes and aspects like heat and moisture transport through the specific building envelope. Contrary, the overall aim is, from these and other specific examples, to learn and generate more general principles for how to easily, flexibly and flawlessly integrate a large range of BIPV products, especially with respect to driving rain exposure and also in general for other outdoor weather strains and transport processes throughout the building envelope. Furthermore, robustness and durability issues will also be important to take care of. Finally, part of the general outcome may also be innovative and totally new BIPV systems, and how to test and characterize these.

Keywords: Building integrated photovoltaics, BIPV, Solar cell, Wind-driven rain, Driving rain, Rain tightness, Water leakage, Large-Scale, Laboratory.

A review of possible pathways for avoiding snow and ice formation on building integrated photovoltaics

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Abstract

As building integrated photovoltaics (BIPV) are becoming more widespread, the demand to utilize the BIPV in the best way with respect to several aspects, e.g. efficiency, power output and aesthetical considerations, will be increasing. Thus, there will also be a growing focus on how to avoid snow and ice formation on the exterior solar cell surfaces. During the winter period there is much less incoming solar radiation, however, this is also the period when the solar radiation is most needed and hence most valuable, both for heating and daylight purposes. In addition, snow and ice covering the solar cell surfaces may also lead to a more rapid degradation. As an example, a building with BIPV on the roof experiencing snow coverage during winter is depicted in Fig.1. The task to avoid snow and ice formation is rather challenging, also due to the fact that snow and ice and ambient weather conditions come in countless variations and processes. For example, snow downfall, freezing of rain water and condensation of air moisture and subsequent freezing, have to be taken care of in a satisfactory way.



Fig. 1 A building with BIPV on the roof experiencing snow coverage during winter (Living Laboratory, NTNU Gløshaugen Campus, Trondheim, Norway)

The review study presented herein goes through and discusses the various possible research pathways for snow and ice avoiding material surfaces, and looks especially at the properties, requirements and opportunities for BIPV applications. A special emphasis is given on materials science research aspects like e.g. self-cleaning, micro- and nanostructured, superhydrophobic and icephobic surfaces.

Keywords: Building integrated photovoltaics, BIPV, Solar cell, Snow, Ice, Self-cleaning, Superhydrophobic, Icephobic, Review.

Design and develop a novel concentrating PV ‘smart window’ for energy generation and solar control

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Abstract

In recent years the search for innovative ways to improve the energy consumption is becoming increasingly popular. The energy used in buildings is largely required for creating a thermally and visually comfortable environment for building occupants through the use of ventilation, heating, cooling and artificial lighting services which are responsible for most of the building energy demand. Amongst the building components, windows have a considerable impact on the building energy consumption and the indoor environment. A prototype novel concentrating PV ‘smart window’ system is developed and experimentally characterised in this work in order to provide a novel way to offset the aforementioned problems and understand its suitability for building integration. This novel ‘smart window’ system is comprised of conventional glazings, thermotropic reflective layer and solar cells and can be thought of as an electricity-generating smart window. It has been designed to automatically control the solar radiation entering buildings and at the same time generate clean electricity, therefore helping to mitigate the artificial light, cooling and heating loads. A hydroxypropyl cellulose (HPC) hydrogel polymer has been selected for the reflective layer of the smart window. Various weight percentage of the HPC has been synthesized, and the optical and thermal characteristics of the HPC reflective layer have been tested using an Ocean Optics Spectrometer 2000+UV-VIS-ES and in house developed temperature controller. The electricity generation rate of the system is monitored by using a Keithley K2430 I-V source meter where the developed system is investigated at different solar incidence angles and solar radiation intensities. Furthermore, 3D ray trace simulation was undertaken, for a better understanding of optical performance of the developed smart window and has been validated with the experimental measurements.

Theoretical and experimental study of a solar cooling adsorption system

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Abstract

Solar cooling is a viable technological solution to ensure comfort conditions. An important advantage of the solar cooling devices is that the greatest need for cooling coincides with the highest performance of the system.

Solar energy can be used to obtain cold by using thermal panels or photovoltaic panels. The analyzed, experienced or produced thermal solar cooling systems (closed cycles) are absorption cooling and, in the last decades, adsorption cooling systems.

The paper presents an analysis of a solar adsorption system. The experimental set up consists of solar thermal panels, a puffer and an adsorption cooling device. A mathematical model of the adsorption cycle is elaborated. The influences of operating conditions and the puffer on adsorption chiller performance are obtained. The results are presented in graphical form.

Passive solar floor heating in buildings utilizing integrated solar flat plate collector heat

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Abstract

Floor heating systems provide a comfortable indoor environment, because they allow heat to flow slowly in a natural way from the floor upwards. In this way the occupants of the space feel hotter on the feet and cooler on the head enjoying the indoor environment. To this contributes the temperature uniformity over the entire floor. Thermal mass integrated to the floor can act as a thermal reservoir that can store the solar gains of the day and, in this way, cover the heating needs of the building under certain climate conditions. In this study we examine the use of the foundation concrete as a storing material in new buildings, where the heat gains of a flat plate collector array on the south wall are transferred and accumulated.

As a first step, a model building typically insulated and with walls facing the four cardinal points was chosen for the study. The south wall area was assumed to be covered with Integrated Solar Flat Plate Collectors, and water was let to circulate with a pump between the collectors and the foundation concrete when the water temperature exceeded 40°C. A simulation model was built in TRNSYS with the above scenario and hourly results (for the winter period) of the collected solar energy and building thermal load were computed for the climatic conditions of Limassol, Cyprus.

The hourly results of TRNSYS, where then used as input in a simulation in COMSOL Multiphysics. The solar energy collected was directed for storing in the foundation concrete. After an initial time priming, the foundation's temperature was raised enough in order for it to be able to provide the daily heating load of the building. A part of the daily solar energy collected with the collector facade on the south wall, was also provided in the foundation for replenishing the lost energy.

The heat distribution over time is described by the general heat transfer equation based on the energy balance. Thus the three-dimensional conservation of the transient heat equation for an incompressible fluid used is as follows:

$$\rho c_p \frac{\partial T}{\partial t} + \nabla \cdot \mathbf{q} = Q \quad (1)$$

where T is the temperature [K], t is time [s], ρ is the density of the foundation material [kg m^{-3}], c_p is the specific heat capacity of the foundation material at constant pressure [$\text{J kg}^{-1} \text{K}^{-1}$], Q is the heat source [W m^{-3}] and \mathbf{q} is given by the Fourier's law of heat conduction that describes the relationship between the heat flux vector field and the temperature gradient.

