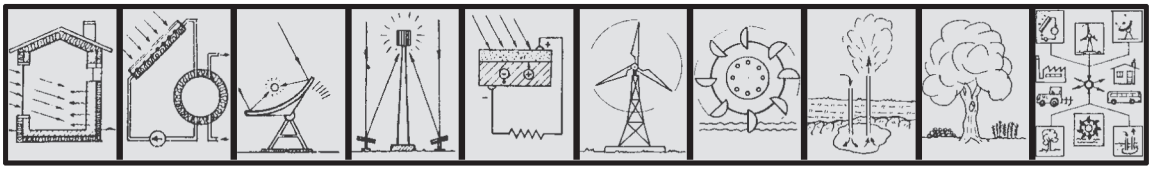
INSTITUTE OF SOLAR TECHNOLOGY

11th National Conference On Renewable Energy Sourses

March 14 - 16, 2018
Thessaloniki, Greece

Book of
ABSTRACTS

THESSALONIKI 2018



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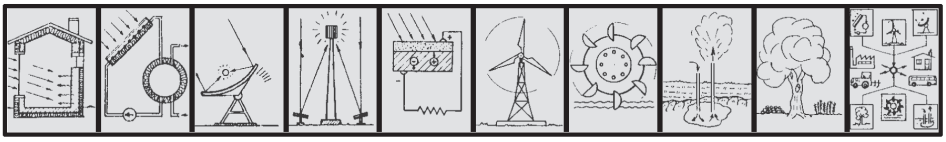

11th NATIONAL CONFERENCE ON RENEWABLE ENERGY SOURCES: BOOK OF ABSTRACTS
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INSTITUTE OF SOLAR TECHNOLOGY

The Institute of Solar Technology (IST) is a scientific and educational organization established in 1980, in Thessaloniki.

Objectives of IST are:

- To encourage research, development, and use of Renewable Energy Sources (RES).
- To collect and disseminate information in the area of RES utilization through conferences, seminars and publications.
- To establish international connections and to encourage the transfer of knowledge in the area of RES.
- To elaborate suggestions and energy policy alternatives aiming to promote the diffusion, utilization and development of RES.

In promoting the above objectives, IST has already organized ten National Conferences on Renewable Energy Sources (in years 1982, 1985, 1988, 1992, 1996, 1999, 2002, 2006, 2009 and 2014), where the majority of Greek scientists active in all fields of renewable energies and energy conservation have participated, while more than 1000 scientific papers were presented. The proceedings of the conferences present the state of research and work done in Greece in the field of Renewable Energy Sources and its development during the last two and a half decades.

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PREFACE

The present volume contains the abstracts in English of the 100 papers presented in the 11th National Conference on Renewable Energy Sources. The 11th N.C. on RES was organized in Thessaloniki, Greece, March 14 – 16, 2018, by the Institute of Solar Technology and the Mechanical Engineering Department of Aristotle University of Thessaloniki.

The number of papers, the number of participants, and the variety of the subjects as well, demonstrate the vigour of the work carried out in Greece in the area of Renewable Energy Sources and Energy Conservation.

I hope that the present volume will give the opportunity to colleagues from abroad to assess the state of research and development work in Renewable Energy Sources in Greece, and that may help the formation of fruitful collaborations.

Finally, I would like to thank the Mechanical Engineering Department and the School of Engineering of Aristotle University of Thessaloniki for their financial support.

Prof. George Tsilingiridis
President of the Board of Administration
Institute of Solar Technology

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OFFSHORE WINDFARMS IN GREECE: ARE THERE ANY PROSPECTS?

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ABSTRACT

Based on the collected data by the research team from the growing activity in the field of offshore wind energy in Greece, an assessment of the progress made so far in a regulatory and licensing framework as well as an assessment of the potential and prospects for the development of offshore wind farms OWF) until 2030 is presented

The new legislation is taken into account within the framework of "Target model" and the progress of the investment plans for the implementation of OWF in Greece through the wind energy market is assessed. A case study on the development of OWF in Greece is presented, analyzing all the technical, constructional and economic parameters of such an exercise. In addition, problems are expected to emerge, while an estimation of the future development of OWF in Greece is attempted.

Keywords: offshore wind farms, perspectives, regulatory & licensing status, submarine cables, offshore substation.

MODELLING OF AN ENERGY HARVESTING DEVICE THROUGH EXPLOITING FLOW-INDUCED VIBRATIONS

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ABSTRACT

Typically, engineering structures that are prone to flow-induced vibration are designed with the aim of minimizing fatigue due to this effect. Recently, it has been proposed to reinforce such vibrations in order to maximize the response with the aim of energy harvesting from environmental flows. In this work, we develop a mathematical model for a hydrokinetic energy converter that exploits angular vibrations of a cylindrical body induced by vortex shedding in its wake. The converter consists of a cylinder that can perform angular oscillations with respect to a pivot point while its axis remains normal to an incident free stream in a fashion similar to a tethered body. The motion of the cylinder is predicted by solving the equation of motion (torque balance) subject to external forcing from the surrounding fluid. The hydrodynamic model is based on the decomposition of the total force into reaction and excitation components. The hydrodynamic model introduces terms that act as added fluid excitation, damping and inertia. The resulting equation of motion describing the coupled fluid-solid system is highly non-linear and is solved by numerical integration in time. Two different configurations are considered where the cylinder is located either downstream or upstream of the pivot point. We have examined in detail the effect of the length of the arm connecting the cylinder with the pivot point and the damping of the system. The results have shown that the configuration where the cylinder is located upstream of the pivot point is more energy efficient as that yields higher frequency oscillations of the cylinder, which have a beneficial effect. For both configurations, there is an optimum level of damping around 10% that maximizes the energy capture yielding efficiencies of approximately 12%.

Keywords: *Hydrokinetic energy, Energy harvesting, Vortex-induced vibrations, Mathematical modeling.*

NUMERICAL AND EXPERIMENTAL INVESTIGATION OF A WELLS TURBINE

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ABSTRACT

Waves of the sea are an important renewable energy source, which, if appropriately exploited, can make a significant contribution to the electrical supply to areas surrounded by the sea. A number of technologies have already been proposed, studied and in some cases tested under real circumstances. One of these technologies is the combination of an Oscillating Water Column (OWC) and a Wells turbine.

This paper presents the results of the design and the computational analysis of such a turbine for different air velocities and for various rotor speeds. The computational results presented relate to the flow field (speed, pressure and turbulence) and the rotor performance. The performance of the device was found to reach 60% at 4000 RPM before stall. The results are compared with corresponding experimental results from a device developed in the Laboratory of Fluid Mechanics and Turbomachinery Laboratory of the University of Western Macedonia. Although there is no complete match between computational and experimental results, both show similar trends.

Keywords: Wells turbine, Oscillating Water Column (OWC), CFD, numerical analysis, experimental investigation

THE EFFECT OF A SHROUD ON THE PERFORMANCE OF SMALL HORIZONTAL AXIS AND VERTICAL AXIS WIND TURBINES

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ABSTRACT

Shrouded are a technology developed to increase the power extraction of small wind turbines based on a simple idea. In the context of this paper a horizontal axis wind turbine, a vertical axis wind turbine and corresponding shrouds were designed and the potential of their combination was assessed. For this purpose a number of simulations were carried out for both the bare rotors and the shrouded rotors. Significant results were produced using Computational Fluid Dynamics (CFD).

The analysis showed that the use of shrouds on both types of wind turbines has a positive effect on their performance. This is achieved by reducing the static pressure behind the rotor and leads to improved energy extraction from the air flow. Moreover, the addition of a flange on the exit of the shroud was evaluated. The presence of the flange acts as a barrier to the flow thus forcing the air through the shroud. The flange causes further pressure drop on the shroud exit area and improves the production of useful mechanical work by the rotor. An increase of the flange size results to 2 or even 5 times higher power coefficient.

A comparison of the computational results with experimental results of other researchers shows an agreement of the tendencies observed. The power coefficient is not only increased, but the power coefficient curve is extended to higher tip speed ratios. Based on the comments mentioned above, the addition of a shroud may be a useful modification for small wind turbines.

Keywords: *small wind turbines, shrouds, power optimizations, CFD*

HYBRID WAVE-WIND POWER STATION FOR ENERGY NEEDS COVERAGE IN AUTONOMOUS ISLANDS

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ABSTRACT

The energy needs of the most Aegean islands are covered by the operation of autonomous/local power stations (APS/LPS) using imported oil. The costly operation of the APS/LPS combined with the resulting environmental problems, set the issue of a sustainable and rational energy solution for the Greek islands showing respect to the sensitive islandic ecosystems and acceptance of local communities.

In this context, high wind speeds as well as the remarkable wave potential of the Aegean Archipelagos could be the driving force for a sustainable energy supply solution for these islands by exploiting combined energy sources along with an appropriate energy storage system, comprising a modern hybrid renewable based station.

This specific research examines the combined exploitation of the wave and wind potential of a representative medium-sized island of Cyclades in order to cover its electrical needs. The results show that the possible installation of a hybrid power station contributes to a higher integration of RES into an autonomous micro-grid and the stochastic production of wind turbines could be counterbalanced due to the smoother (time-dependent) production of waves, which have greater "inertia" in the instantaneous meteorological changes. In addition, the ability to store excess renewable energy enhances the energy supply security of the island micro-grid.

In conclusion, the exploitation of wave energy is one of the future priorities of the European Union (Blue Growth) in an effort to support wave energy converters installation, which are in the final stage of the technological development. The relatively moderate wave potential of the Aegean Sea (if compared to the extreme potential of the open seas) is exploitable and if the wave power station is collocated with the respective of a mature energy technology, such as wind energy, the infrastructures could be common lowering the cost and constituting a clean energy solution for the remote Aegean island communities by reducing their oil dependence and increasing their energy supply security.

Keywords: Autonomous Power Station, Micro-Grid, Energy Supply, Non-Interconnected Islands, RES

WAKE MODELS EVALUATION FOR WIND PARK MICRO-SITING

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ABSTRACT

The accurate estimation of the velocity deficit downstream a wind turbine, known also as wake effect or shadow effect, is important as it provides information about the energy that is available for the rest energy extraction devices within a wind park or cluster of wind turbines. Considerable effort has been put by various scientists, resulting to several different wake models which have different classifications, considering the method used in order to predict the velocity deficit that the wind flow suffers when going through and downstream of a wind turbine rotor.

The aim of this research is to investigate the levels of reliability and accuracy of seven different analytical semi-empirical wake models, most of them being widely used in industrial software applications, aiming to optimize the micro siting of a wind park. For this purpose, one 2MW experimental test case and also LES and CFD simulation data have been used from relevant scientific literature, in order to compare the values of this research with available data concerning the wake flow. A multi-criteria comparison is being performed, investigating wake prediction accuracy for different distance data downstream a wind turbine and different wind speed values. The investigation derived various interesting findings, pointing out satisfactory accuracy levels of some analytical wake models.

Keywords: Wind Turbines; Wake Effect; Micro Siting; Velocity Deficit; Energy Deficit

RES in Education

CREATION OF A POSTGATUATE COURCE FOR WIND ENERY AT THE INTERNATIONAL HELLENIC UNIVERSITY

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ABSTRACT

International universities are offering courses on wind energy that vary in duration. The International Hellenic University has an 18-hour course about wind energy for postgraduate students pursuing the MSc in Energy Systems degree. The course is offered solely in English to Greek and international students.

The challenge was to develop a series of lectures that combine the time limitation with quality knowledge taking into account the students' diverse background in sciences. The paper presents the key subjects that a postgraduate needs to know about wind engineering and explains why they need to be taught in that order.

References are made regarding the accredited sources from where material was taken or proposed for further reading. Major internet sources and online tools freely available today were thoroughly discussed and a multitude of links were provided.

Last but not least, the use of technical video and animation presentations was proven to be a most didactic tool which was most welcome by the students.

Keywords: wind energy, teaching, RES development

ESTIMATION OF THE OPTICAL PROPERTIES OF CLOUDS, AEROSOLS AND FORECASTING OF DIRECT NORMAL IRRADIANCE FROM ALL-SKY IMAGES

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ABSTRACT

Aerosols and clouds affect the direct and global irradiance reaching ground, while their large spatial and temporal variability is the most important error factor for forecasting solar potential.

In recent years, the all-sky images are used to estimate the optical properties of aerosols, cloud coverage, type and velocity of clouds in a number of applications. In the present study, we present the summary of the methodologies developed in the Plataforma Solar de Almeria (PSA), within the framework of the European program "Direct Normal Irradiance Nowcasting methods for optimized operation of concentrated solar technologies".

The all-sky images of four Mobotix Q24M cameras are analyzed in combination with measurements of atmospheric components, cameras placed in a solar tower for the recording of shadows and a dense network of ground-based instrument measuring solar radiation. The all-sky cameras are used for:

• The estimation of the optical properties of aerosols from RGB (Red, Green, Blue) channels at specific polar angles

• The estimation of the cloud properties

The outputs are used for the three-dimensional representation of the clouds and are introduced into a radiative transfer model to estimate the direct normal irradiance in a 2x2 km area. Then, using sequential photographs, the velocity of the clouds is calculated and the solar irradiance is forecasted at a 15-minute horizon. Finally, the data are evaluated by comparison with ground-based measurement and shadow maps of the studied area.

Keywords: aerosol, clouds, direct normal irradiance, resource, forecast

RES and the Environment

THE EFFECT OF ECO LABELS ON THE ENERGY CLASSIFICATION OF BUILDINGS

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ABSTRACT

The effect of HVAC systems, defined by their certification on environmental and energy criteria, on the energy classification of buildings is examined in this paper. The aim of this study is to explore the contribution of energy efficient HVAC systems that are already available in the market and their efficiency regarding energy savings in existing buildings concerning the building energy needs, its energy classification in the energy performance certificate, energy savings, the reduction of energy costs and carbon dioxide emissions, initial investment costs and the investment payback period.

The paper focuses on a detached house, where, according to its construction time, the building is constructed: a) before the Thermal Insulation Regulation, b) during the Thermal Insulation Regulation, and c) after the Energy Performance of Buildings Regulation. A parametric analysis is made regarding energy savings in the four climatic zones of Greece, focusing on HVAC systems with eco-label certification. The results are compared in terms of the achieved energy savings, and the rest of the criteria of which energy inspectors are aware, focusing on the energy classification of the building and the investment payback period. Additionally, specific criteria were set in priority, based on the results of a small research conducted on the respective opinions of engineers and energy auditors. Based on this analysis, conclusions are drawn regarding the most advantageous energy saving actions, regarding not only energy savings, but also investment and change of energy classification, putting forward the priorities that are suggested by engineers. According to the results, guidelines are given with regard to the most appropriate investments in HVAC systems or the building envelope, depending on the climatic zone.

Keywords: eco label, eco design, existing building, energy classification, energy savings

THE EFFECT OF THE EMBODIED ENVIRONMENTAL IMPACT ON THE COST-OPTIMAL LEVELS OF NEARLY ZERO ENERGY BUILDINGS (NZEB)

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ABSTRACT

Considering the framework of the European Directive 2010/31/EU (EPBD recast), there is a reinforcement of the legislation for the improvement of the energy efficiency of buildings. Measures such as the increase in the insulation thickness, the use of energy efficient windows or even the use of photovoltaic panels for electricity production lead to an important increase in the use of materials. International and national literature indicate that this extended use of materials relates to an increase in the embodied energy, with a final share of embodied energy between 74% and 100% in the total life cycle energy of nearly zero energy (nZEB) residential buildings. The current European legislation for the energy efficiency of buildings is characterised by an "incompleteness" of the assessment as it considers the environmental impact -in terms of carbon dioxide emissions- only from the operating phase of the building and ignores the embodied impact from the remaining phases of the building's life cycle. Nevertheless, the accompanying guidelines of the delegated regulation 244/2012 acknowledge this "incompleteness" and provide the potential extension of the boundaries into a full life cycle costing and Life Cycle Assessment (LCA) approach. The current study considers this potential extension and its application to a nearly zero energy residential building located in the city of Thessaloniki. The current scope involves the calculation and the analysis of the effect of the embodied environmental impact on the cost-optimal levels, for the macroeconomic perspective and through an extended sensitivity analysis, with the further goal of assessing the "incompleteness" of the European legislation. The results indicate a limited effect of the embodied impact on the cost-optimal levels. That same effect is located in the extended calculation periods (50 and 60 years) and the low discount rates (2% and 3%) of the analysis and in combination with other key parameters, such as the low energy and fuel prices or the high carbon prices. The extension of the European legislation into a full life cycle approach leads to a variation in the cost-optimal level and the cost-optimal variants, with a transposition to variants with lower insulation thickness, lower number of window panes and consequently lower embodied environmental impact.

Keywords: Life Cycle Assessment (LCA), embodied environmental impact, nearly zero energy buildings, cost-optimal level, carbon dioxide emissions

LIFE CYCLE ANALYSIS OF SOLAR THERMAL SYSTEMS IN HOTEL BUILDINGS

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ABSTRACT

This paper evaluates the environmental impact of solar thermal systems in hotel buildings using LCA approach. The energy and the environmental performances of one of the most common renewable technologies have been studied: the solar thermal systems for space heating and domestic hot water production (Solar Combi Systems).

A life cycle assessment has been performed following the international standards of ISO 14040 series, supported by Gabi Software. The aim is to trace the energy system's environmental impact related to its life cycle. Life cycle thinking in environmental impact assessment has been for over 40 years now prevalent in the industrial and the service sector, with some early Life Cycle Analysis (LCA) type practitioners bringing a multi-attribute quantitative approach to decisions related to beverage packaging as far back as the 1960s. This approach evolved into LCA, with well-established international standards for guidance. LCA is therefore a science-based, quantitative and integrative methodology that measures the material and energy flows to and from nature over the lifetime of a product or service, and assesses the potential impact of those flows on resources, ecosystems and human health. These impacts occur in various segments of the manufacturing value chain and throughout the life of the product. Often the assessment is referred to as a cradle to grave evaluation. Commonly reported impact metrics include global warming ("carbon footprint"), acidification ("acid rain"), eutrophication ("algal bloom"), photochemical oxidant creation ("summer smog"), and ozone depletion ("ozone hole").

The main purposes of LCA are to identify hot spots in the value chain, identify and quantify alternatives, and disclose environmental information. The following phases have been evaluated: production and transportation of energy and raw materials, production process, installation, maintenance, disposal and transports occurring during each step. The LCA approach used is best termed as "streamlined" LCA (SLCA), as it does not take into account the recycling of building materials or their disposal into landfill while it is more focused on two impact categories global warming impact, or carbon footprint, and embodied energy.

A comprehensive review of similar analysis for energy systems is presented and the results are compared with the ones derived from conventional systems as well as other renewable energy technologies. The results presented in this paper include the analysis of the production, disposal and transportation of the materials and energy used for the manufacturing processes of the building's energy systems, which include an oil and a gas fired boiler as auxiliary sources and the solar combi system (solar collectors and all the other components).

The goal is the integrated environmental evaluation of solar thermal energy systems as well as the comparison of the system analysed with other conventional ones in order to add the environmental criteria and the energy consumption to the selection of energy systems in hotel buildings.

Keywords: life cycle analysis, solar thermal systems, energy efficiency, hotel sector

ENERGY BEHAVIOUR OF BUILDINGS OF THE TERTIARY SECTOR IN THE CONTEXT OF THEIR ENVIRONMENTAL PERFORMANCE ASSESSMENT TOOLS: COMPARATIVE REVIEW AND ANALYSIS

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ABSTRACT

Buildings energy behaviour is a component of their overall operation that is of great significance for their environmental profile and, generally, for the sustainability in the building sector; indeed, buildings' energy behaviour and the parameters that are related to it are inextricably connected with factors that are associated with the environmental (energy consumption, use of renewable energy sources, environmental loadings, etc.), the economic (cost of installation and operation of the electrical and mechanical equipment etc.) and the social (provision of indoor environmental quality of a satisfactory level etc.) dimension of their performance. As a consequence, buildings energy behaviour could not but hold a significant position in the context of methods for the assessment of their environmental performance and the respective tools.

