6th National Conference

On Renewable Energy Sources

Volos, Greece, November 3 – 5, 1999

Special Issue

SUMMARIES

of papers presented

6th *NATIONAL CONFERENCE ON RENEWABLE ENERGY SOURCE: Summaries*

PREFACE

The present volume contains the summaries in English of all invited lectures and more than 150 contributed papers presented at the 6th Conference on renewable Energy Sources, organised by the Institute of Solar Technology and the Mechanical & Industrial Engineering Department, and held in Volos, Greece, November 3-7, 1999.

The papers presented at the conference cover a broad spectrum, from theoretical investigation of complex phenomena to the study and evaluation of practical devices and the consideration of environmental, economic and legislative issues. The number of papers and the variety of the subjects demonstrate the vigour of the work carried out in Greece in the area of Renewable Energy Sources.

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 section in Greece and that it may aid the formation of fruitful collaborations.

Finally, on behalf of the Organising Committee, I wish to acknowledge the financial support of the Organisations that made this conference possible.

Professor V. A. Sotiropoulos,

President of the Board of Administration
Institute of Solar Technologies

INSTITUTE OF SOLAR TECHNOLOGY

The Institute of Solar Technology (IST) is a scientific and educational organisation established in 1980. Its office is in Thessaloniki.

The objectives of IST are:

- To encourage research, development, and use of renewable energy sources.
- To collect and disseminate information in the area of renewable energy sources utilisation through conferences, seminars and publications.
- To establish international connections and to aid the technology transfer in the area of renewable energy sources.
- To elaborate rules and energy policies aiming at the development, diffusion and utilisation of renewable energy sources.

In pursuing the above objectives the IST has already organised six successful National Conferences on Renewable Energy Sources (in 1982, 1985, 1998, 1992, 1996 and 1999). In each Conference more than 150 scientific papers were presented in all fields of renewable energies with more that 500 participants.

The IST has published the Proceedings of the conferences, which present the state of research and development work in Renewable Energy Sources area in Greece and its progress during the last two decades.

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	Mr. Papakostas, Aristotle University of Thessaloniki

For further information please contact:
Institute for Solar Technology
P.O. Box 487, Aristotle University of Thessaloniki
GR 540 06 Thessaloniki
GREECE
Tel.: +30-31-996084, 6087– Fax: +30-31-996019
email: tsil@eng.auth.gr

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INVITED SPEAKERS

Energy and Environment – Economics and Policy

by Achilles G. Adamantiades
Adjunct Professor of Energy Economy, George Washington University,
Consultant to the World Bank

The title concepts of are closely inter-related and mutually determined in the framework of contemporary social and economic life. The present study aims at showing the importance of this inter-relationship and the impact of coordinated decisions and measures for effecting the desired objectives, through the presentation and analysis of specific examples.

As energy constitutes a basic input for the economic development and improvement of the living standards of people, securing energy supply availability and of secure transport channels becomes a major objective of policy as well as of diplomacy of national governments and international bodies. On the other hand, the environment is bound to suffer the potentially serious impacts of increasing production, transport, and consumption of energy resources, primarily of fossil fuels. For the achievement of the dual goal, namely, of the availability of adequate energy resources with parallel stabilization or even reduction of the environmental impacts, coordinated efforts are being made on a local, regional and global level. The international treaties of Montreal (1989), Rio (1991), Kyoto (1997) and Buenos Ayres (1998) are major examples of such international efforts. The objectives of the World Bank and other multilateral donor organizations, such as the Global Environment Facility (GEF), are based on and pointing to these priorities. The efforts are focused on the following two-prong approach: (1) energy efficiency through advanced technology and rationalized consumption, and (2) accelerated and economic introduction of renewable energy resources (solar, wind, biomass, geothermal, and small hydro). As a result of the discussions of the last few years, there is also an intense debate on the controversial subject of a "carbon tax".

Major tools for the achievement of the desired goals are appropriately designed energy prices as well as a series of other economic incentives (for example, tax credits, offsets, etc.), which, however, must have the appropriate structure, level, application, and duration for maximum efficacy. Most governments now realize that they have a significant role to play in this complex game, through the design and introduction of the needed measures of energy and environmental policy.