Subsequently, the simulations were directed in examining the effect of various parameters, like the thickness of the concrete, the initial temperature, the amount of heat available and that which is stored, as well as the controlling technique. The results show that in the climatic conditions of the chosen area, the system chosen can cover completely the heat requirements of the building and provide comfortable conditions for the occupants during winter.

Evaluation of performance at experimental buildings and real demonstration sites in BFIRST project: Theoretical and practical aspects for BIPV monitoring system

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Abstract

Automatic data acquisition systems are generally required for monitoring, performance evaluation and exchanging data of PV systems. Standard IEC 61724:1998 “Photovoltaic system performance monitoring –Guidelines for measurement, data exchange and analysis” provides a guideline that shall be followed in these cases. As far as Building Integrated Photovoltaics (BIPV) are considered, besides electrical parameters there is in addition the need to monitor the specific building performances. That is because a BIPV module operates as a multi-functional building construction material; it generates energy and serves as part of the building envelope. In support of this, Standard EN 50583-1&2 “Photovoltaics in buildings” considers the following five specific functions for BIPV products: 1) Mechanical rigidity and structural integrity, 2) Primary weather impact protection (rain, snow, wind and hail), 3) Energy economy (such as shading, daylighting, thermal insulation), 4) Fire protection and 5) Noise protection.

BFIRST, Building-integrated fibre-reinforced solar technology, is a funded European project, project reference number 29601, which deals with the design, development and demonstration of a portfolio of innovative photovoltaic products for building integration, based on cell encapsulation within fibre-reinforced composite materials. The project is now in its final stage, under which demonstration and monitoring of the installed products are the most significant activities. Since the building related performances are not included in the aforementioned IEC standard, a general guideline was prepared within the project, which contains recommended procedure for:

- a) monitoring the basic electrical characteristics of BFIRST photovoltaic (PV) modules (as separate units or as an integral part of a whole PV array) such as the output and/or input power, voltage and current values in respect to non-electrical parameters such as irradiance at PV modules plane, as well as ambient and modules temperatures;
- b) monitoring of parameters related to the outdoor and indoor microclimate that can be used as a reference for experimental test sites or for climatic environmental characterization. These data are necessary in order to characterize the thermal and optical behavior of BIPV module;
- c) exchanging and analysis of monitored data.

This was the theoretical aspect of the activity. In practice two levels of monitoring activities have been adopted within the project:

- 1) experimental test sites: one in Portici (Southern Italy) and one in Pikermi (Greece)
- 2) demo sites with real size products: a retrofitted office in Zamudio (Spain), a newly built residence in Mons (Belgium) and a retrofitted residence in Pikermi (Greece).

The monitoring activity has been started very recently, by early June this year. More precisely, the monitoring of roofing shingle elements have been started at Mons demo-site over a plant of about 7 kW, while a module of 125 W has been installed in Portici for experimental purpose. The evaluated performance ratio is good enough, since values of about 0.9 were obtained both for the experimental test site and the demo site.

Next figures present real data both from experimental test site in Portici and from demo site in Mons. For further details, Fig. 1 illustrates the irradiance at the plane of a roofing shingle PV element (125W peak power) as well as the output power of the module for four clear and low wind days of July. Furthermore, Fig.2 presents the global radiation on the modules plane in Mons, and Fig.3 shows the temperatures on the back side of various roofing shingle modules as well as the chassis of the roof. Finally, Fig. 4 shows the 2 PV generators of the retrofitted office in Zamudio.

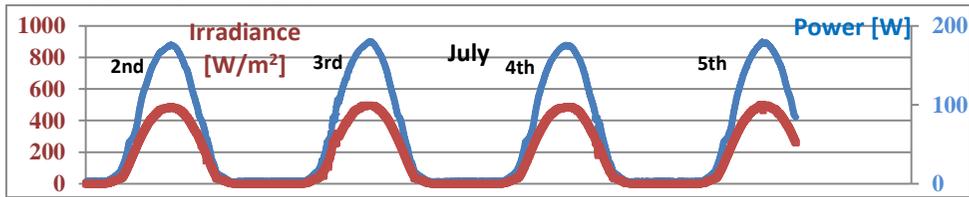


Fig. 1: Irradiance and peak power of a roofing shingle PV in Portici

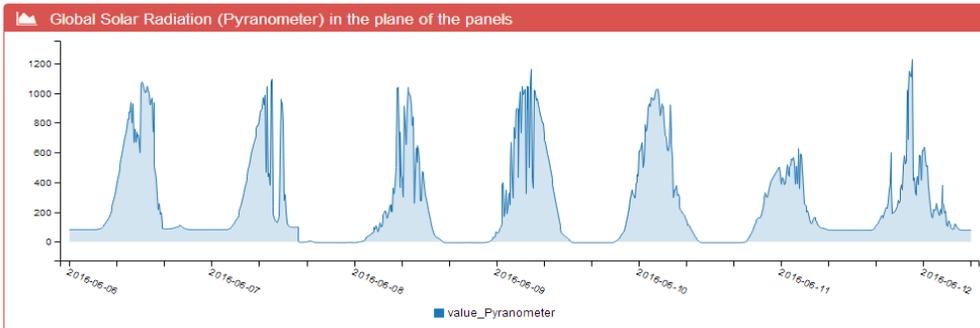


Fig. 2. Global radiation on the modules plane in Mons.

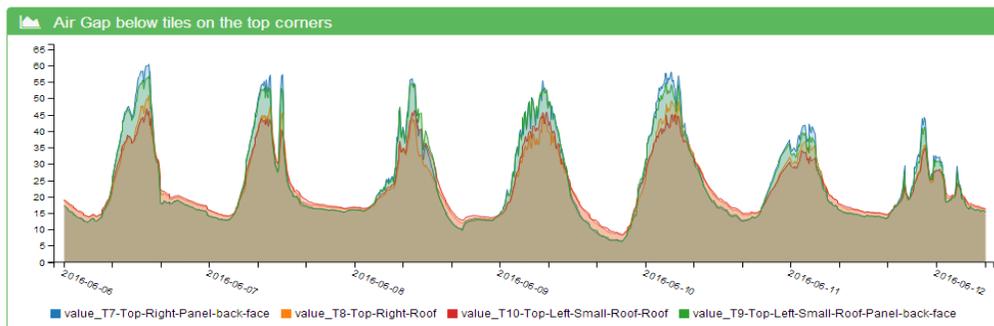


Fig. 3. Temperatures on the back side of various roofing shingle modules as well as the chassis of the roof