In this paper, the review of four widely used methods and tools for the assessment of buildings environmental performance (BREEAM, LEED, CASBEE and SBTool) is presented; the methods and tools under study are reviewed with regard to the way buildings' energy behaviour and the factors that are related to it are integrated in their structure and are taken into consideration in the context of the assessment they perform. In this paper, the versions of these four methods and tools referring to new buildings of the tertiary sector are examined. Specifically, after a short presentation of the assessment tools under study, the parameters that are related to buildings energy behaviour and are included in each one of these tools are systematically presented (issues of different nature, extending beyond the calculation of energy consumptions, are included in the spectrum of these parameters). Additionally, references are made to the applied criteria, to the required levels of performance, to data related to the relative weights of examined parameters in the context of the computational structures of the examined methods and tools, as well as, where considered necessary, to standards and regulatory frameworks associated with the criteria's assessment. The review presented in this paper covers the whole range of the parameters that are related to buildings energy behaviour; the issues and the criteria that are directly connected to the estimation of buildings' energy performance (i.e. computational approach in the context of regulations and standards, calculation of consumptions and comparison with base/reference building, etc.), as they are included in the structure and the evaluation process of each one of the examined tools, are analyzed in greater depth.

Keywords: buildings energy behaviour, buildings environmental performance, assessment tools

PERFORMANCE INDICATORS IN THE FRAMEWORK OF A COMMON EUROPEAN ASSESSMENT FOR SUSTAINABLE DEVELOPMENT OF THE BUILT ENVIRONMENT IN THE MEDITERRANEAN (CESBA MED)

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ABSTRACT

The refurbishment of buildings offers significant opportunities for reducing the energy consumption and the associated environmental impacts, improving the indoor environmental quality and their overall functionality. Considering combined interventions in groups of buildings at neighbourhood scale allows for a holistic and more flexible approach than the corresponding building-level efforts. The CESBA MED project (https://cesba-med.interreg-med.eu) aims to develop a common European sustainable built environment assessment method for sustainable Mediterranean cities in the frame of the Interreg Mediterranean programme co-financed by the European Regional Development Fund. The project aims to capitalize on the results of previous european projects and existing public assessment systems by using well established performance indicators in a new decision making processes. The multicriteria system will help users to overcome the complexities for the design and assessment of large scale interventions and facilitate effective synergies for the development of successful, financially viable and operational solutions for the development of energy efficiency plans for public buildings in the context of their surrounding neighbourhoods. Among the project objectives is the CESBA MED Passport for public buildings to support the comparison in absolute terms of the sustainability performance of neighbourhoods in the Mediterranean area, the development of regionally contextualized sustainability assessment tools, along with educational and training material for different stakeholders. The methodology addresses the main sustainability issues with the proper criteria and indicators for characterizing, quantifying and assessing the sustainability of a building or urban area, including economy, energy and emissions, resources and environment, social aspects, built urban infrastructures. This paper summarizes 14 existing methods and public environmental assessment systems that use 216 transnational performance indicators for the sustainability assessment of buildings and small urban areas, along with an overview of the CESBA MED method, the proposed assessment criteria and key performance indicators, the normalization process for the assignment of a score to the indicator's value, the aggregation for deriving a composite score, and the overall process for developing and testing the regional tools through nine pilot projects in six Mediterranean countries (i.e. Croatia, France, Greece, Italy, Malta and Spain).

Keywords: CESBA MED Sustainable Cities, Performance indicators, Decision making process, Sustainability assessment, Refurbishment of public buildings, Sustainable local urban development

INTEGRATION OF RENEWABLE ENERGY SOURCES IN RECREATIONAL PARKS.THE CASE OF THE "ANTONIS TRITSIS" PARK IN ATTICA, GREECE

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ABSTRACT

Recreational parks present significant electricity consumption that normally leads to increased operational costs. In this context, renewable energy sources (RES) can contribute to the satisfaction of recreational parks' energy needs at rational energy cost, while promoting sustainable development and enabling onsite environmental education. In fact, when it comes to public parks, responsible authorities often develop long-term energy conservation strategies that consider RES integration as a critical aspect.

On the other hand, the performance of RES installations is site-dependent. To this end, in the case of favorable RES potential, the incorporation of RES installations can prevent high electricity bills. Taking into consideration that the "Antonis Tritsis" park is located at West Athens, an area that appreciates high-quality solar potential, one may find several locations considered to be appropriate, combining minimum visual impact and maximum efficiency, for photovoltaic (PV) installations. To this end, the idea of generating electricity through solar PV installations is currently elaborated, aiming to the reduction of the park's operational costs and to the promotion of RES integration into recreational parks, as the best practice. The prevention of bulk electricity purchases enables the reallocation of financial resources into more urgent problems of the park.

In this context, the aim of this work is to identify the optimum size and installation site(s) for grid-tied solar PVs, taking into consideration visual and cost-benefit criteria. The results obtained are next used in order to set an implementation plan that supports the energy self-sufficiency of the park in an annual basis, for the baseline scenario and quantify the resulting costs and benefits. Finally, it is also important to note that the energy analysis carried out is based on actual long-term measurements, while the load demand evolution has been investigated with regards to the future activities that concern the functionality of the "Antonis Tritsis" park.

Keywords: PV Modules, Solar Radiation, Net Metering, Cost-Benefit Analysis, Green Energy

Energy Sorage - Hydrogen

ADOPTION INTENTION AND WILLINGNESS TO PAY FOR A RESIDENTIAL INTEGRATED GEOTHERMAL AND SOLAR ENERGY STORAGE SOLUTION

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ABSTRACT

The residential building sector is responsible for a large proportion of the energy consumption worldwide, mainly due to heating, cooling and domestic hot water needs. TESSe2b solution is the outcome of a four-year Horizon 2020 funded project intending to deal with the above issue, through the enhancement of energy efficiency in buildings. In the context of TESSe2b project, a compact and low cost thermal energy storage technology is designed, developed, validated and demonstrated; small-sized thermal energy storage tanks with phase change materials (PCM TES) are combined with solar collectors and high performance geothermal heat pumps.

A key-issue regarding the successful diffusion of the technology is consumers acceptance and adoption behavior. The present study aims to evaluate the self-reported behavioral intention of the TESSe2b solution in different European countries, as well as the factors that can affect this issue. On this basis, a behavioral survey was performed in five EU Member States (Austria, Greece, Spain, Portugal and Germany) between June 2016 and February 2017. The issues under investigation included: a) consumers' views on perceived benefits of the technology, b) consumers perceived adoption intention of the technology, c) willingness to pay (in €) for the technology and d) acceptable payback period in order for someone to be willing to pay for the TESSe2b system.

In order to examine the total sample of 583 respondents, separate statistical analyses were performed for each country. The sample was primarily analyzed through descriptive statistics, while ordinal logistic regressions were performed in order to examine the effect of socioeconomic and residence characteristics on consumers' views concerning perceived benefits, adoption intention, willingness to pay and acceptable payback period of the TESSe2b system.Kruskal-Wallis non-parametric tests were applied in order to identify any differences between the different countries, regarding participants' views on the issues under consideration.

The main factors that were identified to positively affect consumers views on TESSe2b technology are a) income, b) percentage of income spent on energy expenses, c) educational level, d) previous investments in relevant technologies, e) occupation or interest related to technology or the environment and f) household size. Age of construction, installed heating system and type of residence area are additional factors that have an impact on the subjects under investigation.

In a broader context, the findings of the study contribute to the understanding of consumers' behavior regarding residential heating/ cooling systems.

Keywords: ground source heat pump, solar thermal, thermal energy storage, consumer behavior, socioeconomic characteristics

INVESTIGATION OF THE POSSIBILITIES FOR THE SUBSURFACE ENERGY STORAGE IN THE FRAME OF THE EC-FUNDED ESTMAP PROJECT

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ABSTRACT

The idea of seasonal energy storage at various scales is of interest at European and international level, since it aims at balancing of energy demand and supply, grid management, energy efficiency, strategic reserves and back-up power for interrupted power supply leading to significant energy, economic, environmental and national benefits. Energy storage systems can be either above-ground or subsurface in geological formations. The choice for a certain energy storage technology depends on the purpose of the storage, the type of energy source, the type of storage reservoir available and the available storage capacity. Subsurface energy storage systems include the following types: (a) natural gas storage (UGS), (b) compressed air energy storage (CAES), (c) hydrogen energy storage (HES), (d) underground pumped hydro storage (UPHS) and (e) underground thermal energy storage (UTES). Suitable geological formations and structures for these systems are as follows: (a) depleted hydrocarbon reservoirs, (b) aquifers-traps containing poor quality waters, (c) salt formations and caverns, (d) abandoned mines, (e) engineered rock cavities and (f) cavity host rock units. In the frame of the EC-funded ESTMAP (Energy Storage Mapping and Planning) project, with participation of many European partners (IGME included), publicly available spatial data were collected on existing, potential and future energy storage sites at both national and pan-European level in order to create a harmonized spatial database containing information that can be properly used, analyzed and evaluated by the European Commission. A demonstration of how this database can be used for energy system modelling studies has been performed. Energy system models were successfully coupled with ESTMAP database on large-scale storage potential in EU28 to access its role in the energy system. ESTMAP provides an excellent toolbox and a knowledge base for future research and development. At national level, a total of 37 subsurface sites suitable for different types of storage technologies were proposed, namely: (a) one “planned” site for converting the depleted South Kavala gas field into an underground gas storage facility and (b) 36 “potential” storage sites in geological formations and structures which could be suitable for underground natural gas, compressed air energy, hydrogen energy, pumped hydro and thermal energy storage (22 local to regional-defined aquifers, 3 local-defined hydrocarbon reservoirs, 7 local-defined salt formations and 4 abandoned mines).

Keywords: subsurface energy storage, underground natural gas storage, underground hydrogen storage, underground thermal energy storage, underground pumped hydro storage

OPERATION OPTIMIZATION OF AN AUTONOMOUS INTEGRATED POWER SYSTEM WITH LPG REFORMING AND HIGH TEMPERATURE FUEL CELLS

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ABSTRACT

The purpose of this thesis is to present a systematic methodology for the development and control of a hybrid system that uses hydrogen to generate electrical power. The main motive is to design and develop an autonomous automated and sustainable system that generates power using renewable sources of energy. When multiple heterogenous subsystems must be combined to form an integrated system, many challenges arise from the complex interactions and fast and slow dynamic responses of the subsystems. The goal of this thesis is to study the system's response and develop suitable controllers for the efficient performance of the overall process. In order to achieve these goals, an advanced model predictive control (MPC) framework is designed. The methodology is deployed to an autonomous Li-Ion battery charging unit that consists of a High Temperature Polymer Electrolyte Membrane (HT-PEM) fuel cell stack and a Liquefied Petroleum Gas (LPG) reformer. The HT-PEM fuel cell is used as the main source of power for the charging of the batteries. The required hydrogen is supplied either by a renewable hydrogen production station or an LPG reformer, both of them operating at CERTH.

In the first part of this thesis, the mathematical models of the integrated system (LPG reformer, fuel cell, battery) are developed. Then, the development of model based advanced control methods took place with the use of predictive control algorithms. Considering the modelling of the integrated system, the control goals are recorded and the manipulated and controlled variables are specified under the right constraints. The control framework is completed with the system's simulation in real operation scenarios that include the meeting of the charging demand of the battery and the requirement to operate under different dynamic levels (increase/decrease of power generation). A set of efficiency measurements is defined and the behavior of the integrated system is evaluated by a sum of different charging conditions that utilize both pure hydrogen and LPG reformate.

Keywords: High temperature polymer electrolyte fuel cell, Integrated system, LPG reforming

CRUDE BIO-GLYCEROL AQUEOUS PHASE REFORMING AND HYDROGENOLYSIS

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ABSTRACT

In the present work, an one-pot Aqueous Phase Reforming (APR) and Aqueous Phase Hydrogenolysis (APH) of crude glycerol in a batch reactor containing commercial SiO2eAl2O3 supported 65%Ni catalyst is performed.

The effect of: i) the glycerol's impurities, ii) the operating temperature (200e240 _C) and iii) the crude glycerol concentration (10e40 wt%) is investigated.

The main gaseous products are H2, CH4 and CO2, while the main liquid products are propylene glycol (PG), ethylene glycol (EG), ethanol and acetol. The selectivities of the gaseous and liquid products are not strongly affected by the addition of low concentration impurities of methanol and sodium chloride. Glycerol's conversion increases as temperature and glycerol's concentration increases. Total conversion for both pure and crude glycerol is >90%. The yield of the most useful liquid product (propylene glycol) is reaching up to 30% for a 40 wt% of crude glycerol solution at T=240^{o}C and 4 h of reaction time.

Keywords: crude bio-glycerol, aqueous phase, hydrogenolysis, hydrogen, propylene glycol

PROMOTION OF HIGHER PENETRATION OF DISTRIBUTED PHOTOVOLTAICS THROUGH STORAGE FOR ALL

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ABSTRACT

Battery energy storage (BES) is emerging as one of the most growing storage technologies for power system applications. Indeed, BES can contribute significantly in the proposed energy transition, offering suitable services for both domestic and utility scale applications. Among these services, the balancing of the intermittent electricity generated by solar photovoltaic (PV) systems is considered as the most significant one. However, barriers concerning security and reliability issues as well as financial compensation must be lifted before BESs become a reliable and profitable option. This paper discusses the primary objectives of the StoRES project towards eliminating uncertainties related to battery storage. In the framework of the project, coupled PV-BES residential storage systems will be developed in five countries. On these pilot installations, several energy management schemes will be tested and evaluated. Additionally, this paper analyzes the process of selecting the pilot sites in each country highlighting the importance of the selection criteria developed for each country. Additionally, the examined system configurations, which are going to be tested on the pilot sites, are outlined. Finally, the methodology for acquiring and monitoring the data from the pilot sites is briefly discussed.

Keywords: *Energy management scheme, energy storage systems, self-consumption, photovoltaics*.

Biomass

WOOD BIOMASS PRODUCTION FROM A 10-YEAR OLD EXPERIMENTAL PLANTATION OF *FRAXINUS ANGUSTIFOLIA* VAHL. FOR ENERGY USE

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ABSTRACT

The native forest species *Fraxinus angustifolia* Vahl. (narrow-leaf ash) is a fast growing noble hardwood and it is an interesting and important tree species for the country. It has high sprouting ability, relatively heavy wood (700-750 kg/m^3 - air dried) and it is recommended for energy plantations. Under the frame of the European research program FRAXIGEN (EVK2-CT-2001-00180), eight natural populations were identified all over continental Greece and selected for research. In March 2006, an experimental plantation was established using provenances (13-20 trees/provenance) with 2 year-old seedlings in a planting density 1,110 plants/ha (3 x 3 m), in the area of Messia (Kilkis) near the banks of Axios river. In December 2016, biometric parameters (height, diameter at breast height/DBH, diameter at the base) as well as the production of fresh and dry woody biomass, based on the mean tree of each provenance, were recorded. In the recording, each provenance was represented with 13-20 trees, depending on the availability of the plants established. The mean tree of each provenance was cut and then the fresh and dry weight and the moisture content were measured. The moisture content was calculated by oven drying of fresh samples (70□75° C) for 48 hrs. Four categories of woody biomass were defined based on diameter/thickness of trunks/branches, as following: category (I) >12 cm (mainly trunk/stem wood), category (II) 8-12 cm (thick branches), category (III) 4-8 cm (medium branches) and category (IV) 0-4 cm (thin branches). In relation to diameter (DBH), results showed significant differences between provenances: provenance 14FAN developed the largest diameter (15,9 cm) whereas provenance 09FAN the smallest (12,6 cm). In relation to the basal diameter (DB), significant differences were also found: provenance 14FAN gave the largest diameter (20,6 cm) whereas provenance 09FAN the smallest (16,5 cm). However, despite of these differences at this stage, almost all provenances depicted significant diameter growth. In relation to the total height, results did not show much difference between provenances probably due to the high competition between trees. The moisture content was calculated and ranged between 30,8-33,7% (of the fresh weight), depending upon provenance and biomass category. Regarding the total fresh biomass, it was ranged from 82-157 kg/tree while the dry biomass from 54-107 kg/tree (or 60 - 118,8 tns/ha), depending on provenance. Assuming an average heating value 19 MJ/kg of wood, the total thermal energy of the produced biomass per 0.1 ha ranged from 114.000 MJ (or 31.692 kWh) for the provenance 08FAN up to 224.960 MJ (or 62.500 kWh) for the provenance 14FAN. Regarding biomass categories, important finding is that the category of thin branches (IV/0-4 cm) gave relatively high values of dry biomass ranged from 34,20% to 39,92% of the total dry weight (of the mean tree). The correlation between diameter at breast height (DBH) and total dry weight (T.D.W.) was not found significant ($p = 0,079$) with $r^2 = 0,427$. On the contrary, the correlation between diameter at base (DB) and the T.D.W. was significant ($p = 0,020$) with $r^2 = 0,624$ and the linear model was: T.D.W. = -109,104 + 9,983 DB. Based on this model the T.D.W. of a standing plantation can be estimated. The research keeps on, while the plantation acts as pilot experiment (the first in the country) for production of woody biomass of the studied species.

Keywords: forest plantation, narrow-leaf ash, biometric parameters, woody biomass, energy use.

LIFE CYCLE ANALYSIS OF 2nd GENERATION BIOFUELS FROM OPTIMIZED CASTOR BEAN CULTIVARS IN CENTRAL MACEDONIA

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ABSTRACT

The urgent need to tackle global warming via the transition to renewable energy sources necessitates the introduction of biofuels in the energy mix. The sustainability of biofuels and the extent of their contribution in the reduction of CO_2 emissions depend strongly on the type of biomass that is used as feedstock. Biomass used for biofuel production should not compete with the food chain and should be able to grow on marginal land without extensive fertilization and irrigation.

In the frame of the bilateral Greece-Israel research project Johan-Fuel (2013-2015), castor bean cultivars, suitable for cultivation in Central Macedonia with high oil yields, were identified. Moreover, project activities included the experimental investigation of castor oil processing in conventional refinery processes with the aim to convert this alternative renewable feedstock to high quality biofuels.

This study reports the evaluation of the environmental impacts of green diesel production from castor beans via Life Cycle Analysis (LCA). The LCA was conducted considering all steps in the life cycle of green diesel and more specifically the cultivation and harvest of castor beans, the crushing of castor beans for castor oil extraction and its refining, the transportation of castor oil to a conventional refinery and the co-processing of castor oil in a conventional hydrocracking unit for the production of diesel fuel. By-product valorization was considered by including the processing of the residuals from the castor bean crushing, the castor bean cakes, via catalytic fast biomass pyrolysis for bio-oil production. The produced bio-oil was assumed to replace heavy fuel oil for heating applications.

Comparison of the green fuel produced from the value chain proposed in Jonah-Fuel with fossil diesel and biodiesel from rapeseed and sunflower oil transesterification and hydrogenation demonstrated the great promise of the Jonah fuel since it exhibited the lowest consumption of total energy (both renewable and fossil) compared to all other fuel scenarios. Additionally, the process chain proposed exhibited also the most favorable GHG emission balance, confirming the sustainability and promise of the castor oil-based diesel.

Keywords: *biofuels, Life Cycle Analysis, castor beans, diesel, refinery*

CASTOR OIL UPGRADING VIA THE CATALYTIC CRACKING PROCESS

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ABSTRACT

A current trend is using biomass for the synthesis of various added value products. Thus, renewable feed stocks like vegetable oils, lignocellulose and other agro-residues constitute raw materials for the synthesis of bio-plastics, biodiesel, bio-lubricant, bio-adsorbent, and bio-ethanol products, which have been introduced successfully at commercial level in many countries and comply with the principles of circular economy and green chemistry. European Union initiatives support the cultivation of non-food feedstocks, which are able to grow on marginal lands and produce bio-based products within a sustainable agricultural system. A relatively well established non-edible oilseed crop is castor bean (Ricinus communis), widely spread to the Mediterranean area and Middle-East. Castor bean contributes to only 0.15% of the vegetable oil produced in the world, however the oil produced from this crop is of importance to the global specialty chemical industry because it is an abundant source of a hydroxylated fatty acid. The worldwide consumption of this commodity has increased more than 50% during the past 25 years, while even this rise is not considered sufficient to meet the anticipated increase in demand. The high content of ricinoleic acid in castor oil is the reason for its versatile uses, including the production of coatings, oil-based formulations of lubricants, grease, polymers, foams, textile finishing agents, plastics and cosmetics, etc. The present study focuses on exploitation of potential uses of castor oil towards fuels production via thermochemical refinery processes (like Fluid Catalytic Cracking: FCC). Incorporation of castor oil products and residuals in conventional refineries is aimed at converting this alternative renewable feedstock to biofuels.