COMPUTATIONAL FLUID DYNAMICS IN ENERGY PROCESSES

G. Bergeles

Department of Mechanical Engineering, Nat. Technical University of Athens, Heroon
Polytechniou str. 5, Athens, 157 70 Greece

The paper presents recent developments in computational fluid dynamics with references to technological problems in the energy process industry. Particularly the author's team contribution to topics as higher descretisation schemes, domain decomposition, telescopic grid, complex terrain and large eddy simulation techniques are presented and assesed within technological problems such as coal combustion, internal combustion engines, electrostatic filters and siting of wind generators.

It s is evident that CFD has become a reliable engineering design tool which has reduced considerably design to prototype time by order of magnitude; however progress in direct numerical simulation, body fitted coordinates in complex shapes and processor speed must be achieved in order to reduce engineering design times to practical values.

ENERGY & BUILDINGS: FROM THEORY INTO PRACTICE AND FROM SMALL-SCALE ENERGY INTERVENTIONS TO COMPREHENSIVE SOLUTIONS

Niobe Chrisomallidou

Laboratory of Building Construction & Building Physics

Aristotle University Thessaloniki – Department of Civil Engineering

Thessaloniki, 540 06 P.O.Box 429

Tel. (031) 995665, Fax: (031) 300586, E-Mail niobe@civil.auth.gr

A brief presentation is made - in four groups - of the final results of an extensive investigation into the thermal behaviour of 53 buildings. To be specific, the first group consists of a total of 18 typical textbook cases of buildings of different sizes, the behaviour of which was calculated with a simulation program. The second and third groups provide information regarding consumption levels, internal temperatures and building size based on measurements recorded in 30 buildings between 1 and 45 years of age. The first 15 of these were mainly multi-storey buildings, while the rest were two-storey detached houses. Finally, the fourth group consists of a total of 5 buildings, whose design was based on the principles of bioclimatic architecture and which incorporated passive solar systems within their shells. A comparison of the results permits an evaluation and ranking of the buildings in terms of energy efficiency, which in turn provides a basis for drawing up basic proposals for the design and construction of buildings with a targeted maximum energy consumption level of 50 kWh/m^2 annually. At the outside, a secondary level of between 51-100 kWh/m^2 annually would also be acceptable.

THE STRATEGY IN RESEARCH AND DEVELOPMENT IN THE AREA OF RENEWABLE ENERGY SOURCES[*]

Komninos Diamantaras

European Commission, General Directorate of Research

The keystones of the energy policies of the European Union are based on: (a) the commitment to the Kyoto Protocol, (b) the increase of the contribution of renewable energy sources (RES) in the energy consumption from the current 6% to 12% in 2010 and (c) the increase in energy efficiency. The diffusion of RES in Europe will greatly contribute to the attainment of the Kyoto Protocol emissions. In this direction positive role will play the tax exemptions for RES uses and the CO_2 tax enforcement. The research and development in the energy sector is one of the prime aims of the 6th Framework Programme commencing at the beginning of 2003. Emphasis will be given to the improvement of currently available technologies, which will be undoubtedly the technologies implemented in 2010.

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[*] *This summary was prepared by the editor and was based on the author's presentation in Greek.*

GEOTHERMAL ENERGY: HISTORY, APPLICATION AND PROSPECTS OF A RENEWABLE ENERGY RESOURCE

Mich. Fytikas

Department of Geology, Aristotle University, GR 540 06 Thessaloniki, Greece

The paper deals with the history, applications and prospects of geothermal energy worldwide and in Greece. Geothermal energy results from the inner heat of earth, which exhibits several types of manifestation at the earth surface, such as geysers, fumaroles and hot springs. The latter were known and appreciated from antiquity for bathing. The various applications of geothermal energy are divided in electrical and direct uses. The former use high temperature fluids (T>180°C), although waters with temperature as low as 90°C can be used for electricity generation in a binary organic Rankine cycle. The total installed capacity for electrical uses is expected to exceed worldwide 9000 MW_e in 2000. The direct uses include space heating, drying and dehydration of agricultural products, aquaculture, de-icing, ore leaching, and bathing and swimming. Despite the fact that Greece is one of the richest European countries in geothermal energy, no electricity is produced by this resource and the installed capacity of direct uses (mainly greenhouse heating) is only 23 MW_t (excluding balneology).