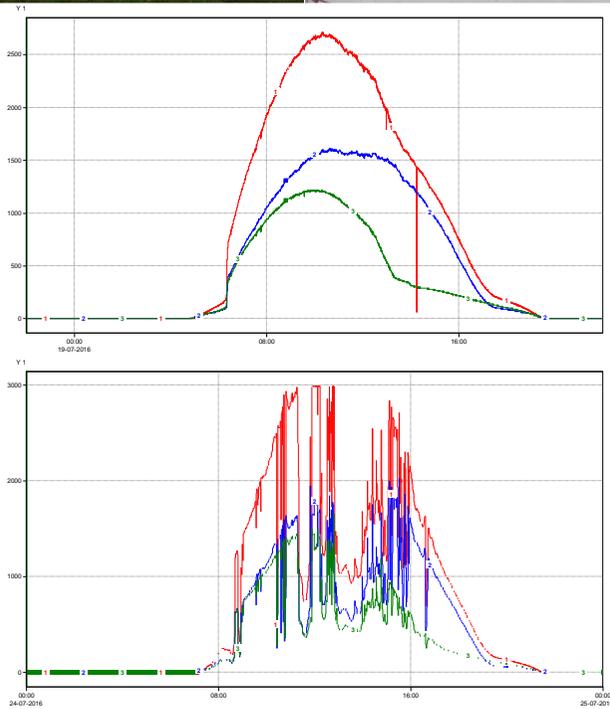


Fig. 4. The retrofitted office building in Zamudio, with the ventilated façade (up left) and skylight (up) generators. Below 2 days of performance (active power) of the 2-generators (blue skylight and green façade) and single inverter and no grid injection (red colored).

In the final paper results both from two experimental test sites, as well as from the three demo sites will be presented. Last but not least energy yield factors will be presented and discussed.

Design of an inverted absorber compound parabolic concentrator for air heating

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Dublin Institute of Technology

Abstract

In the present days there is a wide range of micro and macro renewable and sustainable energy methods available for reducing the inefficient use of fossil fuels, minimising carbon emissions and maximising energy use in a clean and environment-friendly process. In this context, solar energy plays an important role due to its abundance and ubiquity. Solar thermal systems (STS) provides thermal energy that meets local demand, whether for heating (water, air, space), cooling or for industrial processes. Hence, the main objective of this research is to design an inverted absorber compound parabolic concentrator (IACPC) collector capable of receiving solar insolation for at least 8 hours a day in the period of April to September. The methodology employed aimed at the selection of the collector's dimensions for building integration and the materials – glazing, absorber, reflectors and insulation – for its fabrication.

Thermal mass performance of concrete panels incorporated with phase change materials

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Abstract

Using the mass of a building as thermal storage system can reduce the demand on the auxillary heating and cooling systems of the building. Concrete combines a high specific heat capacity with a thermal conductivity that is appropriate for the diurnal heating and cooling cycle of buildings. The heat storage capacity of concrete can be enhanced by adding phase change materials (PCMs) which provide a high latent heat storage capacity. However the addition of PCM to concrete reduces the conductivity of the concrete due to the low conductivity of the PCMs. This reduction in conductivity may affect the ability of a PCM-concrete panel to absorb and release heat within a particular time period, for example a diurnal cycle, which hinders the efficient utilisation of the additional heat storage capacity provided by the PCM. Research was carried out to investigate different methods of combining concrete and phase change materials to form PCM/concrete composite panels. In the first method microencapsulated paraffin was added to fresh concrete during the mixing process. In the second method butyl stearate was vacuum impregnated into lightweight aggregate which was then included in the concrete mix design. The primary aim of the study is to determine which method is the most effective way to improve the thermal mass characteristics of a concrete panel in the context of a thermal energy storage system for space heating in a building. Follow on research was carried out to explore methods of improving the conductivity of PCM-concrete composites.

The study observed the rate at which the different panels absorbed and emitted heat, and how the heat flux varied throughout the depth of the panel. The panels were heated in a controlled environment provided by a specifically designed light box in which radiation was used as the heat transfer mechanism. Surface and internal temperatures of the panels were recorded during heating and cooling periods. The data recorded, together with the determined densities and thermal conductivities, were used to determine the influence that the method of incorporating a phase change material, had on the effectiveness of the PCM to improve the thermal mass characteristics of the concrete panel.

The study highlighted the complexity of thermal behaviour of PCM/concrete composites. The panels containing PCM displayed significantly greater thermal storage capacity despite having reduced thermal conductivity and density. The study concluded that the panel containing lightweight aggregate/PCM composite is more effective at providing additional thermal storage particularly within the first 100mm of depth of an element of structure.

The pilot photovoltaic/thermal plant at the university of Catania: description and preliminary characterization

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Abstract

In the perspective of the full exploitation of solar energy in urban and suburban area, the suitable surface for solar modules can become a disputable resource. Photovoltaic/thermal (PV/T) technology presents many attractive features since it is able to produce electricity and thermal energy at the same time with better overall performances and reduced surfaces in comparison with the two separated solar technologies. However, the effectiveness of the PV/T modules is most evident when they are integrated in complex systems, capable of fully exploiting their multi-functionality (e.g. heat pump coupling, multi-storage interconnection, etc.). The main objective of the present paper is to describe the features and technical characteristics of the pilot co-generative photovoltaic/thermal plant (PVTP) installed in the campus of the University of Catania, Catania, Italy (see Fig. 1). The crucial element in such system is the PV/T module (PVTM), unglazed tube and sheet type, that is the connection point between the two separate subsystems: the electrical subsystem (PVTE) and hydronic subsystem (PVTH). The described PVTP is able not only to produce and store at the same time electrical and thermal energy, but also to modulate thermal and electrical demand by means of a chiller and an electronic load, respectively. In this way it is possible to run the PVTMs at given thermal and electrical operating points in such a way to reach the right compromise between cooling the PV cells (high electrical efficiency) and getting high water temperature for domestic hot water and space heating (highest Carnot efficiency). Based on the data collected in real time by the monitoring system, an energy management tool will be included in such a way to optimize, respect with a given global technical/economic objective, the energy production and energy consumption profiles. The design of the experimental PVTP is very flexible to reproduce parallel and series connections of the PVTMs from both electrical and hydraulic point of view; for instance, it is possible to have an electrical series connections and a parallel hydraulic connection. The data acquisition and control functions on the PVTP are performed by means of a Modbus/TCP protocol that makes perfect integration to SCADA software and web based applications. Finally, some preliminary experimental measurements will be reported and discussed.