FCC experiments were realized in CPERI aiming to co-process different amounts of castor oil (2 and 5 wt. %) with a conventional VGO feedstock both in bench scale and pilot FCC unit, which can provide a more realistic evaluation of the potential for co-feeding castor oil in existing refinery infrastructures (FCCUs). The bench-scale tests evidenced that castor oil can be cracked even without catalyst producing mainly heptanal (which is the main oxygenate in gasoline) and undecylenic acid (which is the main oxygenate in diesel). During experiments in the pilot FCC unit, it was shown that castor oil can be introduced in the FCC unit without any operating problems at least till 5 wt%. In all cases the oxygen comes mainly to H_2O, CO and CO_2 but the semi-quantitative analysis of 2DGC-ToFMS showed the possible presence of some oxygenates (0.36%) in the liquid products of pilot tests. 50 oxygenated components were identified at very low concentrations. Experiments from both units suggested that the presence of castor oil in the inserted feedstock decreases the gasoline and LPG olefins as well as the hydrogen yield, while it increases the LCO and coke yields both in bench and pilot scale units.

Keywords: castor oil, catalytic cracking, co-feeding, bio-fuels

PRODUCTION OF ENERGY VIA THE VALORIZATION OF GLYCEROL, BY PRODUCT OF BIODIESEL PROCESS: LITERATURE REVIEW

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ABSTRACT

The increasing production of biodiesel during the last few years has highlighted the need for the energy utilization of glycerol which is the main by-product of the transesterification reaction. As a result, finding new alternative feasible uses for the glycerol is urgently required, as such technologies will not only solve environmental problems related to disposal but will significantly increase and the global demand. Glycerol except in very particular and important physical and chemical properties can be used for energy production, via catalytic processes can be produce hydrogen and synthesis gas. The hydrogen can be fed into fuel cells to generate electrical energy and the synthesis gas can be used in Fischer-Tropsch processes.

Keywords: Hydrogen production, Glycelor, Biodiesel, Steam reforming

INCORPORATING AVAILABLE MICRO GAS TURBINE IN AN ANAEROBIC DIGESTION SYSTEM

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ABSTRACT

The present paper aims at examining the performance of an anaerobic digestion system for cheese whey treatment coupled with a commercially available micro turbine. The latter is selected among others in order to obtain the maximum electricity production. The irreversibilities and thermodynamic inefficiencies of the system are evaluated by examining the exergetic performance and estimating the amount of exergy destruction and the efficiency of each cogeneration system component. The hybrid system achieves an exergetic efficiency of about 36%, which is significantly higher than that of the initially AD system model without the incorporation of the micro turbine. According to an economic analysis based on the NPV method it can be shown that the developed system constitutes a profitable and sustainable investment with significant savings. In addition, the effects of the various performance parameters are assessed. The analyses showed that the exergetic performance is affected significantly by the turbine isentropic efficiency, while for the NPV analysis it appears that the temperature of the gases after micro turbine s combustion chamber plays a major role.

Keywords: *Cheese Whey, Exergetic analysis, Economic analysis, Micro turbine, Biogas plant*

ENERGY AND ENVIRONMENTAL ASSESSMENT OF PELLETS PRODUCED FROM SOLID RESIDUES OF THE WINERY INDUSTRY

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ABSTRACT

The aim of the study entitled Energy and environmental assessment of pellets produced from solid residues of the winery industry was the assessment of the potential of waste by-products of the Cypriot winery industry, to be pelletized and used as raw material for solid biofuels. In terms of this study, two different biomass blends have been pelletized and assessed as energy source for domestic hot water boilers. The samples were composed of Grape Pomace (P1) and Grape Pomace & Vine Shoots Blends (P2). The raw material was sampled by a Cyprus local winery named Aes Ambelis (Nicosia, 35°01'12.4"N 33°09'19.5"E). The raw material was dried and pelletized at the facilities of the Agricultural Research Institute (ARI), in Cyprus. The produced pellets were analysed to define their moisture and ash content, based on well-established standardized methods, at the Sustainable Solid Fuels Lab of Frederick University. Combustion tests with the produced pellets were also carried out at the Boilers Lab of Frederick University. The measurement campaign focused on the flue gas analysis and particularly on the concentration of carbon monoxide, carbon dioxide, oxygen, lambda, water temperature and boilers efficiency measured.

The results obtained from the analysis of the investigated samples showed that the majority of the examined pellets satisfied the minimum requirements of the EN ISO 17225-2 and EN ISO 17225-6 standards for woody and non-woody pellets respectively. Ash content and moisture content for both sample were also found to be within the limits of the standards. The results of the measurement campaign were also found to be in good agreement with results delivered by other studies conducted for similar biomass raw material.

Study results showed that grape pomace and grape pomace vine shoots blend could potentially be used as an energy source for producing heat which could be exploited for both the domestic and the industrial sector. The exploitation of this waste stream for energy production purposes could offer economically and environmentally smart solutions for the winery industry in Cyprus, satisfying the circular economy principles, which are currently at the forefront of the European environmental policy

Keywords: Solid biofuels, grape pomace, vine shoots blends, pellets, ash content, moisture content, combustion emissions

ASSESSMENT OF WOOD BIOMASS USE IN RURAL ISLAND COMMUNITIES (CASE STUDY: ANOGEIA, CRETE)

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ABSTRACT

In many island communities of Europe, wood biomass is considered as one of the most important sources of energy for heating and cooking, especially for the mountainous and rural ones. However, the extended use of old-fashioned fireplaces may affect indoor air quality and outdoor environment. This study presents a holistic methodological approach in order to improve the existing situation by means of changing the energy behaviour of the local population in the mountainous and rural areas of the Mediterranean, increasing the use of RES and integrating energy efficiency measures as horizontal principles in the local development plan.

To this purpose, a pilot action is under implementation in the study area, the mountainous area of Anogeia (Crete). The planned actions involve: the identification of the quantities and the origin of wood biomass consumed in the community of Anogeia with the analysis of data collected through a structured questionnaire and a dedicated field research; on-site measurements of the variation of air quality (CO_2, CO, NO_X, PM1, PM2.5, PM4, PM10, TPM), between winter and summer months for both indoor and outdoor air quality in mountain households; the promotion of highly efficient and environmentally friendly heating systems suitable for the specific location as alternatives to the local population and local authorities; the exploitation of the locally produced biomass residues and the development of sustainable business models for relevant economic activities for the local businesses.

This study is being implemented in the framework of the European initiative "COMPOSE - Rural communities engaged with positive energy", which aims to promote small-scale RES applications in rural and island regions of the Mediterranean and is co-funded by the European Regional Development Fund under the INTERREG MED program. The project supports the implementation of 5 pilot actions in 11 countries. The overall goal of the project is to propose and test an RES project development methodology that will enable cities and regions of the Mediterranean to increase RES in their energy mix and at the same time to strengthen local businesses and local value-added product and service chains, by applying examples of good practice and building on existing European expertise and know-how.

Keywords: *Wood biomass, GHG emissions, Energy-efficient heating systems, Environmental impacts of wood combustion, small-scale RES development planning*

COMBUSTION CHARACTERISTICS AND MECHANICAL RESISTANCE OF WOOD PELLETS SOLD IN THE GREEK MARKET

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ABSTRACT

The utilization of woody biomass into biofuels production, may provide several environmental, social and economic benefits, especially when it is carried out under the appropriate conditions. In recent years, the use of pellets for power generation and electricity attracts the interest of consumers and their consumption presents a particular increase in North America, Europe, as well as our country. Only few Greek companies produce pellets, because of the very low prices of pellets coming from the neighboring countries (Bulgaria, Albania, etc.), and parallel, the total absence of control of the characteristics of pellets, imported legally or illegally, may lead to the possible consumption of questionable quality pellets with the probability of harmful effects on health, atmosphere and of damages to the combustion equipment. This study examines for the first time the characteristics of pellets being sold in Greek market (Northern Greece), such as the percentage of ash content, which is one the most important factor, according to the corresponding international standards concerning biofuels, according to which the material is classified into different categories of authorized use (residential, industrial, etc.), but also the mechanical strength of pellets, the moisture content and the bulk density of pellets are examined in order to draw useful conclusions about the suitability of these specific pellets to be combusted.

Keywords: ash, bulk density, mechanical strength, pellets

DEVELOPMENT AND IMPLEMENTATION OF A DECISION MAKING SYSTEM FOR THE GASIFICATION OF BIOMASS

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ABSTRACT

Commercially available technologies are used for the production of electricity from biomass in combined heat and power plants and in internal combustion engines, where biogas that is produces by landfills or by the anaerobic fermentation of organic waste, is processed. The less mature technologies of gasification and pyrolysis are freshly grown on a commercial scale or they are in an experimental demonstration.

The main objective of this study was the development and implementation of a decision-making system for energy recovery from biomass. This system was created by collecting and processing data for the available methods and experimental results for biomass gasification. It was developed taking into account the chemical and ultimate analysis, water content of the biomass used and the performance of the biomass gasification technology.

This system was applied for the calculation of the electric power production from biomass gasification taking into account the availability and transfer cost of biomass produced in the Pella region.

Keywords: gasification, biomass, decision making system

A NOVEL SOLAR PHOTOELECTRO-FENTON PILOT UNIT FOR WATER AND WASTEWATER TREATMENT

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ABSTRACT

This paper summarizes the main results of a joint research work carried out at the Plataforma Solar de Almería in Spain (PSA/CIEMAT) with the aim to successfully start-up and operate a novel wastewater treatment plant at pilot scale (200 L). The pilot unit combines three processes, a) anodic oxidation on a boron doped diamond (BDD) electrode, b) electro-Fenton (reaction between the electrogenerated hydrogen peroxide and ferrous ions towards the production of strong oxidants, like hydroxyl radicals, $^{\bullet}OH$) and c) solar regeneration of the catalytic iron species in a compound parabolic collector of 2 m^2 irradiated surface. The objective of such a hybrid process is the elimination of recalcitrant organic pollutants in drinking water sources and industrial wastewater, like pesticides, pharmaceuticals, phenols, humic compounds, etc., in an effective, economic attractive, and environmental friendly manner.

The capacity of the unit to produce in situ hydrogen peroxide (H_2O_2) was initially optimized. An experimental design was carried out based on Central Composite Design (CCD) with Response Surface Methodology (RSM) to evaluate the effects of the key process parameters (current density, air sparging rate in the cathodic electrode, feed solution pH, electrolyte concentration) and their interaction towards the attainment of optimum condition. Under the optimum operating conditions (pH 3, 7.4 A, air flow rate 10 L/min, feed flow rate 5.3 L/min), H_2O_2 was produced with a mass rate of 64.9 mg/min, current efficiency 89.3% and energy consumption 0.4 kWh/m^3 (for a single pass of 25 L of 50 mM Na_2SO_4 solution through a filter-press cell containing a BDD anode and an oxygen diffusion cathode, both of 100 cm^2 area and an inter-electrode gap of 6 mm). Pilot tests were carried out next under the optimum operating conditions with the aim to investigate the oxidation/mineralization of model refractory organic compounds. The hybrid process allowed the degradation of refractory short-chain acids (butyrate>propionate>acetate) and pesticide molecules (methomyl>pyrimethanil) with a rate that depends strongly by the molecular structure of the target organics (higher degradation for electron-rich compounds and lesser for electron-poor, like acetate anions), their initial concentration, and the competition with other organic components included in the feed water (e.g. organic solvents in the case of experiments with commercial pesticide products).

Keywords: advanced water treatment, anodic oxidation, electro-Fenton-like reactions, solar regeneration of ferrous iron

CATALYTIC AQUEOUS PHASE REFORMING AND AQUEOUS PHASE HYDROGENOLYSIS OF GLYCEROL IN A BATCH REACTOR

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ABSTRACT

In the present work, the catalytic Aqueous Phase Reforming (APR) and Aqueous Phase Hydrogenolysis (APH) of glycerol are studied. The reactions take place in a batch reactor containing SiO_2- Al_2O_3 supported 65% Ni catalyst.

The dependence of: a) the gaseous and liquid product selectivities and b) the glycerol's conversion on: 1) the reaction time (30-240 min), 2) the operating temperature (200-240 °C), 3) the glycerol concentration (1 or 10 wt.%), 4) the catalyst weight (0.5-10 g) and 5) the gas to liquid phase volume ratio (1.4 or 5 ml/ml), is investigated.

H_2, CH_4 and CO_2 are the main gaseous products, while propylene glycol (PG), ethylene glycol (EG), ethanol and acetol are the main liquid products. Both the reaction evolution and the increase of the temperature increase the glycerol's conversion, reaching a plateau. It is found that hydrogen yield maximized and reaches up to 23.5%, at short reaction times, low glycerol concentrations and increased gas to liquid phase volume ratios. In contrast, the PG yield improves under the opposite conditions, reaching up to 22%.

Approximately, 73.6% is the higher conversion to gaseous products, whereas 35.6% is the higher conversion to liquid products. It is also found that the increased catalyst concentration favors the C-C bond cleavage as well as the formation of ethylene glycol, ethanol and CH_4.

Keywords: glycerol, hydrogen, aqueous phase reforming, hydrogenolysis, nickel, propylene glycol

PHYSICAL AND CHEMICAL PROPERTIES OF PELLETS MADE FROM OAK, POPLAR AND PINE LOGGING RESIDUES

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ABSTRACT

The biomass residues that remain in the forests after logging have attracted high interest as an energy source. In this work, logging residues of oak *(Quercus frainetto)*, pine *(Pinus nigra)* and poplar *(Populus alba)* were evaluated as raw materials for pellets. For this, laboratory-scale pellets were made from different parts of residues, and their chemical and physical properties were determined and compared to the EN ISO 17225-2 standard requirements. The results showed that pellet made of thick and thin branches of poplar and pine meet the standard requirements. Oak pellet and pellet made of pine twigs, because of their high ash and nitrogen content, did not fulfill the standard requirements for pellets production. The heating value of the pellets produced from oak residues varied from 19.26 to 19.31 MJ/kg, from poplar residues 18.26 to 18.27 MJ/kg and from pine residues 20.80 to 20.95 MJ/kg.

***Keywords**: logging residues, pellets, forest biomass, poplar, oak, pine*

Geothermal Energy

PARAMETRIC ANALYSIS OF TWO MODELS THAT SIMULATE THE THERMAL BEHAVIOUR OF EARTH TO AIR HEAT EXCHANGERS

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ABSTRACT

The integration of renewable energy systems in existing HVAC systems can lead to a decrease in their nominal installed capacity and also increase energy efficiency. Earth to air heat exchangers consist of a number of pipes, horizontally buried underground, through which ambient air is transported by fans and draws or dumps heat from/to the ground. Due to the high thermal capacity of the ground, underground temperature is lower than the ambient during summer and higher during winter, allowing the air that flows inside the earth to air heat exchanger to exploit the temperature difference in order to preheat or precool the air before it is actually used for ventilation.

The energy efficiency potential of earth to air heat exchangers has garnered the attention of a number of researchers as early as the 1980's, while the main effort has been focused on the evolution of simulation methods that can be used for the prediction of their thermal behavior, so that they can be integrated in the overall HVAC system. A typical simulation process is based on heat and mass transfer equations and aims to:

- Dimension the pipes
- Calculate the heat that is transferred between the air and the earth
- Calculate the temperature change of the air between the inlet and the outlet of the pipes
- Calculate the pressure drop of the air inside the pipes, in order to increase overall efficiency and minimize the operational cost.

In the present study, a comparison between two one-dimensional simulation models from the literature is conducted. The criterion for their selection was the simplicity of the calculations used so that results can be obtained quickly, without too many parameters taken into consideration, in order to be used for a preliminary sizing of an air to earth heat exchanger.

The impact of various parameters like the length, the diameter, the depth, and the number of the buried pipes in the ground on the outlet air temperature, on the heat exchange (W/m²), and the efficiency of the earth to air heat exchanger are assessed. The simulation is done for the meteorological data of Athens for a typical winter and summer day. For the evaluation of the two models, results from both models are compared with actual measurements.

Keywords: earth to air heat exchanger, simulation models, parametric analysis

GEOTHERMAL DEVELOPMENT IN GREECE AND EUROPE

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ABSTRACT

The installed geothermal capacity in Greece is estimated to 257 MW_{th}, used for heat purposes and balneotherapy, while the share of geothermal energy in the production of electricity is zero. The confirmed high enthalpy geothermal potential remains untapped in Milos and Nisyros islands. The past attempt to explore and exploit the medium enthalpy resources in Northern Greece did not concluded successfully, due to bureaucratic reasons. The Greek geothermal market is dominated by the shallow resources and the Ground Source Heat Pumps, which share 63% of the total installed geothermal capacity (250 MW_{th}). Regarding direct uses, balneotherapy constitutes the most common geothermal use in Greece (42 MW_{th}), followed by greenhouse heating (~43 MW_{th}) and other less developed applications, such as soil heating, dehydration and aquaculture (8 MW_{th}). Most of the geothermal projects (new and existent) are realized in Northern Greece, where the investment environment is more favorable due to the existence of well-studied and easily accessed geothermal systems (less risk), public acceptance and support from the local authorities. The most substantial new investments in the geothermal sector regard the operation of two large greenhouse units in Neo Erasmio (Xanthi) and Eratino (Kavala), totaling so far 15 ha, whereas a similar project is under development in Nea Kessani (Xanthi).

The use of geothermal energy in Europe (Turkey included), especially for heat, exhibits a steady growth during the past years. As for the end of 2016, the total installed geothermal capacity was 35.5 GW. Europe has 100 geothermal power plants, with total installed capacity around 2.5 GW_e, but, with several new projects under development, it is believed that the installed capacity will reach 3 GW_e until the end of the decade. The growth of the geothermal power market is attributed almost entirely to the rapid and impressive enlargement in Turkey. District heating is the most developed sector (4,8 GWth) of the direct uses, with 280 plants in 22 countries. Several countries use geothermal heat in agriculture (1.67 GW_{th}) and balneology (2.24 GW_{th}). The shallow geothermal sector constitutes the largest market, with 1.7 million installations of GSHPs across Europe (22.3 GW_{th}), but a declining installation growth rate.

Three EGS (Enhanced Geothermal Systems) power plants operate in Europe (Soultz-sous-Forets in France, Landau and Insheim in Germany) and one new heat plant in Rittersshoffen (France). Ten (10) more plants are under development in France and Hungary, whereas another ten (10) projects are under investigation in France, Germany, UK and Switzerland.

The target for the future is to expand faster the geothermal market and increase the geothermal energy use. This can be achieved, among others, by adapting the new and suitable technologies in each sector, increasing the public and decision maker's awareness of the geothermal energy benefits and advantages, and, finally, by securing adequate financial support

Keywords: *geothermal potential, geothermal electricity, direct uses, shallow geothermal energy*

EVALUATION OF SOCIAL ACCEPTANCE OF GEOTHERMAL ENERGY IN GREECE

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ABSTRACT

The promotion and successful implementation of renewable energy projects requires the acceptance of the local communities [due to environmental and economic issues, participation of the local community, NIMBY (Not In My Back Yard) type acceptance issues], assisted by public's knowledge and awareness of these forms of energy. Geothermal energy is a form of RES that has encountered problems of social acceptance in Greece, which have, in combination with other factors, hampered the development of this type of energy. Scope of this paper is to examine the subject of social acceptance of geothermal energy in Greece, taking into account all work performed so far on this issue.

Initially, a review of all published research dealing with the public's knowledge, information, views and acceptance of geothermal energy is performed, aiming to form a comprehensive view of the issues under examination. The aforementioned process includes Greek and foreign language studies that deal with the social issues of geothermal energy for power generation, direct use, or use through ground source heat pumps (GSHPs).It should be noted that the majority of the studies identified deal only partly with geothermal energy, emphasizing either on other forms of RES, or on RES in general, while the number of studies focusing exclusively on geothermal energy is small. This review also presents the overall knowledge/ information/ evaluation/ acceptance of geothermal energy compared to the different RES forms applied in Greece.

Subsequently, emphasis is given - presenting all the facts hitherto - in the case of Milos Island, as it is a typical example of reaction of the local community to the exploitation of geothermal energy. The negative example that has been created is one of the factors that have affected the further development of geothermal energy in Greece, at least when taking into account electricity production. In addition, other relevant cases, such as those of Nisyros and Kimolos Islands, where social acceptance issues have raised are examined.