THE ROLE OF RESEARCH IN EXPLOITATION
OF RENEWABLE ENERGY SOURCES

Anastasios J. Karabelas

Chemical Engineering Department, Aristotle University of Thessaloniki and

Chemical Process Engineering Research Institute

Univ. Box 455, GR 540 06 Thessaloniki, Greece

A summary is provided first of the current contribution of various Renewable Energy Sources (RES) to the European and World energy balance, and contrasted with the targets set (in particular by the European Union) for increased RES utilization in the near future. The potential and main characteristics of various RES are reviewed next, including their basic (or inherent) shortcomings that hinder their broad exploitation. Furthermore, a brief account is given of the current technological targets as well as of the research frontiers for facilitating utilization of each RES such as biomass, geothermal, wind and solar energy.

Based on currently available data, it appears that in the forthcoming two to three decades, all RES types can contribute towards mitigation of environmental problems, but to a rather **limited** degree. The required (long-term) extensive substitution of fossil fuels by RES (to avoid dangerous climatic and other imbalances and to secure a sustainable growth on Earth) seems to be feasible, mainly by the large scale exploitation of solar energy, for production of electricity and most likely of hydrogen. To succeed in these plans, it is stressed that basic and applied research will be called upon to play a decisive role. Indeed, systematic research efforts, addressing the inherent shortcomings of solar energy and of other RES (such as small "density" and temporal fluctuations), are required to develop energy efficient and economically attractive methods of exploitation.

ENERGETIC OPTIMIZATION AND PRODUCT QUALITY ENHANCEMENT IN SOLIDS PROCESSING: A DILEMMA?

E. Tsotsas
Thermal Process Engineering, Otto-von-Guericke-University,
Universitätsplatz 2, D-39106 Magdeburg,
e-mail: evangelos.tsotsas@vst.uni-magdeburg.de

In solids processing, energetic optimization and product quality enhancement may be indifferent, synergetic or antagonistic to eachother. This is illustrated by three examples concerning drying, a major industrial energy consumer. Specifically, the recovery of heat from convective dryer exhaust gases, the dynamic modelling and automatic control of fluidized bed dryers, and the combination of grinding and drying in one apparatus are discussed. In cases of potential antagonism product quality is an unconditional must.

Η Ενέργεια σε Παγκόσμια Κλίμακα: Αποθέματα και Αειφορία
World Energy: Resources and Sustainability

Γιώργος Γιαδικιάρογλου / *George Yadigaroglu*
Ινστιτούτο Ενεργειακής Τεχνολογίας / *Institute of Energy Technology*
Πολυτεχνείο Ζυρίχης, / *Swiss Federal Institute of Technology*
ETH-Zentrum, CLT
CH-8092 Zurich, Switzerland

It is evident that, on a global scale, we continue consuming energy at an accelerating pace; the developing countries will likely be the driving forces for future increases (as the product of simultaneous increases in population *and* per capita consumption). A number of urgent ecological problems are linked to the non-sustainable use of energy resources; these include the exhaustion of fossil fuels, the rise of atmospheric CO_2 concentration and its effects on climate.

The three dimensions of sustainable development are ecological, social and economic compatibility; these are «to be managed with the same priority» (Rio Congress, 1993), implying that the costs of renewable energies, presented as a solution to the sustainability problem, must also be considered. Short-term solutions to the sustainability problem include energy savings (an obvious solution that is, however, in reality, not easily accepted and implemented by the public and the politicians), better utilization of energy, solar and other renewable energies, and nuclear energy (that cannot be rejected a priori).

Worldwide, 18 % of the primary energy used today comes from renewable sources. However, 98 % of this fraction is classical hydroelectricity and biomass; the contributions of solar and wind are 0.8 % and 0.1 %, respectively. The part of renewables in electricity production is much smaller. The experience from the last 30 years of development shows that, in spite of promotion efforts, in the medium term, we should not expect much more substantial contributions from the renewables, in particular for electricity production.

In Europe the fraction of renewable primary energy is 4 %. In Switzerland, renewables such as wood, wood scraps and industrial wastes produced 2.6 % of the primary energy in 1991. An ambitious «Energy-2000» goal to reach 3 % in primary energy and 0.5 % in electricity production from renewables by the end of 2000 was achieved; for electricity generation, the main contributor was the incineration of domestic wastes. Further increase of electricity production from waste incineration is limited by the availability of garbage.