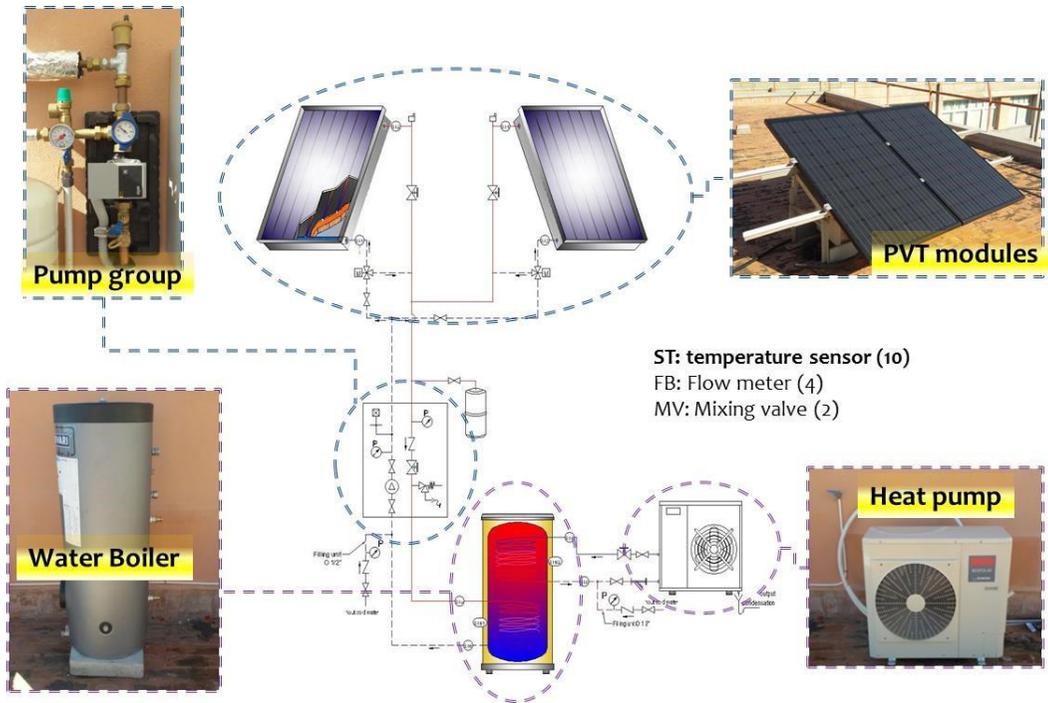


Fig. 1: PV/T power plant at the University of Catania (Italy): schematic and main components

Technical and economic analysis of a micro photovoltaic/thermal system working in Polish climatic conditions

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Abstract

Solar energy technologies harvested energy from the sun and either use it directly for lighting, or convert it into other useable forms of energy, such as electricity or heat. One of the most popular and the most promising methods of using solar energy is the direct conversion of solar radiation into electricity applying inner photovoltaic effect (using photovoltaic cells). Unfortunately, PV cells generally become less efficient with increasing cell temperature. This problem is particularly important in the case of building integrated photovoltaic systems, because then there is no possibility of natural cooling. One solution of this problem is applying a suitable heat extraction with a fluid circulation, keeping the electrical efficiency at satisfactory level. This solution is called photovoltaic/thermal (PV/T) and is the main subject of this study.

The first part of the paper presents some aspects of Polish climate conditions especially solar radiation conditions and solar energy availability. Considered solar installation is located in central Poland, in Warsaw. Sunshine durations in Warsaw is approximately 1600 hours and solar irradiation is approximately 1000 kWh/m²/year.

The second part of the paper presents the mathematical model and the assumptions used in the analysis of the photovoltaic thermal solar system operation. The analysis was carried out for the micro-installation (on grid type) supplying energy to a standard single-family home. It was assumed that the electricity produced is consumed on a regular basis and the excess is put into the power grid. It is also assumed that the heat gained is used for pre-heating domestic hot water. Ambient temperature, solar irradiation and its components were used as input data. Semispherical radiation incident on an inclined plane of the receiver was determined using the isotropic diffuse solar radiation model (Liu-Jordan). To determine the electricity and heat output the extended Hottel-Whillier-Bliss model was used.

The third part of the paper describes the economic analysis. The analysis considered several variants: different types of net metering, program NFEP&WM "Prosument" (grants) and feed in tariffs.

In the last part of the paper the guidelines for the configuration of this type of PV/T system in Polish climate conditions were formulated. Analyses show that the smaller power of installation, the shorter simple payback time and the greater the annual consumption of electric energy, the more profitable photovoltaic/thermal installation.

Keywords: solar energy, photovoltaic/thermal, climatic conditions

Economics of building-integrated solar thermal systems

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Abstract

Building-integrated solar thermal (BIST) systems will penetrate the building sector when they are more cost-effective than other solution and when this cost-effectiveness is obvious. Economic calculations like net present value are known since the 19th century. However, building-integrated solar systems are more complex than components of the building envelope. Therefore there are special challenges in finding most economic solutions.

This conference paper will present methods to calculate the value of BIST systems and will identify typical challenges for the application of these methods. It will present the calculation of the costs of three BIST facades as well as procedures to measure and to model innovative facades so that their value can be quantified.

Experimental performance comparison of a hybrid photovoltaic/solar thermal (HyPV/T) façade module with a flat ICSSWH module

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Abstract

The Energy Performance of Buildings Directive and Renewable Energy Framework Directive requires that Renewable Energy Systems (RES) are actively promoted in offsetting conventional fossil fuel use in buildings. A better appreciation of solar systems integration will directly support this objective, leading to an increased uptake in the application of renewables in buildings. By integrating these systems into the building elements (walls, roofs, etc.) not only means replacing a conventional building material (and associated costs), but also aesthetically integrating it into the building design leads to improved architectural integration.

A modular Hybrid Photovoltaic/Solar Thermal (HyPV/T) Façade technology that utilizes Integrated Collector Storage (ICS) solar technology, providing cost effective solar PV and thermal energy collection for direct use in the building, whilst providing significant thermal insulation has been developed and evaluated experimentally at Ulster University. The HyPV/T system, based upon a patented ICS solar thermal diode concept and shaped into a flat modular profile incorporating PV cells/module can provide space heating, domestic water heating and power generation. The complete system is designed to be compatible with traditional façade structures and fenestration framing arrangements, facilitating direct integration into new and retrofit building applications.