Additionally, through the study of the subject on an international level, best practices that can contribute to the improvement of the social acceptance of the particular form of energy are presented. These practices are important to be implemented during all stages of project development (idea development, decision making, planning, implementation, operation) and include a) public awareness and engagement actions; b) promotion of dialogue; c) prevention and minimization of adverse effects and d) creation of benefits for local authorities and residents.

Keywords:*geothermal energy, social acceptance, local community, best practices*

EFFECTS OF THERMAL LOADING ON THE MECHANICAL BEHAVIOUR OF FIXED-HEAD ENERGY PILES

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ABSTRACT

Integrating geothermal loops into conventional structural piles constitutes an environmentally friendly way for the heating and cooling of a building. Energy piles take advantage of the shallow geothermal energy in order to satisfy the thermal needs of the building. However, the exploitation of geothermal energy creates additional thermal loadings. Thermomechanical finite element analyses are conducted in order to examine the effect of the additional thermal loading on the mechanical behaviour of single energy piles, with fixed head, in sandy soil. Both mechanical and thermal loads are applied. This paper summarizes the effect of: i) the duration of thermal loading and ii) the coefficient of thermal expansion of the soil on the mechanical behaviour of the pile. Additionally, the effect of thermal loading on the pile's bearing capacity is investigated. The results show that the effect of thermal loading on the bearing capacity of the pile is not significant. On the other hand, both the duration of the thermal loading and the relative values of the coefficient of thermal expansion of the pile and the ground modify the axial stresses of the pile and affect significantly the mechanical response of the pile.

Keywords: swallow geothermal energy, energy piles, fixed pile, finite element analysis, foundations

CONTRIBUTION OF CO_2 GEOLOGICAL STORAGE TO THE GEOTHERMAL ENERGY EXPLOITATION

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ABSTRACT

CO_2 Geological Storage (CGS) in suitable deep (>800m) porous and permeable geological formations (saline aquifers, depleted oil/natural gas reservoirs), which are overlain by impermeable rocks (cap rock), is considered as effective way of reducing anthropogenic greenhouse gas emissions in the atmosphere and subsequently mitigate the adverse effects of climate change. The injection and storage of CO_2 can contribute to the utilization of the geothermal potential. CO_2 displays significant advantages compared to water (e.g. larger expansivity and compressibility, lower viscosity, higher mobility, larger flow velocity for a given pressure gradient, different enthalpy behavior in relation to pressure and temperature, higher heat extraction rates, less effective as a solvent), and therefore makes it preferable for use as a working fluid in geothermal systems. Several proposals for the use of CO_2 in the exploitation of geothermal energy have been suggested, but still remain at the early research level: (a) use of supercritical CO_2 as the working fluid in Enhanced Geothermal Systems (EGS), which are characterized by limited permeability and fluid circulation, (b) injection of supercritical CO_2 into a deep saline aquifer and formation of a "CO_2 Plume Geothermal (CPG) system", that is heated by the naturally increased underground thermal energy within the reservoir, thus providing energy utilization, (c) a hybrid two-stage, integrated, energy recovery approach (initially brine and later brine and CO_2) from a deep saline aquifer, (d) use of CO_2 as both a pressure-support and working fluid to generate artesian pressures for CO_2 and brine production, using both fluids as working fluids and improving the economic viability of geothermal energy production in sedimentary formations, (e) CO_2 dissolution in the brine of the reservoir and energy recovery of CO_2-enriched hot brine in a geothermal doublet and (f) capturing CO_2 from ambient air and storing in the basaltic basement (mineralization) close to an existing geothermal power plant.

This paper presents the aforementioned proposals for combining geological storage of CO_2 and exploitation of the geothermal potential, pointing out its advantages. CO_2-based technologies make it possible to extend the use of geothermal energy, by also helping to reduce the cost of CO_2 capture and storage. In addition, they can be a connection between today's electricity production, which is dominated by fossil fuels and a future RES-based power generation. Furthermore, they can contribute into turning CO_2 from a damaging factor to a valuable resource for the future.

Keywords: CO_2 Geological Storage, geothermal energy, Enhanced Geothermal Systems, CO_2 Plume Geothermal, Heat Extraction

Energy Policy

OVERVIEW OF THE GREEK LEGISLATIVE FRAMEWORK FOR GEOTHERMAL ENERGY EXPLOITATION

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ABSTRACT

Scope of the present paper is to summarize the current Greek legislative framework concerning the exploitation of geothermal energy, as well as to provide targeted proposals for its improvement. In particular, this work focuses on legislation and ministerial decrees referring mainly to: a) electricity production, b) district heating, c) agricultural applications, d) balneology and e) ground source heat pumps (GSHPs).

It is worth noting that the first □chronologically□ Greek legislation which makes a mention to geothermal energy is 210/73 (Government Gazette 277 A/1973), entitled "Mining Code"; geothermal energy is mentioned particularly in Article 2 □ 1(ιβ). Since then, laws, ministerial decrees, provisions, etc. have been issued, aiming to the creation of conditions for the rational exploitation of geothermal energy in Greece.

Today, the basic and fundamental law in force, concerning research, exploitation and management of geothermal energy in Greece is Law 3175/2003. This law refers mainly to the case of power generation and district heating through the exploitation of geothermal potential. At the same time, according to the aforementioned law, it is noted that the possibility of geothermal exploitation in Greece aims directly at serving the general interest and promotes sustainable development, since geothermal energy is a renewable energy source (RES).

On the other hand, the imperative need to improve the legislative framework in Greece aiming to the exploitation of geothermal energy is underlined, especially in the middle of the economic recession that the country is facing. This is the case, as geothermal energy can play a dominant role as a remarkable RES technology, being an inexpensive energy source with many direct and/or indirect benefits.

Keywords: *Greek geothermal legislative framework, ground source heat pumps (GSHPs), geothermal energy, district heating, balneology*

MAESTRALE: A PROGRAMM FOR BLUE ENERGY DEVELOPMENT IN MEDITERANEAN SEA

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ABSTRACT

Notwithstanding the many academic and technical studies and applications that have been implemented over the last few years on blue renewable energies, both in the northern European countries and globally, there is a general shortage of initiatives and business plans beyond the individual efforts in the Mediterranean Sea. The potentials that Mediterranean sea can offer for the blue renewable energy solutions are numerous and indescribable. However, the lack of a clear-cut for all member countries, of a European legal framework, a comprehensive development plan, and extensive research on whether or not the implementation of already-known technologies is also within the Mediterranean possible, are issues that prevent growth. The answer to these problems is to be given by MAESTRALE, program funded under the Priority Axis 1 - Innovation of the Interreg MED 2014-2020 Program, with eight participating countries and with Greek partner the Department of Architectural Engineering of the Aristotle University of Thessaloniki. The main objective of the program is to lay the foundations for a strategic development of blue energy in the Mediterranean region. Starting with the research and inventory of existing and innovative technologies, as well as by discovering the barriers and prospects in the participating countries, MAESTRALE aims at widening the exchange of knowledge among scientists, policy makers, entrepreneurs and citizens, as well as promoting actions and investments in blue growth. More specifically, project partners will work together to identify prospects for the development of blue energy on the basis of the natural, legal, technological, economic and social context, while addressing environmental sustainability, technological innovation, citizens' acceptance and possible conflicts with marine ecosystems. Through the creation of a network of Blue Energy Labs (BELs), a BEL from each partner country, involving local businesses, public authorities and institutions related to knowledge and citizens, MAESTRALE will provide the basis for supporting future policies in relation to blue energy and the design of compact strategies for blue growth. At the same time, a series of pilot projects will aim at raising awareness among local stakeholders, facilitating social acceptance, reducing uncertainty and enhancing the sustainability of interventions. All of the above will provide the necessary bases for creating the right conditions for the best use of renewable energy sources in the marine environment, while preserving the environmental and cultural values of the region.

Keywords: *Blue Energy, Renewable Sources of Energy, Wave energy, Environmental Development and Design, Strategic planning*

OBSTACLES AND OPPORTUNITIES FOR INTEGRATING CLIMATIC DESIGN CRITERIA IN GREEK URBAN PLANNING

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ABSTRACT

Within the context of European energy policy all new buildings should consume nearly zero energy from 2020 onwards. The intense urbanization of Europe renders the building energy issue a primarily urban one, since achieving the goal of nearly-zero energy consumption demands solutions that transcend individual buildings in order to deal with the complexity of modern urban environments. One of these solutions is the efficient adaptation of urban form to the local climate, which in turn requires an integrated legislative framework of environmental urban design. How can the synthetic nature of climatic design be regulated with planning tools? What are the obstacles and the opportunities for integrating climatic design criteria in Greek planning? The present paper attempts to answer these multifaceted questions.

Keywords: NZEB, Urban planning, Climatic urban design, Greek planning, Bioclimatic design

BETWEEN THE CLASSIC FORMS OF ENERGY PRODUCTION AND RENEWABLE ENERGY IN EU15

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ABSTRACT

The decoupling of energy consumption from economic growth is one of the basic principles of sustainability. In addition, the change of energy production from fossil fuels to RES can also have a positive effect on climate change without affecting overall energy consumption. The present work presents initially the analysis of total energy consumption in 15 countries of EU15 from the beginning of the energy balance recording up to date (1960-2014) and the comparison of the countries between them. Then, it analyzes the decoupling of total energy production from GDP and compares the decoupling of conventional energy and RES forms. It is also explored in which countries a decoupling from the conventional forms of energy has been achieved and a shift to RES has been realized and to whom not.

Keywords: Renewables, Conventional Forms of Energy, Decoupling, EU15

PENETRATION OF RENEWABLE ENERGY SOURCES IN ELECTRICITY PRODUCTION OF GREECE

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ABSTRACT

In the last decade, the contribution of Renewable Energy Sources (RES) in the electricity production of Greece is increasing continuously, hand to hand with their simultaneous increase in installed capacity. In this study a thorough analysis of the progress of RES contribution in the annual demand throughout the period 2008-2017 is presented.

The data used were collected from: The Independent Power Transmission Operator S.A. for the interconnected system regarding the distribution network of high voltage, the Hellenic Electricity Distribution Network Operator S.A. for the distribution network of medium and low voltage, as well as the Operator of Electricity Market S.A.

The contribution of RES technologies was examined in hourly, daily, monthly and annual basis with or without contribution from large-scale hydro power plants (LSHPP) excluded. The penetration of LSHPP is very much dependent on water reserves during each year therefore in arid years their load coverage is rather limited rendering the total of RES contribution lower.

The annual load duration curve of RES input (with or without LSHPP) shows valuable information and showcases a total of hours per year that RES contribution reaches certain amounts.

The analysis of the electricity market through the hourly data collected from the Independent Power Transmission Operator provides a detailed picture of the hourly RES penetration and demand coverage.

Lastly, based on the previous analysis and conclusions and considering the estimations for the future level of demand in the following years (by the Operator in charge), various scenarios of new RES capacity to achieve the national goal of RES penetration by the year 2020 are examined.

Keywords: Renewable Energy Sources (RES), Large-Scale Hydro Power Plants (LSHPP), Capacity Factor and penetration of RES and LSHPP, duration curves of energy and penetration of RES and LSHPP, RES penetration scenarios.

THE INSTITUTIONAL FRAMEWORK OF THE NEW RES SUPPORT MECHANISM AND THE PILOT TENDER FOR PHOTOVOLTAIC INSTALLATIONS

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ABSTRACT

In line with the "*Guidelines on State aid for environmental protection and energy (2014-2020)*" (2014/C 200/01), Greece ran a pilot tender in 2016 for a 5% of the total Renewable Energy Sources' (RES) capacity which was to be installed within the period 2015-2016.

In accordance with the Greek legal framework and specifically Law 4414/2016 "*New support scheme for renewable energy sources power plants and high efficiency combined heat and power plants. - Provisions on the legal and functional separation of the supply and distribution branches in the natural gas market and other provisions*" ("Law"), Greece implemented a new RES support mechanism. One of the main purposes of the Law was the development of an adequate support scheme for power generation from RES in the context of a common European Member States' policy on fighting climate change, reducing greenhouse gas emissions and achieving the target of RES participation in gross final energy consumption. In this legislation framework, specific provisions took place for the planning, organization and execution of a pilot tender. The legislation stated that "*RAE shall be responsible for carrying out competitive bidding processes and certifying their results*".

For this purpose, a specific innovative electronic platform was developed to simplify the procedure, secure its accuracy and transparency and increase the competitiveness with the use of an electronic tender. According to the Law, Article 7, par. 9, the pilot tender on photovoltaic plants should have the following main characteristics:

- the tendered capacity should be at least 40 MW,
- the PV-Plants should be divided in two Categories, according to the installed capacity of each installation (Category I for PV-Plants ≤ 1MW and Category II for PV-Plants > 1 MW), whereas the tendered capacity of Category I could not exceed 20% of the overall auctioned power.

In compliance to the main legislative guidelines, two competitive bidding processes took place online on the 12th of December 2016, in cooperation with a Greek company specialized in B2B online auctions. The maximum allowed bidding price was set at 104 €/MWh for Category I and 94 €/MWh for Category II. One of the most important outcomes of the online application procedure was that this allowed the participants to upload all the necessary technical and legal documents that had to be sent for the participation in the tender, minimizing workload and simplifying the procedures in hole, with both, participants and RAE, benefiting from the simplicity. The main goal is to adopt the procedure as a best practice in the future tenders for RES installations.

Keywords: RES, Pilot Tender PV, Online Tenders

RESEARCH OF THE ENERGY BEHAVIOR OF HOUSEHOLDS IN NORTH GREECE – THE PHENOMENON OF ENERGY POVERTY

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ABSTRACT

Energy poverty has first entered the vocabulary of the EU institutions in the process of preparing the Third Energy Package. The growing importance of energy poverty within the EU's political sphere is demonstrated in the Opinion on Energy poverty in the context of liberalization and the economic crisis, adopted by the European Economic and Social Committee on 14 July 2010, which concluded that "energy poverty affects the energy sector" and also affects "health, consumer habits and housing".

However, "energy poverty" was introduced to the greek vocabulary over the last four years. It is pressing problem that play a major role due to the complex integration of the rising energy prices, the downgrade of the incomes and the inability of people to pay their bills, the high levels of unemployment and the low rate of energy performance measures implemented in residential buildings. But the economic crisis has aggravated the phenomenon.

This paper presents the in-situ research carried out from January 2015 to June 2016 concerning the investigation of the energy behavior of households in Northern Greece and especially in areas without the use of district heating systems. The present work is an attempt to capture and analyze the phenomenon of energy poverty. Its main scope it to present the current situation especially in Northern Greece and to clarify if there is a connection between living conditions, energy poverty and other indicators. Therefore, the results are a useful tool for further research, focusing on the technical, economic and social dimensions of the problem.

Keywords: Energy poverty, North Greece, Socioeconomic factors, Energy consumption at households, Vulnerable consumers.

SOCIAL APPROVAL OF WIND AND PV PROJECTS IN GREECE, DURING THE PERIOD OF ECONOMIC CRISIS

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ABSTRACT

During the last fifteen years, the contribution of wind parks and photovoltaic stations in Greece has significantly increased, with their total installed capacity overcoming the 5000MW_e. More specifically, throughout the economic crisis period, the two most important economic activities, resulting to significant figures in employment as well, were the noticeable revolution concerning the installation of PV parks of various sizes and the steady investment in new wind parks. In this context, the social community in Greece has been in favor of the new renewable energy sources installations, a fact that also results from a series of published research papers.

Nevertheless, once renewables have ceased to be the small-scale energy alternative option, numerous cases of new-planned projects that have been treated with strong criticism have been recorded.

In an effort to investigate the RES-based applications acceptance on an objective basis, a team of postgraduate students from our Laboratories, Optimisation of Production Systems Laboratory & Laboratory of Soft Energy Applications and Environmental Protection of Piraeus University of Applied Sciences, has served relevant questionnaires to an appropriate number of respondents, originated in rural and urban areas. The respondents have been all questioned under the scope of capturing their attitude towards existing but also new wind and PV power stations.

The results of the research have been statistically processed and compared with previous relevant national and international surveys. Conclusions support the positive attitude of the local communities towards RES applications in Greece, but also underline the need for proof evidence concerning the benefits resulting from the operation of the proposed installations in total, as well as their long term economic viability.

Keywords: Wind energy, Photovoltaics, Questionnaires, Public Acceptance, Perception to Invest

PENETRATION OF RENEWABLE ENERGY SOURCES IN THE ELECTRICITY SECTOR OF CYPRUS. CURRENT STATUS AND FUTURE PROSPECTS POTENTIAL

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ABSTRACT

In the electrically autonomous island of Cyprus the penetration of Renewable Energy Sources (RES) is of great significance for the energy policy of the country, because it contributes in the gradual decrease of dependence from the imports of expensive conventional fuel (mazut and diesel) and the strengthening of its energy independency. Moreover RES penetration has an environmental impact as it is a key factor in the reduction of the greenhouse gases emissions and their subsequent costs.

In this report, an analysis of the current level of penetration and its progress throughout the period 2011-2016 is presented. In addition there is a comparison between Cyprus and Crete, as far as RES penetration is concerned, in order to find out similarities and differences between two autonomous electrical systems of same characteristics and size.

The data used were collected from the official archives of the Transmission System Operator of Cyprus as well as the Hellenic Electricity Distribution Network Operator S.A.

Initially it is presented the existing institutional framework of Cyprus along with information on the electricity generation plants (installed capacity, production and penetration per energy source). Later there is an analysis of penetration for each and every one component of RES technologies and their real capacity factor respectively in monthly and annual basis. A comparison between Cyprus and Crete on the same aspects has shown useful conclusions regarding the level of penetration in these two islands.

Lastly, based on the above facts and conclusions and in accordance with the estimations for the future level of demand in the following years (by the Operator in charge), they are examined various scenarios of new RES capacity in order to achieve the national goal of RES penetration by the year 2020.

Keywords: Cyprus, Renewable Energy Sources (RES), energy contribution-penetration, capacity factor, RES penetration scenarios.

Building Integrated RES

INSTALLATION OF GREEN ROOFS AND BUILDING INTEGRATED PHOTOVOLTAICS ON AN OFFICE BUILDING IN CYPRUS: ENERGY, ENVIRONMENTAL AND ECONOMIC ANALYSIS

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ABSTRACT

The ever-increasing concentration of people in cities around the world alters local geomorphology and has a strong impact on the environment. The building sector, which is responsible for an annual increase of 3% in total anthropogenic greenhouse gas emissions, combined with energy consumption from human activities, intensifies the degradation of the environment. In order to cope with these negative effects of buildings, various techniques and technologies are proposed and applied, including the integration of green roofs and photovoltaic systems. This study examines the benefits of combining these two technological solutions into a typical office building under the climatic conditions of Cyprus. Energy analysis of the building envelope was carried out using the dynamic simulation software Energy Plus on an hourly basis. The building envelope's energy demand results were eventually transformed into primary energy consumption figures using a special code for simulating the operation of heat pumps that are used for heating and cooling purposes as well as the national conversion factors of final to primary energy. Based on these results, the alternative technologies are compared, and the energy benefits are determined. Their environmental assessment is based on the use of indicators related to the emissions of carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) resulting from the energy consumption. The economic viability of the proposed technology solutions is considered for an economic lifetime of 20 years, including the initial construction cost, the annual maintenance and energy consumption costs and the environmental costs associated with CO_2, NO_x and SO_2 emissions. The results of the study show that the proposed technological interventions are energy and environmentally beneficial. Primary energy consumption of the typical office building, the emissions of CO_2 and local pollutants, and the net present value throughout the lifespan are significantly reduced.

Keywords: Green roof, BIPV, feasibility analysis, office building, Mediterranean region.

BUILDING INTEGRATED RENEWABLE ENERGY SYSTEMS FOR ENERGY RETROFITTING OF A SINGLE-FAMILY RESIDENCE TOWARDS AN NZEB

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ABSTRACT

The building sector is an integral part of today's everyday life, especially in the developed countries. The energy behavior of buildings is, however, far from being satisfactory, making them one of the major polluters and energy consumers. The European Union's objective is to minimize the energy needs of the building sector and to introduce nearly Zero Energy Buildings (nZEBs) after 2020, while promoting interventions for the improvement of the existing building stock, with emphasis on renewable energy production, on site or nearby the buildings.

This paper explores the potential for energy retrofitting of existing buildings, in the region of Northern Greece, by analyzing proposed interventions in a typical existing dwelling in Oreokastro, Thessaloniki. Various ways are investigated for converting the single-family house into an nZEB, by a balanced integration of Renewable Energy Systems (RES) into the building shell in order to cover a large part of its heating, domestic hot water (DHW) and electricity demands. Moreover, the economic feasibility of these interventions is studied for buildings, like this one, that have not been constructed to meet modern energy requirements, such as those of KENAK, taking into consideration their architectural and aesthetic upgrading.