Figure 1: Images of the HyPV/T (left) and flat ICSSWH (right) modules under solar simulation testing

The experimental performance of a prototype Hybrid Photovoltaic/Solar Thermal (HyPV/T) unit has been determined and compared with a flat ICSSWH under constant indoor solar simulated conditions (Figure 1). The thermal performances of various modified HyPV/T and flat ICSSWH designs have been investigated and the thermal performance and collection efficiencies are presented. Figure 2 illustrates the simplified collector efficiencies for the various collector formats based on the absorber area. Whilst the HyPV/T presents a lower overall collector efficiency ‘curve’ profile, the tested unit had a PV layer and was unglazed and yet still exhibited a rate of heat loss significantly lower than the bare flat ICSSWH unit and comparable to the double cover flat ICSSWH unit. When these factors are considered, the concept HyPV/T unit becomes a competitive alternative to existing façade integrated technologies.

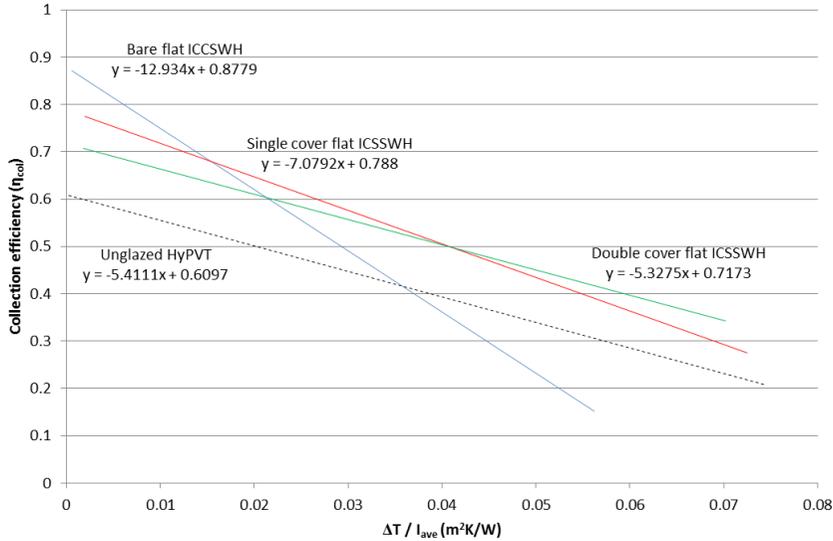


Figure 2: Collector efficiencies for the various collectors based on the absorber area and incident solar radiation of $800 \pm 50 \text{ Wm}^{-2}$

The ability for a single product to offer the multiple functionality, in a unique modular design and being the first to use ICS technology, presents a huge commercial opportunity. The HyPV/T could potentially offer a more cost effective solar investment, combining performance and quality whilst being fit for purpose, robust, visually appealing and exceptionally easy to install. These characteristics are expected in all premium solar collector-related products.

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Modular building intergraded solar-thermal flat plate hot water collectors

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Abstract

All types of buildings either residential, commercial or industrial should provide hot water for the occupant needs. Generally, the temperature for these needs does not exceed 50-60°C but depending on the use, large quantities may be required. In multistory buildings where there is a large number of occupants, adequate separate roof area for each owner, needs to be allocated for collectors and storage devices and for high buildings, even if this is available, the heat losses through the long pipes would be very problematic. A solution to this shortage of roof area and pipe losses, is to use Modular Building Intergraded Solar-Thermal Flat Plate Hot Water Collectors, that could use the appropriate wall areas and also serve as a design and construction element for reducing the material cost of the building.

In this paper an integrated small flat plate hot water collector was built and tested. The purpose was to demonstrate its features and problems of this integration. The constructed unit utilises the face of an existing brick wall, facing south. The unit is enclosed in a frame of approximately 1.8x1 m and in the frame an insulation layer was placed on the wall, which provides insulation both to the collector and the building itself. As in conventional flat plate collectors, in front of the insulation an absorbing plate was positioned as well as the appropriate header and riser assembly for the water circulation. Finally, the collector was covered with a 5 mm glass and the system was connected to a hot water insulated tank for storing the hot water.

The collector was tested during days with good solar radiation. The solar radiation incident on the collector the ambient temperature, as well as the temperatures of the water inlet and outlet during the day, were recorded. The efficiency of the system, defined as the ratio of the useful energy collected over the total solar energy falling on the collector aperture during the same experimental time, was estimated. Furthermore, a second experiment was carried out under stagnation conditions for the measurement of the maximum temperatures the system can attain, which could create fire issues.

The calculated maximum efficiency for the system is 55% and is considered as favourable with respect to existing solar collector systems. The collector tested can easily be mounted on a new or an existing wall (retrofitting). Specific solutions for the required piping to and from the collector were also studied. These show that the piping does not present specific difficulties and in co-operation with the architects, the piping can easily be concealed in the construction.

Modular building intergraded solar-thermal flat plate hot air collectors

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Abstract

Modular intergraded solar-thermal flat plate collectors can act as a cover over a building façade or roof. As the units are modular they can be used across a range of domestic and commercial building structures and typologies. They can substitute common envelope elements in both existing or new structures and provide thermal insulation to the building. With appropriate connections they can also provide direct thermal energy generated on site for either heating water or air and therefore can lower the energy requirements of the building. In this paper three different constructions of integrated flat plate hot air collectors are built and tested. Namely the types are: (a) integrated hot air collector utilising an aluminium foil duct (b) integrated hot air collector with internal metal separators and (c) integrated hot air collector with a mild steel square tube duct. The produced hot air can be circulated either directly in a room to raise its temperature or be blended with the air of a Central Heating Ventilation and Air-Conditioning (HVAC) System to increase the temperature of the circulating air in winter. The study aims to compare the cost, easiness of production/installation and efficiency of the building integrated air collectors.

The constructed units utilise the face of an existing brick wall, facing south. Each unit was enclosed in a frame of approximately 1.8x1 m and in the frame an insulation layer was placed on the wall, which offers insulation both to the collector and the building itself. In front of the insulation an absorbing plate was placed as well as the appropriate ducting/tubing. Finally, the collector was covered with a 5 mm glass and the system was connected to a two-speed air fan for circulating the air through the collector.

The collectors were tested during a day with ample radiation. The solar radiation incident on the collector as well as the temperatures of the air at the collector inlet and outlet were recorded. The efficiency of the systems, defined as the ratio of the useful energy collected during the day over the total solar energy falling on the collector aperture during the same time, was estimated.

The calculated maximum efficiency is considered as favourable with respect to existing solar collector systems. Specifically, the results show that type (a) collector gives a calculated maximum efficiency of 85%, type (b) 80% and type (c) 80%. The simplest and cheapest construction is that of type (a). All types of collectors tested can easily be mounted on a new or an existing wall (retrofitting) and the air duct can be joint directly to individual rooms of the building or integrated together and coupled to a central unit.