More specifically, the paper examines the integration of a modern louvre system, incorporating photovoltaic panels, in front of the transparent building elements in the southwest and southeast facades, combining shading, and thus, minimizing the required cooling loads, while generating electricity. In addition, the use of the existing solar thermal collectors on the roof of the building is explored, to meet the needs of DHW and assist the heating system, which will be upgraded with a natural gas boiler.

Keywords: *Building Integrated Photovoltaics (BIPV), Energy Efficiency, NZEB, Shading Louvres*

NUMERICAL INVESTIGATION ON POWER PRODUCTION MICRO-TURBINE DESIGN FOR ORGANIC RANKINE CYCLE (ORC) SYSTEMS

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ABSTRACT

The urgent need of reducing the use of fossil fuels naturally leads to the increase of sustainable energy sources which are environmental friendlier. Hence, there is a shift appearing in the increased use of renewable energy sources. Towards this direction, hybrid power systems are investigated and developed. In this framework, several studies are conducted regarding more efficient Organic Rankine Cycle (ORC) systems, which are characterized by the capability of operating autonomously, powered by an external and independent source of energy.

This study aims to design a micro-gas turbine having as its main goal to optimize the turbine efficiency and minimize the production costs, in order to be applied in a system of a closed Organic Rankine Cycle. To achieve the goals set, the properties of the working fluid are initially investigated along with the thermodynamic analysis of the whole system. The selection of the appropriate working fluid is an important parameter in such studies as it determines the final design of the turbine stage. Moreover, a preliminary two-dimensional design of the turbine blades is described by utilizing the corresponding velocity triangles. Last but not least, an elementary analysis of the three-dimensional geometry of the blades is provided, by using finite elements and computational fluid dynamics (CFD) codes.

Finally, the efficiency and total power output of the system are calculated. Additionally, the advantages of such technologies and the difficulties that are encountered throughout the system are examined. The most remarkable result throughout this study is that the optimal working fluid for the operation of the particular system is a mixture of isobutane-isopentane (15% - 85%), which is characterized from the highest thermal efficiency and power output. Simultaneously, the system's size is reduced by an order of magnitude as compared to the size of the systems that operate with the remaining fluids that are examined.

Keywords: Organic Rankine Cycle (ORC), turbine design, heat recovery, hybrid systems, computational fluid dynamics (CFD)

EFFECT OF ROOF PV PANELS ON POULTRY HOUSE MICROCLIMATE

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ABSTRACT

The installation of photovoltaic panels (PV) for power generation on livestock building roofs is expected to expand due to the expected increase of the electricity price supplied by the grid and the favorable conditions provided by the legislation for the production of power through 'net metering' for farmers. An issue that always concerns PV's potential users is whether the installation of PV panels on a roof could affect the building's internal microclimate. And this concern becomes more important when the internal microclimate is fully controlled, requiring energy consumption, and the buildings' operation depends on the accuracy of this control. Poultry houses are such a case. Poultry chambers are closed lives tock building where the indoor microclimate is fully controlled with the values of internal microclimate parameters changing everyday of the breeding being important energy consumers.

As study case a state-of-the-art poultry chamber established on West Greece with part of its roof covered by PV panels was studied for a period of summer operation. During the study period the heat flux from the roof (covered by PV panels and uncovered) was measured along with parameters describe the internal microclimate and the external climatic conditions. Initially an analytical energy balance model was developed in order to describe the heat transfer phenomena on the PV covered roof. Then the effect of PV panels on the poultry chamber microclimate was studied measuring the heat flux on the covered and the uncovered part and identifying its dependence on the external climatic conditions. Finally the internal microclimate on the whole chamber was studied with Computational Fluid Dynamics. For the period of summer breeding which was studied it came out that the installation of PV panels on the roof leads to overheating, mainly because during night the chamber cooling is prevented. Nevertheless this overheating is negligible compared to the electricity production achieved by these PV panels during the same period.

Keywords: PVroof, livestock building, internal microclimate, energy balance model, CFD

SYSTEM ANALYSIS OF EARTH - AIR HEAT EXCHANGER OF TECHNICAL UNIVERSITY OF CRETE PREMISES

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ABSTRACT

In the context of this study a geothermal system was analyzed. It's about a ground-to-air or earth-to-air heat exchanger, technology selected not only for the benefits the use of geothermal energy provides, but also due to the existence of an extensive underground passage network, lying all over the Technical University of Crete district. Using latest analysis tools and designing software like EnergyPlus and Google Sketchup, a full energy analysis was held. Results concerning the system's efficiency are displayed on comparing tables and charts.

Keywords: geothermal system, earth / air heat exchanger, energy saving

INTEGRATION OF RENEWABLE ENERGY TECHNOLOGIES IN STUDENT RESIDENCES OF XANTHI AND RESULTS OF PROJECT REUNI

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ABSTRACT

This paper presents the actions and activities implemented for the integration of Renewable Energy Technologies in Students' Residences of Democritus University of Thrace in Xanthi. The building complex comprise of eleven (11) buildings of total area of 14,819.09 m^2, with capacity of 630 students. The project has been implemented by the Special Account for Research Funds of DUTH under the EEA Grants 2009-2014 program. The project targets to alleviate social and economic inequalities by ensuring thermal comfort with the use of RES in social housing such as student residences. The building complex comprises of eight (8) buildings of student residences, one (1) amphitheatre, one (1) restaurant and one (1) building for the electromechanical equipment of heating, cooling and domestic hot water. The integration of RES technologies includes:

- Hybrid system of biomass boiler and solar thermal system of total thermal power of 2.3 MW for heating, cooling and domestic hot water of student residences and the amphitheatre
- Geothermal heat pumps of 225 kW_{th} and replacement of Air Handling Unit for cooling, heating and domestic hot water of the restaurant building
- Autonomous PV station of 51.48 kWp for partial coverage of the electrical loads of one student residence building
- Charging station using the available electrical energy from the PV system for 6 electric bicycles
- Autonomous wind turbine station of 1 kW for charging 6 electric bicycles.

The "Community" of DUTH constitutes a decentralized collaborative energy generation and consumption system. The development of such decentralized systems utilizing RES constitutes a key priority of the European Commission's strategy of the "Energy Union". The implementation of REUNI project contributes in this direction and can be considered as an important case study for the implementation of similar systems in Greece and other Mediterranean countries.

Keywords: Biomass, solar energy, geothermal energy, photovoltaics, decentralized energy generation systems

Energy Conservation

SIMULATION OF THE ENERGY PERFORMANCE OF AN INDOOR AQUATIC CENTER

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ABSTRACT

Sporting centers present considerable amounts of energy consumption, noting that indoor swimming pools have the highest energy consumption amongst sports centers and outdoor pools. This can be attributed to the requirements for high ventilation rates, mainly related to hygienic requirements, while the swimming pool heating load is also significant. The energy performance of indoor aquatic enters has been studied in the relevant literature. Given that dehumidification should be applied, as the swimming pool acts as a major source of latent load, the solution of heat pumps is examined in relevant works, while the additional use of solar energy, on a thermal level as well as provided by PV panels, can significantly reduce the conventional energy consumption.

In the proposed work, the energy behavior of the indoor Municipal Aquatic Center of Kozani is investigated on the basis of simulation analysis. The indoor climate of the aquatic center is characterized by the presence of high relative humidity values, as demonstrated by relevant investigation; this is due to the absence of forced ventilation system. In addition, the envelope is characterized by insufficient behavior in terms of thermal insulation, while despite the covering of the energy thermal needs by the District Heating system in winter time, the oil consumption is high. This occurs during summer, when the District Heating system is out of operation.

The investigation is performed according to the EnergyPlus simulation software; calculation of energy demand and consumption quantities on annual basis takes place. The results allow the evaluation of the benefits through the implementation of the proposed solutions on an energy, environmental and economical level.

Keywords:energy upgrade, simulation,EnergyPlus, indoor aquatic center

ENERGY UPGRADE ANALYSIS OF THE BUILDING OF THE SCHOOL OF EDUCATION OF THE UNIVERSITY OF WESTERN MACEDONIA

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ABSTRACT

Public buildings are a major factor in energy consumption, with significant margins of improvement, as indicated by the special care taken for this category of buildings in the updated European Legislation on Energy Efficiency, Energy Saving as well as use of RES. This paper examines the energy behavior of such a building, the Faculty of Education of the University of Western Macedonia, at Florina. It□s a building complex with high energy consumption, due to insufficient thermal insulation, but also to the absence of Renewable Energy Sources.

In the proposed work, the analysis investigates the applicability of potential solutions for the energy upgrade of the building, focusing on thermal insulation, the replacement of the existing bulbs with corresponding LED technology, the installation of Geothermal Heat Pumps to meet heating and hot water needs and photovoltaic panels to cover the electricity loads. Due to the large area of the building (10500 m□of built-up area), it was preferred to use relatively easy-to-use methodological tools, such us the Degree Days method for calculating heating loads, while for the energy savings from RES systems, rather simplified energy models were used.

The results demonstrate the possibility of converting an energy-intensive building into a □green□ building with zero energy consumption; interventions show a realistic depreciation time.

Keywords: *Energy upgrade, Public Buildings, RES, Geothermal energy, Geothermal heat exchanger*

EVALUATION OF BIOCLIMATIC BUILDINGS, BASED ON THE EXPERIENCE OF USERS: CONTEMPORARY BUILDINGS IN THE MUNICIPALITY OF NEAPOLIS- SYKIES

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ABSTRACT

Today we are dealing with the social, political and economic consequences of climate change, caused by the unscrupulous use of polluting energy sources. Since the build environment is one of the most energy demanding sectors, there is an ongoing effort to create more energy efficient buildings, which will provide their occupants with the best possible conditions of thermal and optical comfort. Even so, many buildings designed to that end, fail to fulfil their initial goals, as they were outlined in the design stage, leaving the occupants unsatisfied, as they realize that the achieved comfort levels do not comply with their needs.

Post Occupancy Evaluation (POE) studie aim to bridge the gap between design, implementation and building operation, by handling the building in a holistic sense while incorporating sustainable design elements. POE studies form evaluation reports, with the purpose of providing feedback on the building's performance during its operation, from a user's point of view.

This particular paper, presents the materialization of a POE study on two public buildings in the Municipality of Sykies (Prefecture of Thessaloniki), with bioclimatic design features: an elementary school and a community center for the elderly. The primary goal of the study was to highlight the important issues concerning the use and operation of each building, from the users' standpoint. The study is of an indicative type, it therefore provides an outline of the sustainable design elements of each building and attempts to compile a list of the most important elements of their performance. The study was performed through site inspections, questionnaires, informal interviews with the occupants, while carrying out a shading study, for both buildings and a natural lighting study for the community center for the elderly.

The findings of the study, highlighted a number of issues that can be classified into three groups: the design, the construction and the use. It was discovered that the school's occupants, although it represents a good example of a building incorporating sustainable design elements, appear to be less satisfied than the occupants of the other building, which incorporates fewer and less complicated elements. This is due to the fact that the school building's users were not informed of how to operate and benefit from these elements and ended up with a negative disposition towards them and a feeling of dissatisfaction.

Keywords: Thermal and visual comfort, POE studies, bioclimatic buildings

ENERGY CONSUMPTION IN GREECE: ANALYSIS OF ENERGY AUDIT DATA

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ABSTRACT

The rapidly growing use of energy on a global scale has already raised concerns about the exhaustion of energy resources and the serious environmental impact, such as global warming and climate change. The contribution of buildings, houses and the tertiary sector to energy consumption accounts for one-fifth of the total energy consumed globally. Total global energy consumption in buildings is projected to increase on average by 1.4% annually from 2012 to 2040. Population growth, the emphasis on improving thermal comfort levels in buildings, as well as the increase of time spent indoors, reinforce strongly the fact that the upward trend in energy demand will continue in the near future.

In Greece, under the Regulation on "Energy Efficiency of Buildings" (KENAK), it is mandatory to carry out energy audits in existing buildings, under certain conditions, while at the same time the sustainable design of new buildings is promoted. In the present study, the data collected during the Energy Performance Certificates of Buildings procedure, for the period 2011-2016, by region and climate zone, are analyzed using descriptive statistical tools and appropriate tests (such as Kruskal-Wallis and Mann-Whitney). In particular, the average consumption of primary energy in public buildings and dwellings (distinguished in detached houses and apartment buildings) is analyzed according to their geographic / climate zone, while the interconnection between energy consumption and the available climatic data per zone for the same time period is examined. The data come from the Regional Prefectures of Heraklion (Climate Zone A), Athens (Climate Zone B), Thessaloniki (Climate Zone C) and Florina (Climate Zone D). This effort to clarify and understand the energy consumption patterns is important for the projection of energy use forecasts. Determining typical behaviors and trends per building use and area can be the basis of the necessary strategic planning by local and national energy saving actors.

Keywords: *primary energy consumption, climate zones, temperature, heating degree days, cooling degree days*

ENERGY MAPPING OF HELLENIC NON RESIDENTIAL BUILDINGS

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ABSTRACT

Energy efficiency has become a common target for all buildings. Non-residential buildings usually exhibit high energy consumption due to their specific building uses, consequently playing a significant role in the energy and environmental footprint of the building stock. In Greece, there are about 785,500 NR buildings that represent about 21% of the building stock, with a total floor area of about 159 million m² distributed among different building types. About 58% of the Hellenic buildings were built before 1980, the year that marks enforcement of the first Hellenic thermal insulation regulation. As a result, the majority of the Hellenic buildings have no thermal protection and they are equipped with old and inefficient heat generation systems, thus exhibiting the greatest potential for energy savings.

This work is based on data from the national EPC electronic repository (buildingcert), presenting the results from an in-depth analysis of data from about 18.500 energy performance certificates of non-residential buildings. As a first step, the available data were screened in order to increase confidence on the data that was used for the analysis. The analysis is performed for different building uses and locations. This is a first step for generating new knowledge about the non-residential building stock in Greece that can be used for building stock modeling, prioritize and target energy refurbishment policies. The sample of buildings is in good agreement with the Hellenic building stock model, since 46% of the buildings are built before 1980, 33% between 1981-2000, 17% between 2001-2010 and only 4% are new constructions (post-2010) corresponding to the KENAK era. The results confirmed the low energy performance of existing Hellenic buildings. Accordingly, about 30% are ranked at energy class-D, while only 6% are ranked in energy class B or better. The average calculated primary energy ranges from 185.9 kWh/m^2 (Educational buildings) to 806.7 kWh/m^2 (Public assembly buildings). Average CO_2 emissions range from 54.8 kgCO_2/m^2 to 248.1 kgCO_2/m^2 respectively. Lighting is the most consuming service (34%), followed by cooling (32%), space heating (28%) and DHW (6%).

Keywords: Non-residential buildings, energy ranking, primary energy

IMPLEMENTATION OF VACUUM INSULATION PANELS IN BUILDING ENVELOPE FOR FOUR DIFFERENT CLIMATIC CONDITIONS IN EUROPE

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ABSTRACT

Nowadays, the ongoing increase of total energy consumption, has important environmental and economic consequences. In Europe, building sector is responsible for the 39% of total energy consumption and also for the 36% of total carbon dioxide (CO_2) emissions.

A key role parameter for sustainable building construction, is the appropriate building envelope s thermal insulation in order to reduce its thermal losses and as a result the necessary energy consumption for space heating. At the same time, it is possible to reduce CO_2 emissions from the building sector by using more environmentally friendly materials during buildings' construction.

Within the framework of this paper, super insulating materials will be studied, and more specifically the Vaccuum Insulation Panels V.I.P.s). V.I.P.s will be installed in existing buildings with incomplete insulation, located in four different European cities, with different climatological data. The energy simulation will take place using Open studio-Energy plus software. Afterwards, an economical assessment will be implemented using Life Cycle Cost methodology, in order to find out whether the implementation of V.I.P.s is an economical viable solution or not.

Keywords: super insulating materials, Vacuum insulation panels, energy efficiency, building envelope

INNOVATIVE SOLUTIONS FOR BUILDINGS' ENERGY RENOVATION: USER'S PERCEPTION AND SOCIAL ACCEPTANCE

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ABSTRACT

This paper investigates the social acceptance of an innovative energy efficient façade refurbishment system in Mediterranean countries. Two types of multiple choice questionnaires were developed and addressed to two different target groups of building professionals and users. The survey elicits information on the interviewee's background and perception regarding the proposed system's characteristics, while professionals also provided with technical information. Both potential users and professionals seem positive towards the system's energy performance; however, the increased cost of acquisition, maintenance issues and the replacement of natural ventilation by mechanical means consist significant constraints that induce hesitations for the users. Professionals are willing to apply a ventilated façade in a future project but the lack of the corresponding knowledge may be an important obstacle to face.

Keywords: building renovation, energy performance, ventilated façade, social acceptance, public opinion survey

ENERGY AND TECHNO-ECONOMIC ANALYSIS OF DEEP RENOVATION FOR A TYPICAL RESIDENTIAL MULTI-STOREY BUILDING INCORPORATING DRYWALL SYSTEMS AND SUPER INSULATING MATERIALS

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ABSTRACT

The present study treats energy and techno-economic analysis of the deep renovation of an existing residential multi-storey building, incorporating drywall systems and super insulating materials. The examined building is a typical five storey building, with 20 apartments, 75m^2 each, located in Athens, built before 1980, hence it was not an insulated building.

Two renovation cases were examined. An advanced renovation and a deep renovation scenario. In the advanced renovation case, insulation was installed at the external walls, the floor and the top of the building, according to the TABULA project (Typology Approach for Building Stock Energy Assessment). The heating system was replaced by a natural gas condensing boiler with outdoor temperature compensation, while a mechanical ventilation system with heat recovery was installed for each apartment. The Domestic Hot Water (DHW) production was achieved with a combination of natural gas condensing boilers and solar panels. In the deep renovation scenario, the external walls were totally replaced by prefabricated lightweight metal frame construction with drywall materials. For further thermal insulation the external walls incorporated a layer of Vacuum Insulation Panels (VIPs). The HVAC and DHW systems were upgraded as in the advanced renovation case. Furthermore, advanced Building Energy Management Systems (BEMs) with forecasting algorithms, monitoring and HVAC control systems, was installed in order to ensure an optimum operation of the technical building systems. An extended Photovoltaic system (PV) was installed on the roof of the building, to meet electricity needs for the operation of the HVAC and DHW systems.

Both cases were evaluated through dynamic energy simulation using the EnergyPlus software. The economic analysis was performed using the Payback Period (PP) method considering all the costs involved. The results showed that the primary energy consumption was reduced by ca. 77% in the case of the advanced renovation and 92% in the deep renovation case compared with the existing state of the building. The payback period was approximately 10.5 years in both cases, but in deep renovation there were consecutive incomings thanks to the sale of electricity from PV system.

Keywords: *Energy Renovation, Techno-economic analysis, Energy Efficiency, nearly Zero Energy Buildings (nZEB), Drywall Systems*.

SOFTWARE ASSESMENT ON THE ESTIMATION BASIS OF HEATING AND COOLING LOADS

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ABSTRACT

In the present work, it is attempted an evaluation of two software estimating the energy behavior of buildings comparing the heating and cooling loads for various insulation thicknesses and modifying the integration simulation time step over a year in one of them. Two software tools being evaluated is widespread and used by various categories of users. The first of them serves the need of energy audits as a key calculation tool (TEE-KENAK) to estimate the energy efficiency of buildings for building energy classification purposes in Greece. While the second software acts as a research tool (EnergyPlus) for the simulation of the buildings energy behavior as it provides greater freedom and parametric definition concerning mainly the general and specific energy behavior of a building shell served by E/M provisions to meet interior comfort conditions. The presence of the users is taken into account in both models - numerical tools that, apart from the E/M devices, define the function of other electrical devices. The software tools owe their existence from two different philosophies for the calculation of the energy efficiency of buildings. The first category is based on a static approach to model semi-fixed monthly step situation, like this is proposed as a possible option in the EN ISO ELOT 13790:2009 standard, while the second category is the so-called dynamic class for buildings energy analysis and simulation for thermal and cooling needs as implemented through EnergyPlus software.