Numerical study of PCM integration impact on overall performances of a highly building integrated solar collector

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Abstract

In this work, we explore the potential of heat loss reduction and thus overall performances improvement of an innovative solar collector using Phase Change Material (PCM). In previous works we presented a highly integrated solar collector with experimental characterisation and an associated validated numerical model.

One of the main issue identified is the thermal losses at high reduced temperatures due to specific geometry of the collector. Several authors explored the potential of thermal storage for traditional domestic hot water (DHW) systems. The main goal here is to take advantage of the high volumetric thermal density of PCMs and to limit both the reduced temperature and the thermal losses during the hottest period of the day while recording part of the stored heat in the evening.

This work is an exploratory study and a lot of configurations have been tested to ensure if this approach is interesting, theoretically speaking. Annual simulations of a whole DHW installation were carried out with measured environmental conditions (solar radiation, wind, ambient temperature). An optimization of the solar collector is performed and the performances of the BISTS is estimated in terms of solar fraction taking into account all the thermal installation and the electrical consumption of the pump.

The mathematical model that describes the thermal process in the PCM is presented. Results with and without PCM are compared leading to an estimation of the potential improvement of the H2OSS solar collector thermal behaviour thanks to the PCM addition.

At last, a Life Cycle Analysis (LCA) is performed in view to estimate the influence of addition of PCM on the environmental impact.

A novel approach towards investigating the performance of different PVT configurations integrated on test cells: an experimental approach

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Abstract

In this study an attempt has been made to develop a mathematical model of electrical and thermal performance for different possible configuration of PVT used as a Building integrated Photovoltaic Thermal (BiPVT) system, and their effectiveness in space heating under different climatic condition. The model has been validated by experimental investigation in outdoor condition at Indian Institute of Technology in New Delhi, India for two different weather conditions; summer and winter. In order to develop a model, four identical test cell has been used on which four different configurations; Case 1 (Glass to glass PV with duct integrated on a test cell), Case 2 (Glass to glass PV without duct integrated on a test cell), Case 3 (Glass to tedlar PV with duct integrated on a test cell), Case 4 (Glass to tedlar PV without duct integrated on a test cell) was investigated in this communication. The characteristic equation for all four cases has also been developed

It is observed that glass to glass PV module give better performance as far as both electrical as well as thermal aspects are concern, and gives hourly average η_m 11.91% and 11.96% in summer whereas in winter, it has 12.65% and 12.70% for case 1 and 2 respectively. Similarly, hourly average η_{th} was 32.77% and 25.44% for case 1 and 2 respectively in winter. Ducted PV modules have high η_m and η_{th} for both type of module attributed to the thermal dissipation as well as this dissipated heat further increase the test cell room temperature, T_r useful for thermal output. However, the implementation of PVT system in hot climatic zone does not give desired results as expected the PVT system due to overheating phenomenon. Overall heat gain and overall exergy for all PV module configurations have also been calculated.

Keywords: Semi-transparent photovoltaic, Opaque photovoltaic, Electrical Efficiency, Solar radiation, Photovoltaic-thermal (PVT) system, Thermal energy, Test cell.

Experimental and simulation-based investigation of the air flow and air gap size of a naturally ventilated BIPV system

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Abstract

A Building Integrated Photovoltaic (BIPV) façade system is formed by the PV panels integrated to a second skin forming an air gap between the two skins. The air gap is responsible to cool the PVs and remove excess heat to avoid building overheating. The ventilation of the air gap can be natural or mechanical.

The system investigated in this study is a naturally ventilated BIPV system. This has a number of advantages, the most important of which is the avoidance of energy to power the fans, the operation with no noise and the avoidance of overheating which can happen when the fan stops in an active system. The system under investigation here is a vertical application for BIPV facades. The investigation is done experimentally as well as with simulations. Both the experimental model and the simulation model have same dimensions.

Regarding the experimental investigation, a custom made single BIPV apparatus with 0.1 m air gap width is tested in natural outdoor conditions without mechanical means to drive the air into the air gap formed between the PV and the wall. Thus, natural ventilation is considered. The aim of the experimental procedure is to measure the temperature at various points on the system and the air velocity in the air gap. Additionally, the performance of the PV is also being monitored in order to observe the effect of the temperature increase on its performance and the effect of the air gap temperature.

For the simulation-based analysis, COMSOL Multiphysics software is used. A 3D model is constructed and all related physical parameters were added regarding the materials and thermal conditions. The aim of this modelling is to observe the effect of the air velocity in the air gap between the two skins and the air gap size, on the thermal behaviour of the system. The model tested consists of a single PV panel, air gap, and a second skin, in same dimensions as the experimental set up. The orientation and geometry of the system was defined and kept constant. Air velocities from 0.02 m/s to 2.5 m/s were tested as well as air gap sizes from 0.05 m to 0.15 m.

Performance evaluation of the senergy polycarbonate and asphalt carbon nano-tube solar water heating collectors for building integration

Aggelos Zacharopoulos, Mervyn Smyth, Jayanta Mondol, Adrian Pugsley
Ulster University

Abstract

The UK government has targeted to reduce greenhouse gas emissions by 10% by 2010 and 20% by 2020. The Energy White Paper sets out the long-term strategy for UK Energy Policy. The key aim is to cut the UK's CO₂ emissions by 60% by 2050 with significant progress by 2020. In order to meet these targets, renewable energy will play an important role. Reduction in energy demand from buildings will have significant impact on UK's emission rate.

The Senergy CNT solar water heating collectors are building integrated solar collectors designed to offset traditional roofing elements. Two working prototypes; one Polycarbonate Carbon Nano-Tube (PCNT) collector and one Asphalt Carbon Nano-Tube (ACNT) collector; have been tested at the solar simulator facility at Ulster University and their performances compared.

The PCNT collector uses innovative poly-carbonate twin-wall sheeting which forms both the solar absorptive surface and the heat transfer fluid channelling elements. The ACNT collector has asphalt based absorber with an embedded serpentine copper tubing to act as the heat transfer fluid channelling element.

Tests were conducted with 800 W/m² illumination intensity and for water inlet temperatures between from 23°C and 47°C. The PCNT collector achieved a 62% maximum collection efficiency compared to 45% for the ACNT collector. The calculated heat loss coefficients were 6.03 W/m²K and 8.11 W/m²K respectively. The performance of the PCNT collector could be improved if a transparent cover with a lower reflection coefficient was used. The ACNT collector performed was lower than a typical unglazed solar water heater with non-selective absorber. This was a result of high thermal resistance between the absorber surface and the water flowing through the collector.

Investigation of the thermal performance of a concentrating PV/Thermal glazing façade technology

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Abstract

Developing effective solar energy technologies which can be integrated into buildings and provide heat, electricity and/or reduce energy needs, is vital to achieving set international targets for renewable energy generation and carbon emissions reduction. While a range of technologies are available at the moment for building integration most of them are simply super-imposed on the building structure rather than becoming an essential part of it. This does not allow for the full advantages of building integration to materialise as it does not reduce costs by replacing conventional building materials and components.

A Concentrating PV/Thermal Glazing (CoPVTG) façade technology that combines glazing based solar concentrating elements, coupled with PV/Thermal absorbers has been developed. The technology is a modular multifunctional building component based on conventional double glazing. It is compatible with traditional façade structures and fenestration framing arrangements which allows easy integration into new and retrofit buildings. It can provide solar generated electricity and air heating through the PV/T absorbers while insulating the building thermally. Depending on the incidence angle the glazing based concentrating elements are designed allow the direct sunlight to enter the building and provide natural daylight when required whilst redirecting it onto the PV/T absorbers to generate electricity/heat when solar gains need to be minimised to reduce cooling demands.

The thermal performance of a 500 mm x 500 mm CoPVTG prototype unit integrated into a conventional window frame has been investigated under controlled conditions in a solar simulator facility. Outlet air temperatures have been measured for a range of inlet temperatures at two different incidence angles of illumination. Generated Hottel-Whillier-Bliss equations show an optical efficiency of 52.6% and a 25.2 W/m²K heat loss coefficient at a 55° incidence angle. At a 20° incidence angle the measured optical efficiency is 43.8% and heat loss coefficient 27.7 W/m²K. The difference in the measured thermal performance is shown to be strongly related to total internal reflection of the light at the surface of the glazing concentrating elements. This is demonstrated by short circuit current measurements of the PVT absorbers.

Reactive power control for smarter (urban) distribution network management with increasing integration of renewable prosumers

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Abstract

Smart cities need to deliver consistent electricity while utilizing every renewable source available in a sustainable manner. A complete understanding of available resources and means for viable integration of distributed generation (DG) is required. From a distribution service operator (DSO) perspective, DG means more and more prosumers - or network customers that both consume and produce electricity - are added into the distribution network. Increasing renewable electricity capacity, through DG such as small wind and PV generation, causes difficulties for the DSO in sustaining adequate and appropriate power quality across the network. The positive impacts provided by such energy sources can be undermined by voltage increases and voltage balance issues. To overcome these problems, urban distribution networks need to transform into smarter energy networks that can deliver renewable electricity locally, predictably and in a controllable and optimized manner. Such network transformation needs to be managed where a linkage between DG capabilities and network constraints is synergized.

The research presented here is based on enhanced electricity network simulation in an urban context. The main focus is the hosting capacity enhancement of distribution networks, while maintaining power quality, which is ultimately a pre-requisite for increasing prosumer engagement. In this regard, a test-bed representation of a 4-wire low-voltage section of distribution network in Dublin Ireland is developed in DIgSILENT Power Factory. Several scenarios considering increasing penetration of renewable prosumers in a smart electricity network context are presented. In this paper, an approach similar to the one adopted by the recently revised international connection standards for DGs is applied for centralized reactive power compensation in order to limit voltage rise and imbalance, which are network manifestations associated with increasing DG penetrations. A Static Synchronous Compensator STATCOM, normally employed in transmission networks, is designed and applied for reactive power control in the distribution network model. The results show that STATCOM, in the context of increasing DG integration, can provide voltage support, without using capacitors banks and reactors, by supplying or absorbing reactive power and thereby facilitating increased renewable DG contributions for a smarter, greener network.

Investigation of joule heating effect on performance of PV modules based on equivalent thermal-electrical model

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Abstract

In general, an individual PV panel has a life expectancy ranging between 15-25 years. During this time, panels are subject to harsh operating conditions and as a result their efficiency decreases. The lifespan of PV panels can decrease due to being constantly subjected to thermal and mechanical stresses.

Understanding the reasons behind the underperformance of a PV module is essential for the development of an accurate operational model for further reliability and durability studies. For instance, the temperature of a PV module affects its overall efficiency, with typical reduction of 0.65% per degree K under conditions of normal illumination. Internally generated heat contributes also to the heating of the PV panels and can negatively affect their efficiency. Under partial shading, the electrical characteristics of PV modules change with the distribution of solar illumination, which causes an electrical mismatch that forces – in the absence of bypass diodes - the PV modules to operate in reverse bias mode and hence experience local overheating or a hotspot. While bypass diodes constitute an efficient solution to avoid the mismatch effects and then assure the current circulation to the entire PV module, they can also be subject to damage and contribute to the problem of heating encountered under partial shading conditions.

This paper aims to study the effect of resistive heating (Joule heating) on the PV devices in forward and reverse bias modes through a steady-state, electro-thermal model using a detailed thermal network approach. The paper will present a preliminary analysis of the impact of internally generated heat on the efficiency of a PV device.

The model will analyse the problem of resistive heating in PV devices when bypass diodes are faulty or damaged by considering ideal and worst case scenarios. The created model will be simulated using the Finite Element Analysis (FEA) package Ansys Workbench and validation will be performed using data recorded by a commercial PV panel.

Energy investigation on households with BIPV modules under net metering scheme

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Abstract

In recent years, many Renewable Energy Sources (RES) power plants have been connected to power networks throughout Europe, in order to meet the EU's objectives for sustainable energy supply. As far as low-voltage distribution networks are concerned, the grid-connected PV systems constitute the most important representative of RES, because these can be easily installed even in densely built-up areas where space problems are inevitable. In this context, residential PV systems with BIPV modules are going to gain ground mainly at newly built or rebuilt residences in densely populated areas. That is because a BIPV module operates as a multi-functional building construction material; it generates energy and serves as part of the building envelope.

This paper addresses the energy benefits of a residence with BIPV modules under Net Metering Scheme. The energy benefits are reflected in different time scales (from Real-time, to hourly and annual scales to the Life Cycle of BIPV modules) as well as by introducing typical days of each season of the year. It is important to note, that although the electricity consumption of the building has been monitored for more than a year, the energy production from PVs refers to a shorter period. Thus, in order to extrapolate the energy benefits on annual basis, the photovoltaic generation is estimated via TRNSYS. Beyond energy benefits, this work is studying the impact of the façade PV subsystem on the internal comfort of the building. The results presented stem from the participation of CRES and CUT in the EU funded project Bfirst "Building-Integrated, Fibre-Reinforced Solar Technology".