The evaluation initially investigates the behavior of a small residential building in Thessaloniki, and calculates the annual energy demands for various insulation thicknesses for both tools and their results are compared. For the same building and its operating schedule are examined the heating and cooling loads and are analyzed the differences between the two models. The results show that the static model gives lower predictions than the dynamic for both types of loads with different behavior for each season. Absolute differences are more important for cooling loads than heating ones. Secondly, the results of time-varying simulations that occur with different time steps are examined and conclusions are drawn regarding the expenditure of time and CPU power in the results of significance.

Keywords: Heating Loads, Cooling Loads, Insulation Thickness, TEE-KENAK, EnergyPlus, Static & dynamic building energy simulations

COMPARATIVE ANALYSIS OF AIR-TO-WATER HEAT PUMPS COEFFICIENT OF PERFORMANCE AND ENERGY EFFICIENCY RATIO

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ABSTRACT

The energy problem is today one of the most important concerns of the world community. Energy is a commodity with increasing demand and the impacts of its use on the environment are crucial. In this context, the European Union (EU) developed the Energy Efficiency 2020 program on the Common European Energy Strategy for the period 2011-2020. The aim of the program is to achieve the "20-20-20" targets, namely 20% of the energy, on the basis of consumption, coming from renewables, 20% reduction in CO_2 emissions, compared to 1990 levels, and 20% increase in energy efficiency. In September 2015, the EU adopted the ErP (Energy-related Products) Directive concerning the ecodesign and energy labeling of energy-related products and appliances. With the implementation of the Directive, conventional high temperature hydronic heating systems will be gradually replaced with low temperature ones. Heat pumps (HPs), and in particular air-to-water heat pumps (AWHPs), are therefore expected to be widely installed in low temperature heating systems,as heating devices which can also provide cooling at appropriate temperatures depending on the design of the systems.

The aim of this paper is to present a comparative analysis of the coefficient of performance (COP) and the energy efficiency ratio (EER) of AWHPs available in the Greek market by various manufacturers over the last 5 years. The comparative analysis is based on the technical specifications of the different models that provide each manufacturer and on the correlation of the coefficient of performance COP and Energy Efficiency Ratio EER, given in the technical manuals, with a) the nominal capacity, b) the outdoor air temperature, and c) the water supply temperatures to the heating and cooling system (according to Eurovent LCP/A/CHP and Eurovent LCP/A/AC conditions). The HPs under consideration are of low, medium and high heating and cooling capacity. These devices are installed in various types of buildings, mostly in thermal comfort applications.

The data presented in this paper can be useful for selecting a heat pump in a building s heating system design project, for calculating its seasonal performance factor as well as for estimating its final energy consumption, given the building construction elements and the climatic data of the region under consideration.

Keywords: heat-pumps, heating systems, cooling systems, Coefficient of Performance, Energy Efficiency Ratio, energy efficiency

ENERGY UPGRADING OF BUILDINGS. A HOLISTIC APPROACH FOR THE NATURAL HISTORY MUSEUM OF CRETE, GREECE

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ABSTRACT

This article presents the fundamental points of the accomplished work regarding the energy upgrading of the building of the Natural History Museum of Crete, Greece, based on a cluster of passive and active measures. The main target was the building's energy efficiency upgrading from D to A+ rank. Among the passive measures, insulation of the building's envelope, installation of new windows and doors, construction of a green roof and planting of an outdoor space at the south side of the building to improve the ambient climate locally are included. Furthermore, small wind turbines and a photovoltaic station on the roof, geothermal heat pumps with an open loop system operating with seawater, new lighting equipment controlled by a central management system and reactive power coefficient compensation constitute the proposed active systems. Energy saving percentages from 40% to 93% are achieved with all the proposed technologies. In total, the primary energy specific consumption is reduced from 273.65 kWh/m^2 to 18.36 kWh/m^2, giving a total energy saving percentage of 93.29%. The building's energy efficiency is upgraded from the rank D to the rank A+, according to the European Union's standards. The total cost of the proposed measures is estimated approximately at 900,000 €.

Keywords: buildings energy saving upgrade; small wind turbines; photovoltaic stations on roofs; open loop normal geothermal systems; heating and cooling loads; bioclimatic measures for outdoor spaces

INSTALLING CONDENSING BOILERS AND VARIABLE SPEED PUMPS IN HEATING SYSTEMS OF RESIDENTIAL BUILDINGS IN GREECE – ENERGY AND ECONOMIC BENEFITS

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ABSTRACT

In 2009 the European Union (EU), following the 1997 Kyoto Protocol, committed to reducing greenhouse gas (GHG) emissions, and imposed the implementation of the 20-20-20 targets in order to reverse climate change, save energy and be transformed into a highly energy-efficient and low-carbon economy. In September 2015 the ErP (Energy-related Products) Directive was adopted in the EU, which established legally binding criteria for the energy efficiency and emissions of heating devices. The Directive excludes from the EU market all products which do not meet the Ecodesign Directive requirements and have no energy labeling. One of the consequences of this directive is that it will no longer be possible to install non-condensing boilers and constant speed pumps in heating systems.

The aim of this paper is to study the energy and economic impacts from the replacement of a high-temperature hydronic heating system, consisting of an oil-fired conventional boiler and constant-speed circulator pump, by a low-temperature system with gas-fired condensing boiler and electronically controlled variable speed pump, in a residential building. The case studies examined are categorized by the overall thermal insulation of the building and by the installed heating system. Specifically, the case studies are: a) building without thermal insulation and high temperature heating system, b) building which falls under the Greek Regulation for Building Insulation of 1979 and heating system of both high and low temperature, and c) building which falls under the Greek Regulation for Energy Performance of Buildings of 2010 and heating system of both high and low temperature. Every case study is examined with or without the upgrading of the thermal protection of the building. In each of the five studies, the heat load of the building is calculated, the central heating system is designed, by selecting appliances and radiators, and the thermal and electrical energy consumption is estimated by simulating the system according to the Bin method. Additionally, the operating cost and the cost of replacing the heating system, and the payback period of the investment (without taking into account the cost of upgrading the thermal insulation) are calculated. In the cases analyzed, without any thermal insulation upgrade, the annual reduction of the thermal energy requirements vary from 26% in Athens to more than 29% in Thessaloniki. By upgrading the thermal insulation according to the Greek Regulation for Energy Performance of Buildings, the thermal energy savings vary from 40% to 84%, depending on the previous thermal insulation level. The use of electronically controlled variable speed pumps leads to electrical energy savings that exceed 87% in all case studies. The economic benefits are also significant as fuel and electricity cost savings (with prices of 2016) are more than 37% for Athens and 51% for Thessaloniki. The payback period ranges from 3 to10 years without upgrading of the thermal protection and from 1 to 5 years with upgrading, depending on the case study.

Keywords:heating systems, condensing boilers, variable speed pumps, energy saving, payback period

Smart Grids and Decision Making Systems on Energy Projects

URBAN AND INTELLIGENT INTERCONNECTED DIGITAL LANDSCAPE: SUSTAINABLE DESIGN THROUGH TECHNOLOGICAL INTELLIGENCE

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ABSTRACT

In this publication, the methodology and the results of examining the urban – intelligent interconnected digital landscape, from the point of view of energy efficiency, resilience and interaction is presented, thus focusing on the sustainable design of public spaces and more specifically of urban squares. In this way, the transition from today conventional design to the technologically intelligent, sustainable design of public spaces is examined. In other words, the transition through a synthetic process of incorporating technological intelligence into the urban space, which does not necessarily need to have a teleologically predetermined operational, morphological and structural result, but is characterised by interaction and dynamic change of specific and interconnected qualities. Multicriteria analysis (method ELECTRE III) is used so as to analyse the in situ observations and relative questionnaires (to users, public bodies and experts), as well as thermal comfort (RayMan method, Ecotect Analysis), so as to systematise and analyse the parameters of various scenarios of the sustainable regeneration of Thraki Square in the Municipality of Lykovrisi – Pefki.

Three scenarios are examined, apart from the base case scenario (existing conventional design of Thraki Square); the 1st scenario is about the sustainable design of the square, without any interconnected smart technology (cool materials and environmentally friendly ones), the 2nd scenario concerns the sustainable design of the square, with technological intelligence of property change (face changing materials, thermochromic, etc) and the 3rd scenario investigates the sustainable design of the square with interconnected technological intelligence of energy production (photovoltaic panels, piezoelectric, etc). These scenarios are examined from the point of view of criteria of direct influences/ economic development (construction costs, maintenance costs, quantitative assessment of the benefits of the design, etc), as well as from the point of view of sustainability criteria (microclimate, thermal comfort conditions, landscape quality, promotion of biodiversity, conservation of natural resources, greenhouse gas emissions reduction, etc) and also spatio-social / cultural criteria (quality of life, social development, social cohesion, equality, avoiding exclusions etc) through multicriteria analysis.

Through this method a theoretical framework is formed for examining public spaces sustainable design practices and conclusions are drawn on the application of technological intelligence in the sustainable design and the energy management of urban public open spaces.

Keywords: urban square, resilience, technological intelligence, interaction, multicriteria analysis

DECISION MAKING SYSTEMS OF ENERGY PROJECTS

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ABSTRACT

The conventional energy sources concede their share to the renewable energy sources due to the exhaustion of the conventional sources and their negative environmental impacts. The investments in new types of energy are compulsory and constitute multidimensional process with a variety of choices, evaluation criteria and multiple different solutions. The decision makers should investigate in depth and with reliable methods all the different scenarios and be able to reach the optimum solution. The level of uncertainty is high and depends on the type of the investment and its general features. The final decision should be taken after the different criteria have been analyzed and critically compared. This paper aims to critically present the different methods applied for the economic and social appraisal of energy projects and to comment on the basic principles that condition the appraisal process of energy projects with two illustrative examples.

Keywords: Energy, Investment Evaluation, Multicriteria Analysis

DEVELOPMENT AND EVALUATION OF A DECISION-MAKING SYSTEM FOR OPTIMAL MANAGEMENT OF RESERVOIRS IN SINGLE TIME HORIZON

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ABSTRACT

The rational use of surface water resources in modern times and their multiple role in meeting domestic water, irrigation and industrial needs, production and storage of energy in hydroelectric power plants, penetration of renewable sources in the energy system, flood protection and conservation of ecosystems, requires complex and difficult decisions, regarding the best management policies that should be followed. The large financial cost of constructing new large-scale water resources and energy projects, combined with the environmental problems that arise during the implementation phase, calls for research into the development of new simulation and optimization techniques to exploit and improve available infrastructure. The complexity and stochastic nature of the temporal and spatial distribution of supply and demand flows for water and energy requires an in-depth investigation of the operation of these systems for multiple objectives in order to maximize the overall benefits.

In the present work an attempt is made to optimize the operation of a complex system of reservoirs in series, which is located on the river Aliakmonas, in Western Macedonia, Greece, and serves multiple objectives. The system is examined and analyzed in a single time horizon of one year, using a step of one month. Three different hydrological scenarios are taken into account, namely dry, average and wet year, and the results are evaluated. System simulation and optimization was implemented through the development of a Genetic Algorithm (GA) code. Results show that, in general, water level at the Ilarion reservoir should be kept as high as possible since the beginning of the year, while the hydroelectric plant at the Polyphytos dam should be the main energy producer.

Keywords: reservoir systems, optimization, genetic algorithms, hydropower, renewable energy sources

A DECISION SUPPORT TOOL FOR ENERGY RETROFITTING OF BUILDINGS

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ABSTRACT

Energy savings in buildings is number one challenge in Europe and mechanisms have been developed to promote interventions in buildings with particularly energy efficient products and systems. At the same time, stringent requirements for new and deep renovated buildings have been enforced in order to have particularly low energy needs in terms of heating, cooling, hot water production, ventilation and lighting. The combination of the optimal energy intervention with the highest efficiency and the lower cost is the goal to reach in the past few years. This point is the subject of the current paper which presents a tool for supporting decision-making on energy retrofitting strategies and the financing of deep renovation in buildings. The purpose of the tool is to analyze financial tools and incentives for energy renovations in an area, as well as other external factors (e.g. noise levels in the area), and in collaboration with knowledge about the building's energy needs, provide an overall assessment of the investment opportunities for energy renovation of buildings. In its final form, the tool is available in the web, in a user-friendly format and an interactive map of the options for deep renovation of buildings, taking into account the particularities of different European countries.

The paper describes the tool architecture, its design and layout, and analyzes the parameters taken into account to provide the optimal choice of building upgrade based on energy, investment and other criteria.

Keywords: *buildings, energy retrofit, web tool, investment support*

DEVELOPMENT OF A SUPPORTIVE TOOL FOR THE ENERGY REFURBISHMENT OF BUILDINGS TOWARDS NEARLY ZERO ENERGY BUILDINGS (NZEB)

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ABSTRACT

The energy efficiency improvement of existing buildings is a priority of the European Union and therefore of our country in recent decades. The majority of buildings, mainly due to their construction age, is characterized by particularly high energy requirements and has significant energy saving potential.

The cost optimal effective solutions for energy refurbishment of the existing building stock are the main issue for all European countries, but also worldwide. This paper refers to the development and use of a computational program (tool) that promotes the energy renovation of buildings in Nearly Zero Energy Buildings (nZEB). This tool, focusing on representative public buildings, aims at the definition of their existing energy situation and the identification of efficient and economically viable solutions to minimize energy consumption and reduce CO_2 emissions. The tool evaluates with cost optimal principles and provides packages of measures for a particular office building in order to meet the criteria of the nZEB buildings.

In this paper, the characteristics of the tool, the calculation methodology and the results are presented, for a public office building in Greece. The results highlight the cost optimal solution of several energy refurbishment scenarios, taking into account both energy and investment perspectives. In addition, a comparison of this study with the results of the national program for the calculation of the energy performance (TEE KENAK) is performed.

Keywords: *nZEB, energy refurbishment, buildings, tool*

Solar Thermal Systems

ENERGETIC, EXERGETIC AND FINANCIAL EVALUATION OF A CASCASE ABSORPTION-COMPRESSION REFRIGERATION SYSTEM DRIVEN BY SOLAR ENERGY

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ABSTRACT

Huge amounts of energy are consumed in order the refrigeration needs to be covered worldwide. These energy amounts lead to higher emissions of global warming gases and this situation creates environmental problems. The use of renewable energy sources for driving refrigeration systems is a way for creating efficient systems and systems with higher sustainability. In this work, a hybrid cascade refrigeration system which exploits solar energy is examined energetically, exergetically and financially. This system includes two refrigeration stages. The low stage is a conventional mechanical compression system and the high stage is an absorption chiller operating with LiBr-H_2O. The absorption chiller is fed with thermal energy from the solar collector field. Evacuated tube collectors of 300 m^2 collecting area are used in order to operate with high thermal efficiency and they have been coupled to a storage tank of 5 m^3. The analysis is conducted with a developed thermodynamic model in EES (Engineering Equation Solver) in time-depended conditions.

In the first part of this study, the system is optimized and the optimum generator temperature levels are selected for different heat rejection temperature levels. The next step is the evaluation of the system for operation on a sunny day. When the heat rejection temperature is equal to 40^{o}C, the optimum generator temperature is equal to 93^{o}C. It is important to state that the system is investigated for different combinations of heat rejection temperatures and evaporator temperatures.

After this procedure, the system is evaluated on yearly basis by examining twelve different days. It is proved that higher refrigeration amounts are produced for higher evaporator temperatures and for lower heat rejections temperatures. The electricity consumption savings are ranged from 30% to 80% and they are greater for operation in higher evaporator temperatures and for higher heat rejection temperatures. For instance, when the evaporator temperature is equal to -20^{o}C and the heat rejection temperature equal to 40^{o}C, the yearly refrigeration production is equal to 155 MWh, the electricity consumption savings 54%, the mean COP is 0.31 and the mean exergetic efficiency is 5.1%. In the last part of this study, the system is evaluated according to financial criteria. Generally, the system is financially viable in the majority of the examined cases and especially in the most difficult operating conditions (low evaporator temperature and high heat rejection temperature). For example, when the system produces refrigeration at -20^{o}C and it rejects heat to the ambient at 40^{o}C, the payback period is close to 14 years and the internal rate of return (IRR) is close to 6.6%,

Keywords: Solar energy, absorption chiller, cascade refrigeration system, exergetic analysis, financial analysis

EVALUATION OF CONCENTRATING SOLAR THERMAL SYSTEMS FOR SOLAR COOLING APPLICATIONS IN THE BUILDING SECTOR

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ABSTRACT

Concentrating Solar Thermal (CST) technology is most known for its power generation applications, typically with large solar fields and a corresponding installed power in the order of tens or even hundreds of MWel, where is already considered as an established option.

However, as technology evolves, there are possibilities for CST systems to play an important role in smaller scale thermal applications, in the temperature range between 1000C and 2500C. Such CST applications are applied in the building sector, combined with two-stage absorption chillers in Solar Air Conditioning (SAC) systems. In this type of configurations a higher overall system performance can be achieved, in comparison with SAC applications with flat plate collectors and single stage chillers.

Primary research objective in this study was the assessment of CST systems to be utilized in the building sector for cooling purposes. Different applications were examined using appropriate simulation tools, covering all Greek climatic zones and also the most widespread typologies of big buildings.

More specifically, the simulation considered the use of parabolic trough collectors systems with two stage closed-cycle absorption chiller for covering part of cooling needs for the cases of:

- a large office building in Athens and
- a residential complex in Heraklion, Athens and Thessaloniki.

The results presented in this paper focus on the systems□energy studies and in particular on the, analysis and evaluation of their performance and suitability.

Keywords: Concentrating solar thermal systems, solar cooling, simulation, energy saving, buildings.

DEVELOPMENT OF A HYBRID SYSTEM OF SOLAR COLLECTORS AND A BIOMASS FURNACE, WITH THE USE OF THE PROGRAM C.A.R.N.O.T., FOR COVERING THE NEEDS IN HOT WATER OF USE IN RENTING ROOMS IN SIDARI OF CORFU

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ABSTRACT

With the help of the CARNOT program, a hybrid system was created, which consists of solar collectors and a biomass burner, for covering the needs of hot water for renting rooms in Sidari of Corfu, in Greece. The CARNOT program is a software tool for the simulation of thermal systems with both conventional and renewable components. It has the ability to simulate systems with different steps (daily, hourly, per second) according to the needs and the programming of the user.

With the model which was created, 3 simulations were made:

- for the existing system of the oil burner

- for a hybrid system with parallel installation of solar collectors

In this frame it was calculated the surface area of the solar collectors that is required, in order to have a minimum coverage of 60%.

- for a hybrid system with the same surface of solar collectors, but with a burner of wood pellets (biomass), of the same power with the oil burner.

In this case it the price was calculated and the amount of the wood pellets that is required in order to heat the water of the renting rooms.

The simulation was made for every second of the month of the hotel's operation, but due to the large amount of data, the results were presented for some characteristic days, and for the total of each month separately.

Keywords: hybrid system, CARNOT program, hot water of use, solar collector

ADVANTAGES AND DISADVANTAGES OF DIFFERENT HEAT TRANSFER FLUIDS FOR SOLAR TOWER SYSTEMS

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ABSTRACT

Electricity production in solar thermal plants, such as solar towers, is a way to replenish the use of conventional forms of energy over the long term. In Germany, the first experimental power plant from a 1.5 MW solar tower was built and is in operation since 2009. By concentrating direct sunlight through heliostats on a central solar receiver, very high operating temperatures can be achieved. This heat is a used in a thermal cycle and transformed into mechanical energy and then with a generator into electricity.
The use of air as a heat transfer medium as well as ceramic structures as recipients of concentrated solar radiation achieves high efficiency factors and high operating temperatures.
In addition to the use of air as a heat transfer fluid, other fluids can also be used such as salt and water / steam system. In Spain and the US solar power towers are in operation, which use one of these two fluids to transfer heat from the solar receiver. The text presents the drawbacks and advantages of various heat transfer fluids as well as the corresponding solar concentrated technologies.
With the use of solar towers, conventional fuel savings and carbon dioxide emissions in the atmosphere are achieved while at the same time reducing energy costs. Especially in Greece, with a remarkable solar potential, the development of this competitive solar technology, which is already a priority in other Mediterranean countries and America, is imperative.

Keywords: solar energy, solar tower, heat transfer fluid, solar thermal power plant

INTEGRATED COLLECTOR STORAGE SOLAR WATER HEATER WITH PHASE CHANGE MATERIAL UNDER PARTIAL VACUUM

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ABSTRACT

The work focuses on the study of the heat diode mechanism in an Integrated Collector Storage Solar Water Heater (ICSSWH) for domestic applications. The solar device combines a horizontal cylindrical vessel with an asymmetric reflector trough (Compound Parabolic Concentrator CPC). The cylindrical storage tank comprises two concentric cylindrical vessels: the outer absorbing vessel and the inner storage vessel. The annulus between the cylindrical vessels is partially depressurized and contains a small amount of water serving as Phase Change Material (PCM), which changes phase (mainly at low temperatures), thus producing vapor and creating a thermal diode transfer mechanism from the inner surface of the external vessel to the outer surface of the internal vessel. The device was optically studied regarding the determination of the distribution of the absorbed solar radiation and also the calculation of the optical efficiency. Two methods were developed, the computational Ray Tracing Method (RTM) and the theoretical method of the Average Numbers of Reflections (ANR). Several experimental results are demonstrated through diagrams, depicting temperature variations, mean daily efficiency and thermal loss coefficient. Additionally, results from the variation of the temperature and the total pressure inside the annulus are also presented. The results clearly show that the vapor's pressure along with the geometry of the reflecting parts of the device play the most important role regarding its thermal behavior.

Keywords: *Integrated Collector Storage Solar Water Heaters (ICSSWH); Heat Diode Mechanism; Thermal Behavior; Phase Change Materials (PCM); Compound Parabolic Concentrators (CPC)*

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HEAT GAINS FROM THE USE OF A SOLAR AIR HEATER

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ABSTRACT

Over the last few decades, there seems to be a clear target for reducing energy needs in the building sector. The above objective can be achieved both by converting the existing building stock into zero or nearly zero energy buildings and by building new buildings that will meet the characteristics of zero or nearly zero energy buildings. In order to convert or build a building in a zero or almost zero energy building, different passive, active and hybrid systems can be used. A system that can be used is a Solar Air Heater Collector. The above system is installed in ZED-KIM (Zero Energy Demand - Kimmeria), by the Laboratory of Environmental and Energy Design of Buildings and Settlements. The ZED-KIM is located at the Campus of the Environmental Engineering Scholl, DUTH at Xanthi, in Kimmeria. In the present study we present the Solar Air Heater Collector and its thermal performance and its contribution to cover heating loads of a Building. In the above system have been adjusted instruments that monitor and record the energy behavior for export and analysis of experimental data. This study will present and analyze the results from the processing of measurement data for the period October 2016 - April 2017. Based on the above results, it is concluded that even with feature extreme weather conditions prevailing in northern Greece during the period of measurements, the use of a Solar Air Heater Collector can contribute up to a significant point to covering the heating loads of a building and in conjunction with other passive and active systems can lead at least into nearly zero energy buildings.

Keywords: Hybrid Systems, Solar Air Heater Collector, Thermal Efficiency

INSTANTANEOUS EFFICIENCY OF A PARABOLIC-TROUGH CONCENTRATING SOLAR COLLECTOR

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ABSTRACT

The overall efficiency of a Parabolic Trough Collector (PTC) depends both on optical efficiency, i.e., the direct solar radiation incident on the receiver, as well as on the thermal losses from receiver to the ambient. It is, therefore, a function of several structural and operational parameters and the exact form of its equation differs from the more familiar one for the instantaneous efficiency of flat-plate thermal solar collectors.

In the course of the present study, the variation of instantaneous efficiency of a typical solar, linear-focus PTC is investigated theoretically and experimentally under different conditions in terms of insulation, ambient temperature and working fluid temperatures and flow rates. Furthermore, a correlation with regard to the geometric features and optical properties of the collector is pursued, along with the resulting formulation of the instantaneous efficiency equation.

The results of the investigation may be utilized both within the framework of testing, aiming at the collector characterization, as well as for the parametric study of its efficiency on the basis of given design choices. They may also be used for the estimation of the expected energetic yield of facilities within which a collector of known efficiency characteristics has been integrated.

Keywords: Solar thermal energy, PTC collector, efficiency

THE EXPLOITATION OF SOLAR ENERGY IN MEDITERRANEAN COUNTRIES

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ABSTRACT

In the Mediterranean region, relatively high solar radiation rates are recorded throughout the year. At the same time, the similar climatic conditions in the area, justify comparable energy needs in key sectors of energy consumption (e.g. building, rural). Therefore, the Mediterranean area is an appropriate field for evaluation and comparison of data concerning production and consumption of renewable energy and, in particular, of solar energy.

Based on the available statistics, this work studies the production and consumption of solar energy in the Mediterranean countries. It studies the evolution of energy production from the Sun in relation to energy production from other renewable and non-renewable sources. It also identifies and examines the factors that impact, positively or negatively, on the exploitation of solar energy in the region. Insofar as the data permit, the study specializes in different areas of exploitation of solar energy (e.g. electricity generation, photovoltaic, solar thermal). The findings help to optimize the utilization of solar energy in the Mediterranean region and in particular in the area of Greece.

Keywords: *Mediterranean Region, Renewable Energy Sources, RES Applications, RES Systems, Solar Energy.*

INSPECTION OF THE RECEIVER TUBES DEVICES OF SOLAR PARABOLIC THROUGH COLLECTORS USING INFRARED THERMOGRAPHY

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ABSTRACT

The need to exploit Renewable Energy Sources (RES) to produce any kind of energy has increased rapidly in recent years. The use of solar energy has reached a remarkable level as continuous research into an alternative source of energy, due to the growing shortage of fossil fuels, is a driving force. Parabolic solar concentrators (PTCs) are one of the most widespread commercial renewable energy generation systems. This is partly due to the possibility of producing thermal energy from the sun in a wide range of temperatures (up to 400 ° C), and so can be used in a variety of applications such as e.g. from power plants to industrial cooling systems, hot water and/or steam. Their functionality and availability at all times in any kind of application is of the utmost importance. However, parabolic through collectors face a number of technical problems that are mainly related to structural integrity and inspection of critical parts such as, for example, of their absorption receivers. Inspection of the absorption tube becomes very difficult because it is covered by a ceramic mantle coating and placed in a vacuum glass casing.

The aim of the present study is to investigate the possibilities of inspecting the absorbers of parabolic through collectors in the field by means of infrared (IR) thermal imaging and to investigate and evaluate its effectiveness as a method of inspecting and analyzing the operation of a solar thermal park in comparison with existing conventional methods. In the context of the thermographic control of the current work, field measurements were initially made on all the receivers tubes contained in the parabolic mirrors of a solar thermal park located in the prefecture of Xanthi, as well as at the entrance and exit of the thermal oil, in each of the six rows of mirrors grid. Finally, these measurements were analyzed and compared with the expected operating temperature of the park.

Measurements in absorption receivers of solar field mirrors have shown that thermal imaging is a promising quality and quick (non-destructive) way of inspecting devices.

Keywords: Infrared Thermography, Inspection, Parabolic Through Collector, Receiver Tube, Solar Energy.

EXPERIMENTAL INVESTIGATION OF SOLAR WATER HEATERS EQUIPPED WITH PUMP AND SOLAR PANEL

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ABSTRACT

This work aims to investigate the behavior of domestic Solar Water Heaters (SWH) functioning in forced heat transfer mode, between solar collector and storage vessel, instead of the widely adopted thermosiphonic flow. The forced circulation is produced by a small DC pump, driven by an also small Photovoltaic (P/V) panel. For this purpose two identical commercial solar thermosiphons have been installed and tested side by side. One of them has been transformed, by the addition of a small pump between collector and mantle heat exchanger. Also, a small P/V panel was incorporated to drive the pump. Both systems are equipped with vacuum tube solar collectors. Comparisons have been made between both systems, under the same meteorological and functional conditions.

For comparison reasons, both systems were tested according to ISO 9459-2 and EN 12976-2 standards. For each test day, the performance of both systems was determined and finally their mean value. Results showed a mean coefficient of performance n_{av} =40,4% and average maximum hot water temperature achieved Tmax=54,45 ºC for the pump system and n_{av} =39,8% - Tmax=53,76 ºC for the thermosiphonic system. Furthermore, a photovoltaic pump SWH with vertical storage vessel was examined tested and results are presented.

It is concluded that the pump system behaves the same and a little better than the thermosiphonic one. So, the use of this combination pump P/V could be applied in domestic SWH with vertical inclined storage vessels, attached incorporated at the back of solar collectors. This arrangement creates higher thermal stratification on storage water and a better esthetic result.

Keywords: *Solar Water Heater (SWH); Photovoltaic pump; Solar thermosiphon*

Energy Meteorology

HEATING DEGREE DAYS IN GREECE – CLASSIFICATION ACCORDING TO THE BUILDING USE TYPE

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ABSTRACT

In this work we calculate the heating degree days for forty (40) locations in Greece, based on the mean monthly temperature of each hour. This hourly approach allows estimate the heating degree days of buildings of various use types, having different occupancy schemes and weekly operation profiles.

The advantage of this method is that the heating degree days calculation is based on the real operation time of each building and not on a 24-hours operation profile, usually assumed. The results of this method allow a more accurate estimation of the building heat oads and the direct comparison between consumption profiles of buildings of different uses.

The corresponding average percent reduction of the required heating load for buildings operating 18 or 14 hours a day (e.g. residences), was estimated to 15,8% and 30,5% respectively. For all other building use types, operating 5 or 6 days every week, the same reduction is very high, 78,1% for office buildings and 69,4% for schools. These high percentage differences compared to buildings operating during 24 hours (at the same temperature basis), supports the need of a more detailed calculation of the heating degree-days or degree-hours, that takes into account their real operating schedule.

Keywords: Heating degree days, heating loads of buildings, energy performance of buildings, Greece.

ESTIMATION OF THE OPTICAL PROPERTIES OF CLOUDS, AEROSOLS AND FORECASTING OF DIRECT NORMAL IRRADIANCE FROM ALL-SKY IMAGES

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ABSTRACT

Aerosols and clouds affect the direct and global irradiance reaching ground, while their large spatial and temporal variability is the most important error factor for forecasting solar potential.

In recent years, the all-sky images are used to estimate the optical properties of aerosols, cloud coverage, type and velocity of clouds in a number of applications. In the present study, we present the summary of the methodologies developed in the Plataforma Solar de Almeria (PSA), within the framework of the European program "Direct Normal Irradiance Nowcasting methods for optimized operation of concentrated solar technologies".

The all-sky images of four Mobotix Q24M cameras are analyzed in combination with measurements of atmospheric components, cameras placed in a solar tower for the recording of shadows and a dense network of ground-based instrument measuring solar radiation. The all-sky cameras are used for:

• The estimation of the optical properties of aerosols from RGB (Red, Green, Blue) channels at specific polar angles

• The estimation of the cloud properties

The outputs are used for the three-dimensional representation of the clouds and are introduced into a radiative transfer model to estimate the direct normal irradiance in a 2x2 km area. Then, using sequential photographs, the velocity of the clouds is calculated and the solar irradiance is forecasted at a 15-minute horizon. Finally, the data are evaluated by comparison with ground-based measurement and shadow maps of the studied area.

Keywords: aerosol, clouds, direct normal irradiance, resource, forecast

APPLICATION OF TYPICAL METEOROLOGICAL YEAR FOR OPTIMUM SIZING OF AUTONOMOUS PHOTOVOLTAIC SYSTEMS

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ABSTRACT

The exploitation of Renewable Energy Sources has taken a massive lead in recent years, with the most significant increase occurring at photovoltaic plants that use solar energy to convert it directly into electricity. When a photovoltaic system is designed, the solar potential of the area is the dominant parameter, as solar radiation is the energy source of the photovoltaic panels. The use of solar energy values, which may deviate from the actual values, has a relatively small impact on the overall energy assessment of interconnected photovoltaic installations. However, in the case of stand-alone photovoltaic systems where the user requires energy autonomy, it is necessary to use hourly solar radiation values with increased reliability as these units require, in addition to photovoltaic panels, energy storage systems that increase significantly the installation cost and consequently the cost of energy production.

In this context, the present study examines the use of time series of solar radiation and air temperature from Typical Meteorological Years (TMY), which have been created for 39 different regions of Greece. The advantage of using TMYs compared to the use of time series of individual years is that the hourly time series of the TMY is shaped in such a way as to represent the climatic conditions that are considered to be characteristic over a long-time period.

More specifically, the values of the TMYs are used for the optimum sizing of an integrated photovoltaic unit combined with an energy storage system capable of providing full energy autonomy to a domestic consumer in the area of Rhodes. From the number of combinations of photovoltaic panels and battery capacity, the combination that achieves the minimum production cost is chosen. In order to test the reliability of the results, the sizing process is repeated by using the measurements of each of the 12 historical years from which the TMY has been created, so that their reliability can be ascertained through the comparative assessment.

Keywords: Remote consumer, Photovoltaic, Energy Autonomy, TMY

STUDY OF SOIL TEMPERATURE VARIATIONS IN VARIOUS METEOROLOGICAL STATIONS IN SOUTH GREECE

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SUMMARY

Ground temperature is an index of the heat (thermal energy) stored in the soil and its knowledge is a crucial factor in energy potential evaluation. Furthermore, it is a significant factor in designing and sizing thermal systems in various ground related applications.

In this paper the variation of ground temperature and the relation to ambient air temperature in eight (8) Meteorological Stations of National Meteorological Service, in South Greece, are investigated, in order to assist the evaluation and exploitation of soil energy potential.

For this purpose 5 years measurements of air and ground temperature in various depths (surface, 2, 5, 10, 20, 50 and 100cm) are used and the mean monthly values are analyzed and compared.

The air-to-ground temperature relation is investigated by analysis of (a) variation of mean monthly values of air and ground temperatures, (b) distribution of ground temperatures in various depths up to 1,0 m, (c) time lag of ground temperature to air temperature variations, (d) correlation of mean monthly values of ground temperatures to mean monthly values of air temperature.

Finally, simple mathematical models/equations calculating ground temperature in different depths up to 1,00 m in relation to ambient air temperature are examined, in order to be useful to form general use equations to calculate ground temperature in various depths in relation to ambient air temperature all over Greece.

Keywords: *Ground temperature, ground-to-air temperature coupling, ground temperature profile*

Building Physics

ENERGY ASSESSMENT OF BUILDING PHYSICS PRINCIPLES IN SECONDARY EDUCATION BUILDINGS

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ABSTRACT

The building sector is the largest energy user; therefore, it is essential to improve energy efficiency and reduce demand, as well as install renewable energy systems to cover thermal and electrical loads for the targets of the upcoming years to be met. Especially for public buildings, any interventions should be accomplished directly, due to the existing commitments within the European Union, constituting, in this way, a role model for the private sector.

Education buildings are highly distinguished among public buildings by their great diversity, because of the different time periods of their construction and their spatial distribution. The necessity of saving energy in education buildings is therefore evident, since they are important energy consumers. However, the potential for energy saving is almost impossible to be captured because of several factors that do not allow for any reliable overall assessment. These are, inter alia, heterogeneity in existing situation, inadequate heating installations and uncontrolled, natural ventilation.

Based on the above facts, the thermal behavior of a typical secondary school building in Thessaloniki is evaluated. Designing factors such as the orientation of the openings and thermal mass and alternative manufacturing solutions such as the location of the insulation layers in the building components, are compared in terms of annual heating and ventilation energy requirements, as well as regarding the maximum required power of the heating system. Alternative scenarios for the heating system to meet peak demands, along with the presence of mechanical ventilation with heat recovery heat exchangers are assessed for their efficiency.

For the evaluation of the alternative scenarios, EnergyPlus software is used, with an hourly time step simulation of the thermal behavior of the building for a reference year.

Keywords: *education buildings, heating, thermal insulation, EnergyPlus*

COMPARISON OF CALCULATION METHODOLOGIES USED TO ESTIMATE LIGHTING ENERGY SAVINGS OF DAYLIGHT DIMMING SYSTEMS

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ABSTRACT

Daylight exploitation is a cornerstone strategy to reduce energy consumption in office buildings. This can be realized through the use of control systems capable to modify emitted light flux from the luminaires according to a signal from a photosensor. The wide adoption of these systems, despite the extremely high energy savings potential, is adversely affected by a number of causes, such as the complex design process, the unreliability of energy savings calculation methods and finally the non-acceptance of these systems by the users of a space when not properly commissioned. Therefore, it is obvious that the use of different energy savings assessment tools at various design stages, simple at the initial design phase and more complex at the end can affect significantly the estimation of possible energy savings. In the present paper a series of calculation methods are examined and the results concerning lighting energy savings are compared with the results obtained from a full simulation of a dimming system including both luminaires and the control system with the light sensor. Full simulation requires a) accurate calculation of daylight b) accurate simulation of sensor performance, and c) reliable simulation of the emitted light flux from the luminaires in relation to the control voltage. The latter two characteristics have been measured in laboratory. The results show significant differences, depending on the method used, with the highest absolute value (74%) occurring between full simulation results and results obtained with the use of Daylight Factors while the lowest value appears when simulation methods are used (~ 1%).

Keywords: Energy savings, artificial lighting, daylighting

COMPARISON OF DYNAMIC AND THEORETICAL CALCULATION OF THERMAL TRANSMITTANCE IN GREEN ROOFS

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ABSTRACT

The installation of green roofs in modern cities is expanding taking into account their multiple benefits, such as improving the microclimate and energy saving for cooling and heating of buildings. However, their thermal insulation properties have been limited researched, and the energy simulation software used, is not properly programmed for this purpose. The calculation of the thermal transmittance, U-value, firstly gives a concise picture of the heat-insulation profile of the green roof component, and secondly, it is necessary to give input for a complete energy study of a building with an installed green roof. The purpose of this paper is to compare the theoretical calculation of thermal transmittance, using heat transfer calculation software, with a dynamic experimental calculation, according to the PASLINK method. From the calculation and comparison of the models, a significant difference which ranges between 27 and 40% arises with the theoretical method overestimating the U values. This is mainly due because, in the theoretical calculation, the layers of the planted roof are considered individually as fixed conditional building materials and not as a system whose parts interact.

Keywords: green roofs, Test Cells, PASLINK method, TRNSYS, thermal transmittance

THERMAL PERFORMANCE ANALYSIS OF A BRICK WALL INCORPORATING SHAPE-STABILIZED PHASE CHANGE MATERIALS

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ABSTRACT

Phase change materials (*PCMs*) is shown to be a promising strategy to achieve energy reduction goals for buildings because of their potential to absorb and release large amounts of heat without temperature alteration. This study investigates the efficiency of shape-stabilized phase change materials (*SSPCMs*) on improving the thermal performance of a brick wall. To accomplish this, shape-stabilized phase change materials, with different phase change temperatures and thicknesses, were installed on the inner surface of a brick wall and a parameter thermal analysis was performed. The examined wall structures are exposed to weather conditions that correspond to the third climate zone of Greece, during the spring period. The effect of shape-stabilized phase change materials on enhancing the thermal behaviour of the brick wall is stressed, while the selection of the proper phase change temperature and thickness is shown to be of great importance. The results are expected to be useful for optimizing the design of novel building envelopes incorporating shape-stabilizes phase change materials in order to attain acceptable indoor conditions with minimum energy demands.

Keywords: Phase change materials, Shape-stabilized phase change materials, Thermal performance, Thermal analysis

OPTIMIZATION OF BUILDING OVERHANG DESIGN USING BUILDING INFORMATION MODELLING (BIM) AND LIFE CYCLE ANALYSIS (LCA)

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ABSTRACT

The development of computational tools and the ability to simulate a large amount of data in relation to a variety of climatic conditions has helped to make informed decisions about alternative design solutions for bioclimatic building elements. At the same time, the combination of advanced models and tools such as BIM and environmental assessment models such as LCA provide the opportunity for holistic technical, economic and environmental approaches for the environmental design of buildings.

This study aspires to deliver a comprehensive model for the optimal computational design of building overhangs through the use of an integrated building information model. The analysis is implemented for different normalized shading projection geometries, different orientations and different climatic data, using the Solar Analysis module of a BIM software. In order to quantify the embodied energy and the environmental impact of the different geometries analysed in this study, Life Cycle Analysis (LCA) and the EcoHestia database of the Frederick University's Sustainable Energy Research Group were used. This study also presents the energy intensity indicators of the overhangs examined in relation to the energy savings achieved through their use as well as the calculation of the energy depreciation time of the alternative designs. The results of this work are expected to be a guide for a well-documented design of overhangs for bioclimatic buildings, as well as a benchmark for analysis in a corresponding combinational logic (BIM and LCA) building bioclimatic elements.