The residence under study is a low energy consumption building and it is equipped with a ground heat geothermal heat pump, which serves the heating and cooling demands of the building. In addition, the building is equipped with a PV system of 3kW peak power, which is divided in three subsystems. More precisely, the first one is installed around two balconies (figure 1), the second one is installed as a façade on a vertical wall which faces the south-east and the last is installed as shading elements that also face south-east (figure 2). The BIPV modules which have been installed are based on an innovative developed technology (project Bfirst) for solar cells encapsulation within glass fibre-reinforced composite materials. Such BIPV modules present advanced characteristics in terms of adaptability to non-planar building geometries, low weight and reduction of stages in the manufacturing process, issues to which BIPV modules were lagging behind even in the recent past.

The connection of all PV subsystem to the low voltage electricity network was preferred to be implemented by using single phase micro-inverters and not a string technology inverter. The benefits of this approach are not only to avoid power losses due to mismatch between PV modules with different orientation and/or inclination, but also the optimal matching of PV modules characteristics with the individual micro-inverters of appropriate power.

Solar photovoltaic system inverter configuration performance analysis for a building integrated system experiencing shade

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Abstract

A Solar Photo-Voltaic(PV) system inverter configuration analysis for a Building Integrated PV (BIPV) system, which incorporates the quantification of expected shade on the PV modules, is presented. Measured losses from BIPV systems have been reported to be of the order of 20%, due to shade, mismatch, differences in orientation and inclination, and temperature effects. BIPV products, which often avail of spaces that are non-optimal for PV Modules, and retrofit residential PV systems are prone to shading losses, which produce over-proportional power losses which are difficult to predict with accuracy. Decisions regarding suitable inverter configurations are complex, and are a function of the proportion and duration of shade on the PV array, and the local climate conditions; having implications for installation and Balance-of-System (BOS) Costs, and the Energy Yield being generated, which influences the payback on the investment. The analysis quantifies the maximum available power and energy in the array, for a given shading scenario, using experimentally validated power-voltage curves. The DC energy is calculated for an AC Modular Inverter configuration and a String Inverter Configuration. An AC Energy Yield analysis is performed, using a model derived from measured performance data, as a function of Maximum Power Point Tracking (MPPT) capability and with discussion of the inverter input voltage range limitations.

Solar air shutter with split-system

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University of Corsica -IUT

Abstract

We present a second version of the solar air shutter, patented and named volet'air®. The concept of solar air shutter, patented and named volet'air® produces a low temperature heat directly from the sun without any other energy supply. The objective is to provide a part of the hot air needs in maintaining a healthy ambiance in the housing. It can be used both:

- in principal residence occupied all the year;
- in secondary residence, often no-occupied during a long period of the year and for which the thermal balance and ventilation are just provided by natural energy exchanges from outdoor to indoor;
- in isolated houses not connected to the electrical grid.

This version substitute the channelling of warm air by a heat transfer fluid such as water in order to minimise the drill diameter in the wall to provides calories.

Smart façade air solar collector system – SFA SCSys

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University of Corsica -IUT

Abstract

This project is the development of a complex solar system involving different pieces of equipment and different technologies in order to provide equipment compatible with energy requirements.

The innovation of this system is a new use of a classic solar hot water collector marketed; it would be used for air heating and cooling in individual or collective housing, tertiary.

Solar vacuum tubes collector is integrated in a thermal loop which is composed by an air/water heat exchangers situated inside the habitat. Calories are transferred from solar collector to the habitat through the air/water heat exchangers by natural convection or by forced convection with a pump.

Interior or exterior air (A) is drawn through turbine (1) and passes through the air filter (2). Solar collector warms the fresh air through the heat exchanger (3) which is integrated in the thermal loop. collecting warm air is impel (B) through turbines (4). To control the thermal loop, regulation system with temperature setpoint is installed.

For a new habitation, Solar vacuum tubes collector is integrated in facade and cover by a smart dynamic glass as electrochromic glass with control of glass transparency. This system is used to control solar energy according seasons with high insolation and heat requirements. PV modules can be installed to control electrochromic glass.

Large-scale laboratory investigation of building integrated photovoltaics

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Abstract

The world's attention towards energy-efficient and zero emission buildings is increasing, where one key aspect among others is to utilize non-polluting and renewable energy sources. Building integrated photovoltaics (BIPV) represent an interesting solution both for existing and new buildings. For the development of new BIPV products, it is important to address the properties, requirements and possibilities of both the solar cell and building envelope for BIPV. The work presented herein focuses on large-scale laboratory investigations of BIPV with the aim to identify methods and opportunities for future design of improved BIPV systems. This work will summarize concepts, principles, existing standards and apparatuses which can be used in large-scale laboratory investigations of existing and developing BIPV products, with particular emphasis on wind-driven rain exposure and water tightness.

The main and long-term aim of this study is to determine precisely the methods for testing existing BIPV systems, especially with respect to wind-driven rain exposure, and also in general for other outdoor weather strains. Furthermore, robustness and durability issues will also be important to address. Finally, part of the general outcome may also be innovative and totally new BIPV systems, and how to test and characterize these.

COST Action TU1205: Building Integration of Solar Thermal Systems (BISTS)



Overview of the Action:

Energy use in buildings represents 40% of the total primary energy used in the EU and therefore developing effective energy alternatives is imperative. Solar thermal systems (STS) will have a main role to play as they contribute directly to the heating and cooling of buildings and the provision of domestic hot water. STS are typically mounted on building roofs with no attempt to incorporate them into the building envelope, creating aesthetic challenges and space availability problems. The Action will foster and accelerate long-term development in STS through critical review, experimentation, simulation and demonstration of viable systems for full incorporation and integration into the traditional building envelope. Viable solutions will also consider economic constraints, resulting in cost effective Building Integrated STS. Additionally, factors like structural integrity, weather impact protection, fire and noise protection will be considered. The most important benefit of this Action is the increased adoption of RES in buildings. Three generic European regions are considered; Southern Mediterranean, Central Continental and Northern Maritime Europe, to fully explore the Pan-European nature of STS integration. The Action consortium presents a critical mass of European knowledge, expertise, resources, skills and R&D in the area of STS, supporting innovation and conceptual thinking.

Action web page: <http://www.tu1205-bists.eu/>

Domain: Transport and Urban Development (TUD).

http://www.cost.eu/COST_Actions/tud/Actions/TU1205

Countries participating: Austria, Belgium, Bulgaria, Cyprus, Denmark, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Serbia, Spain, Turkey, United Kingdom.



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