Keywords: Shading projection, optimal design, energy input, life cycle analysis (LCA), building digitization model (BIM), energy pay-back time (EPBT)

ASSESSING THE IMPACT OF COOL MATERIALS APPLICATION ON THE URBAN MICROCLIMATE. APPLICATION IN A REPRESENTATIVE URBAN DISTRICT IN THE CITY OF THESSALONIKI

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ABSTRACT

The application of cool materials has been widely investigated as a strategy towards the improvement of the outdoor thermal environment and the mitigation of the urban heat island effect; yet, most of the existing studies focus on their effect during summer period at the pedestrian level, without a further quantification of cool materials performance throughout the year and at different heights from the ground level. In this context, this study aims (i) to assess the impact of high albedo materials on the outdoor thermal environment, in terms of surface and air temperatures under different meteorological conditions, (ii) to investigate air temperature s vertical distribution inside the urban canyons so as to evaluate the attenuation of their impact due to height and (iii) to examine the effect of cool materials on the parameter of mean radiant temperature under summer and winter conditions. To this aim, microclimate simulations using the Envi-met model were performed for current conditions and after cool materials application on the ground surfaces of a typical urban area in the city of Thessaloniki. Simulations were carried out for representative days of each season, issued from a statistical analysis of long-term air temperature data. The analysis revealed important surface temperature modification during spring and summer days while the reduction was rather limited in winter, due to low solar heights and long term shadowing of ground surfaces by building volumes. Regarding air temperature, maximum reductions during all seasons were reported at the pedestrian level, in areas being exposed to solar radiation, while the intensity of air temperature reduction was progressively attenuated as the distance from the ground increased and became minimum at the rooftop level. Finally, the obtained results indicated that the implementation of cool materials on ground surfaces will strongly increase the mean radiant temperature at the pedestrian level during summer, provoking thus a high risk of severe thermal stress for the pedestrians; yet, a moderate increase of the parameter during winter may have positive effects on the pedestrian s thermal feeling.

Keywords: representative days, cool materials, Envi-met model, microclimate

INVESTIGATION OF THE EFFECTIVENESS OF PHASE CHANGE MATERIALS IN ENERGY PERFORMANCE OF LIGHTWEIGHT STRUCTURED OFFICE BUILDINGS

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ABSTRACT

This paper investigates the performance of lightweight structured buildings in the region of Athens (Greece) with and without the use of phase change materials (PCM) on annual base. With reference of a typical office building and the use of dynamic simulation software, the parametric study is conducted by diversifying the melting point of PCMs, the thickness, the location of implementation and the orientation. The investigation and the comparison of the performance of PCMs will be studied with regard to energy savings of the building in winter and in summer season.

Keywords: Phase change materials, lightweight building, energy performance

METHODOLOGICAL APPROACH OF AN INTEGRATED EVALUATION OF COMFORT & VENTILATION IN OFFICE BUILDINGS

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ABSTRACT

The upgrade of indoor environment conditions, without the increase of the buildings' energy consumption, is nowadays imperative. As depicted by the national and European institutional framework, building sector is responsible for 39% of the final energy consumption, and therefore measures should be implemented. In this line of approach, a variety of measures and policies are to be implemented focusing on improving the energy profile of the constructions while maintaining or even improving the occupants' comfort.

People spend 60-90% of their lives within the structured environment, therefore, ensuring high levels of comfort and well-being is important. Special interest is denoted in cases of office buildings, which constitute the second most important category of buildings of the tertiary sector. Moreover, in these building types, users tent to spend at least one third of their day. Therefore, it is necessary to define the individualized parameters and conditions that affect the convenience of users.

In framework, this research is carried out, aiming at the integrated evaluation of comfort and ventilation conditions of an office building in Thessaloniki, Greece. More specifically, the building under evaluation, is an office building located in the area of Panorama and is the Town Hall of the Municipality of Pylea-Hortiatis. This building was built in 2002 and complies with the existing national thermal insulation regulation.

The integrated evaluation of indoor and outdoor comfort and ventilation was carried out during the winter season of 2016, through field measurements, questionnaire survey and the implementation of DIAL + simulation tool. In particular, a number of thermophysical parameters of the indoor and outdoor environment were identified using the appropriate laboratory equipment, and through the qualitative data, statistically significant correlations were identified, which noted all the parameters that influence the perception of comfort and air quality of the occupants.

In conclusion, a comprehensive assessment of environmental conditions can make a decisive contribution both to improving occupants' comfort conditions and to inform policy makers regarding the directly and indirectly identifiable parameters that may affect the occupants' comfort conditions.

Keywords: Indoor environment conditions, Mediterranean climate, office buildings, comfort, natural ventilation

IMPROVEMENT OF NATURAL VENTILATION IN SHEEPCOTE

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ABSTRACT

Sheepcote are open livestock buildings where ventilation due wind (cross ventilation) in combination with ventilation due thermal buoyancy is used for the control of internal microclimate in order to provide thermal comfort conditions to the animals. The thermal comfort conditions are consisted by specific ranges of desirable temperature, relative humidity, air velocity as well as affordable levels of pollutants concentrations. In the case of an open building ventilation is used for temperature control and humidity removal under the condition that air velocity at animals level will be preserved in tolerated values depended on the season. Nevertheless the issue of ventilation on sheepcotes has not been adequately studied leading to construction according thumb rules, while the operation of openings remain manual and based on the subjective sensation of thermal comfort of the respective farmer. In the present study a state-of-the-art sheepcote chamber for a 1000 animals situated in Central Greece was studied in order to examine the optimum openings geometry.

In the present study the transport phenomena inside the building were simulated using Computational Fluid Dynamics. Two CFD models were developed, one simple 2D and a 3D full model which were validated against internal microclimate measurements. Then the CFD models were used for parametric studies. Initially the 2D model was used where only the continuity, momentum, energy and turbulence conservation equations are solved for the study of ventilation due wind and thermal buoyancy for various year seasons, for various type and size side openings (vertical and tilting) and for two positions of central opening cover. Conclusions about the optimum opening size was drawn based on the achieved temperature and air velocity at the animals' level. Finally conclusions about the thermal comfort conditions are drawn using the 3D full CFD model which includes humidity and ammonia distribution simulation. Animals inside the chamber were modeled as porous volume sources of heat, humidity and ammonia.

Key Words: natural ventilation, thermal buoyancy, CFD, livestock building, thermal comfort

NUMERICAL AND EXPERIMENTAL STUDY OF THE FLOW PAST A GENERIC CUBIC BUILDING WITH OPENINGS EMBEDDED IN A TURBULENT BOUNDARY LAYER

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ABSTRACT

The configuration of a surface mounted prism exposed to a turbulent boundary layer has been the study of numerous experimental and numerical studies in the past, due to the apparent correlation with the strength of structural components exposed to high speed winds. However, even in low-speed winds, ventilation rate, air penetration, and ultimately air quality in and around the building, depend on the flow field and the pressure distribution on its external surfaces. The characteristics of the upstream atmospheric boundary layer are crucial to this dependence, but their association with ventilation and air quality issues are still under research. In the present study, the case of a surface mounted cube exposed to two different upstream boundary layers, is examined. The presence of openings on the vertical faces of the generic building allow the air penetration inside it which initiates to further investigate the interaction of the internal and external flow, the surface pressure distribution and consequently the effects of air change in and around the building.

All experiments were performed in the large (3.5m x 2.5m x 12.0m - width x height x length) test section of the National Technical University of Athens wind tunnel. A uniform scale of geometric and dynamic similarity equals to 1:400, was achieved for the generic building and the atmospheric boundary layer. Mean velocity and turbulence kinetic energy profiles were measured with a hot wire anemometer, the surface pressure measurements were performed using a pressure scanner and a differential manometer, while Stereo Particle Image Velocimetry (PIV) tests were used for the mean velocity distribution and turbulence lengths around the generic building.

The computational model represents the reduced-scale model used in the wind-tunnel measurements. The Finite Volume Method in the In-house CFD code, is used to solve the approximate forms of the 3D steady RANS equations in combination with SST k-ω turbulence model. The coupled CFD simulation (indoor and outdoor airflow modeled simultaneously in the same computational domain) in combination with Multi-Local Mesh Refinement Technique (MLR) achieved the calculation of ventilation rate, which was associated with the characteristics of the upstream boundary layer.

A considerable dependence of the flow field and the ventilation rate around the building is observed along with the upstream boundary layer. This dependence, though, is not evident to the outer surface of the cubic building and its pressure distribution. The fact comes to contradiction to the empirical methods that are widely used for the numerical calculation of the ventilation rate.

Keywords: *Natural Ventilation, Atmospheric Boundary Layer, Computational Fluid Mechanics, Wind- tunnel, Particle Image Velocimetry*

Photovoltaics

ENVIRONMENTAL, ECONOMIC AND SOCIAL ANALYSIS OF A PHOTOVOLTAIC POWER PLANT OF 97 kWp FOR A PERIOD OF 4 YEARS IN GREECE

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ABSTRACT

The present paper involves the evaluation of a small photovoltaic (PV) power plant on the ground which started its operation in November of 2012. The installed nominal capacity of the project is 97 kWp placed in Rodopi county. This case study, which is representative for small and medium-sized businesses that have invested in PV power plants to 100 kWp (36,4 % of total installed capacity in Greece, around 950 MW). It is reflected the energy, environmental, economic and social footprint of this activity through the design, implementation and operation & maintenance for the last four years. The work aims to present the applied practices for this plant and the experience gained from the overall project in economic and environmental terms. In this paper are given quantitative and qualitative information on the operation of the power plant (from the start of development as the time of operation of the four years) in a difficult economic environment with frequent legislative and regulatory changes. The green distributed power generation has a positive contribution to sustainable development and tackling climate but also manages to be economic viable, productive and with positive environmental dimension in the society.

Keywords: Green energy, photovoltaic plant, power, regional development.

EXPERIENCES FROM THE 6-YEARS OPERATION OF HELLENIC PHOTOVOLTAICS AT INTERCONNECTED PV PLANTS

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ABSTRACT

This paper presents the way of the Hellenic photovoltaic (PV) manufacturing industry to date and a detailed analysis is provided for this sector. An investigation into the causes that guided to the shutdown of manufacturing units is executed. Also, the experiences from the six-year operation (3/2011-2/2017) of two photovoltaic plants (ground-based) of nominal capacity of 19,8 kWp in Rodopi that have Hellenic polycrystalline silicon PV modules (from Patras) of 220 Wp. An assessment of their energy production is carried out, faults are reported and the results of the measurement of the performance of the I-V curves of the PV modules and of the thermography carried out by an independent company are given. The average annual energy efficiency of the PV plants for the six-year study is 1579 and 1597 kWh/kWp, while the I-V curves and thermography results; the performance of the PV modules is satisfactory without significant deviations from the nominal values specified by the manufacturer. This paper deals the serious issue that concerns a large number of energy producers from photovoltaic plants, who have Hellenic PV modules and no longer have guarantees and support due to the shutdown of their manufacturing plants, but they are also innovative for the experimental performance of Hellenic PV modules is presented for the first time using operating data and experimental measurements and controls for a satisfactory operating time.

Keywords: *hellenic phototovoltaics modules, energy production, I-V measurement, thermography, Silcio.*

ENERGETIC AND EXERGETIC EVALUATION OF A HYBRID PV OPERATING WITH NANOFLUIDS IN YEARLY BASIS

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ABSTRACT

Hybrid PV collectors are devices which exploit the incident solar irradiation for producing low-grade useful heat and electricity. Their thermal efficiency is generally low and thus many techniques have been used in order to increase it. The use of nanofluids as working fluid is a promising method which can enhance the thermal performance of hybrid PV and to make them a competitive technology. The objective of this work is the yearly evaluation of a hybrid PV working with nanofluids. The use of Cu nanoparticles dispersed in pure water is the examined nanofluid and it is examined for volumetric concentration equal to 2%. The examined solar collector has 2m^2 aperture and it is connected to a storage tank. The storage tank volume is examined parametrically and it takes values from 50 L up to 300 L and finally the case of 150 L is found to be the suitable choice exergetically. The integrated system is examined for 12 days, one for every month of the year. During the daily evaluation, the ISO 9459-2 is followed and according to this protocol, the heat is stored in the tank during the day and after the sunset, the stored energy is evaluated.

The examined solar collector is investigated with a developed thermal model in EES (Engineering Equation Solver). This model is validated with experimental literature standards and the deviations are found lower than 2%. The next step of this study is the energetic and exergetic evaluation of the system for operation with pure water and nanofluid. Moreover, the system is examined parametrically for different storage tank volumes and finally the case of 150 L is examined in details.

During the yearly evaluation of the solar collector, it is found that the use of nanofluids leads to performance enhancement of the solar collector compared to the operation with pure water. More specifically, for the optimum storage tank volume, the useful thermal output is increased 4.4%, the electricity production 1.5% and the exergetic output 3.2%. Moreover, it is important to state that the yearly thermal output is calculated at 1615 kWh and the electricity production at 466 kWh. The thermal efficiency is found 43.8%, the electrical efficiency 12.6%, the total 56.4% and the exergetic 17.7% on a yearly basis.

The results of this study can be exploited for the yearly evaluation of hybrid PV collectors for operation with pure water and with nanofluid. Moreover, it is proved that the utilization of nanofluids is a promising choice for the thermal and electrical enhancement of solar collectors and their investigation is of high importance.

Keywords: Hybrid PV, Nanofluids, Exergy analysis, Yearly performance, Integrated system

LIFE CYCLE ASSESSMENT (LCA) OF HYBRID PHOTOVOLTAIC / THERMAL (PV /T) SOLAR SYSTEMS FOR DOMESTIC APPLICATIONS

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ABSTRACT

Photovoltaic/ Thermal (PV/T) devices comprises PhotoVoltaics (PV) and Solar Thermal Systems (STS) in one unit.The technical viability of these systems depends on two basic factors: the achievement of the required thermal energy and most importantly, the production of electrical energy achieving the highest possible electrical efficiency. The present work deals with the application of Life Cycle Assessment (LCA) and experimental study methods to (PV/T) technologies. The paper examines the environmental impacts throughout the life cycle of energy systems based to these technologies and analyzes the energy output and the cost benefit during the expected life time operation period. For that purpose selected studies carrying out LCA and energy and experimental study of energy systems are structurally reviewed by applying a three categories classification. Each category examines a different part of the above methodologies investigating different types of renewable energy systems. In addition the experimental study and the LCA methodologies were applied in specific PV/T systems in order to draw general conclusions for the viability of such devices for energy production (electrical and thermal).The aim of this study is to provide to the researchers a useful guide for the applicability of the LCA, experimental study methods to such technologies and to present an extend analysis of the advantages and disadvantages of these technologies for domestic applications.

Keywords: Photovoltaic / Thermal (PV/T) devices, Life cycle assessment (LCA), Experimental study

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ENVIRONMENTAL FACTORS EFFECT ON THE DEGRADATION OF DYE SENSITIZED SOLAR CELLS PERFORMANCE

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ABSTRACT

Dye Sensitized Solar Cells (DSSCs) have attracted considerable attention in recent years, both in scientific community and photovoltaic market. DSSCs have been considered as a low-cost alternative to conventional crystalline silicon solar cells, while offering a number of outstanding characteristics. However, the long-term stability of DSSCs is still an open issue that needs to be tackled, in view to their widespread commercialization. The present paper is a comprehensive investigation on the effect of the main environmental factors leading to the degradation of DSSCs performance. Accelerating ageing tests were conducted on DSSCs, fabricated in the laboratory using commercially available materials, prepared for DSSCs application. The accelerating ageing tests involve isothermal fatigue at high or low temperatures, thermal shock cycling, hydrothermal fatigue and reverse biasing of DSSCs, simulating partial shading of photovoltaic modules. In each case, solar cells performance was determined in conditions very close to the standard test conditions (irradiation intensity 1000 W/m^2 and temperature 30 ^{o}C). The variation of solar cells electrical characteristics, including short-circuit current, open-circuit voltage, fill factor and energy conversion efficiency, is shown for each case of accelerating ageing. One-diode model equivalent circuit analysis was applied to DSSCs characteristic curve in order to derive the key circuit elements values, determining their efficiency, and to reveal the mechanisms leading to the degradation of their performance. In each case, the variation of the photo-generated current, ideality factor, dark saturation current, as well as of internal parasitic resistances demonstrated changes in both of the component materials properties and interfaces developed in DSSCs structure. The results showed that moisture in combination with high temperature is the most important environmental factor leading to the degradation of DSSCs performance. In all cases of accelerating ageing, solar cells stability seemed to be highly dependent on desorption phenomena of the conventional hydrophilic ruthenium dye (N719) from the TiO_2 semiconductor.

Keywords: Dye Sensitized Solar Cell, Stability, Degradation, Accelerating ageing, Environmental factor

EXPERIMENTAL EVALUATION OF A PV/T COLLECTOR

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ABSTRACT

A retrofitted PV/T collector assembled and installed together with a commercially available PV panel, on northern hemisphere, facing south and tilted to 40^{o}. Its absorber type was serpentine-flat-water-based and it was made of copper sheet and tubes. The absorber was placed and fixed at PV's rear side with wood ribs. The PV/T and the PV panel were connected each one separated in a battery, equipped with MPPT system in order to earn the maximum power from each panel. In order to evaluate the system's performance during the spring period, outdoor experiments were conducted and a PC-based automatic data acquisition unit has been used. The results show that the PV/T collector is superior to electricity generation compared to conventional PV panel, yielding 6.64% - 10.2% more during the experimentation period and and also yields significant amounts of thermal energy.

Keywords: PV/T collector, Hybrid collector, PV/T absorber

OPERATIONAL CHARACTERISTICS OF A GRID-CONNECTED 1 MW_p PV SYSTEM

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ABSTRACT

Previous years, due to favorable investing environment, thousands of PV systems of different sizes, have been installed and operated in Greece, of total installed capacity at the end of 2017 of 2.60GWp. These installations are scattered throughout the country, both at the National Interconnected Grid and the Local autonomous Grids of the islands of Crete, Rhodes and the smaller islands of the Aegean Sea.

Up to now the evaluation of these installations mainly concerned their economic performance, i.e.issues about producers/investors income. The performance evaluation of these facilities, were not in the priorities of the investors, as well as of the installers, the equipment suppliers and the financiers. As a result the published papers and reports are limited and they mostly refer to the finance and less to the technical assessment/evaluation of the PV systems concerning theirplace (roof or ground), their geographical position and the prevailing climate conditions (solar radiation, air/cell temperature, wind speed), the sun tracking system used, etc.

The range of the installations, concerning construction place (on the ground or on the roof-top of buildings), the installed power, the sun monitoring system (stationary, moving on single or dual axis) and the local climatic conditions, make each facility unique, thus widening the scope of research and the comparisons that can be made.

In this paper the evaluation of the performance of a 1 MW_p PV system, installed in the industrial area of Serres, North Greece, and connected to the grid on March 2013 is presented.

The performance of the PV installation is examinedon the base of specific parameters used internationally, e.g. Final Yield, Reference Yield, Performance Ratio, Capacity Factor, efficiency and avoided CO_2. These parameters have been calculated on an annual, monthly and daily basis. The calculation of these factors is based on the electricity production of the system, and on solar radiation and ambient air temperature measurements.Finally, system's performance parameters arecompared to the performance parameters of PV systems from the literature.

Keywords: *PV systems, grid-connected, performance, efficiency, yield, capacity.*

PERFORMANCE EVALUATION OF A ROOF TOP GRID-CONNECTED PV SYSTEM, OF 9,8kW$_p$ POWER

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ABSTRACT

In this paper the evaluation of the performance of a photovoltaic installation of 9.8kW$_p$, placed on the roof top of the building of Municipal Water and Sewerage Company of the city of Veria, is presented.

The performance of the PV installation is examinedon the base of specific parameters used internationally, e.g. Final Yield, Reference Yield, Performance Ratio, Capacity Factor, efficiency and avoided CO_2. These parameters have been calculated on an annual, monthly and daily basis. The calculation of these factors is based on the electricity production of the system, and on solar radiation and ambient air temperature measurements. Results of the system's performance are compared to the performance of PV systems from the literature.

Based on the calculated results, and on the comparisons to other PV systems performance,measures/actions to improve systems performance are suggested, such as i) installation of a more efficient monitoring system, ii) more frequent and in depth check of the individual system componentsand connections situation, and iii) more regular and efficient cleaning of PV modules.

Keywords: *PV systems, grid-connected, roof top, performance, efficiency, yield, capacity.*