Although certain renewable energies have an enormous theoretical potential, their real exploitable potential is much more limited. One of the main obstacles to the introduction of renewable energies is that they are diffuse: in all cases, (solar, wind, biomass) the achievable energy collection density is in the range 0.5 to 10 W/m^2 of ground surface. This creates the need for expensive concentration and collection techniques and extensive use of materials. Although the costs of renewable energies may be diminishing constantly, they face an «unfair competition» from the fossil fuels.

Other drawbacks of renewables are the non-coincidence of production and utilization sites, combined to the fact that they are not easily transportable; their intermittency (solar, wind) creating a need for storage; difficulties of integration in the existing electric grid (not an important issue as long as contributions remain negligible); the non coincidence of offer/demand peaks (daily, seasonal); and, surprisingly, the occasional lack of local acceptance (e.g., wind turbines).

Nuclear energy has certain sustainability advantages in meeting electricity demands: if breeding is considered, very important nuclear fuel (uranium and thorium) resources exist. Without breeding, the resources are limited (to about the level of oil and gas reserves). The energy density of nuclear fuel is very high; in normal operation, emissions are negligible and manageable; external costs have already been internalized (reserves for reprocessing, elimination of wastes); the acceptability of risks has been confirmed — at least in the West; and the cost of electricity depends very little on the cost of fuel.

Real problems of nuclear energy include the need to avoid releases of radioactive products in severe accidents that could result in large-scale land contamination and the need for political solutions to proliferation concerns. The production of nuclear electricity is *perceived* as unacceptably dangerous by a segment of the public and of the politicians (who take for granted and forget the benefits of the product: electricity).

Finally, nuclear wastes are an exaggerated «problem,» at least in comparison with other waste disposal problems. Radioactive waste disposal is presented as an ethical question (mortgage for future generations), while other similar ethical problems, for example, the exhaustion of fossil resources, other serious impacts on the environment, and the danger of a climatic catastrophe due to the atmospheric CO_2 increase, are not even mentioned. The waste disposal problem needs a mainly political resolution and public acceptance of existing technical solutions.

In conclusion, and considering that: fusion technology will not be ready for a long time (when and if it materializes, it will be complex); the introduction of renewable energies for electricity production is very slow; the industrialized world does not seem to be ready to intensively save energy (in spite of lots of talk to this effect); developing societies are hungry for energy; it can be concluded that continuing reliance on nuclear energy seems to be «inevitable» (at least as a transition solution) to stabilize atmospheric CO_2 levels and avoid the exhaustion of useful fossil fuel resources.

MEASUREMENT AND ELABORATION OF
METEOROLOGICAL DATA

THE SOLAR RADIATION IN ATHENS THE LAST 40 YEARS

H. Sahsamanoglou
Department of Meteorology and Climatology, Aristotelian University of Thessaloniki

The yearly values of total solar radiation measured in Athens, show a tendency to increase, although some sort periods of significant decrease. The trend of this increase is 7.155 (MJ/m^2)/year, which means that the recent values are 5,2% higher than the values at the beginning of the period. During the same period in Athens, there was a general decrease of the sunshine with a trend of 3.034 h/year. If these hours are transformed in solar radiation, appears that the real trend of solar radiation is 13.335 (MJ/m^2)/year, which is a total increase of 9,7% and not 5,2%.

During the period 1965-1975, there is a decrease of the solar radiation in Athens, but not of the sunshine.

The range of monthly values of solar radiation shows an important relationship with the solar activity (sun spots).

The daily values show that the solar radiation measured in Athens during the winter, often reach the top possible values. However the same does not happen during the summer. During the winter we have realistic values such as 12-14 (MJ/m^2)/day, but during the summer these values rarely exceed 33.5 (MJ/m^2)/day, which is significantly lower than the realistic value of 36.7 (MJ/m^2)/day.

METEOROLOGICAL DATA MEASUREMENTS

IN SOLAR VILLAGE-3, ATHENS, GREECE

G. Tsilingiridis, K. Gatsos, K. Tzoutzomitros, V. Sotiropoulos,
Department of Mechanical Engineering, Aristotle University
540 06 Thessaloniki, Greece
tel: 031 996084, fax: 031 996019, e-mail: tsil@eng.auth.gr

In this paper, elaborated meteorological data from Solar Village-3 (SV-3) meteorological station in Athens are presented. Meteorological data measured are:

-ambient air temperature (°C)
-total solar radiation on horizontal surface (W/m²)
-total solar radiation on 45° slope plan (W/m²)
-total solar radiation on vertical plan (W/m²)
-diffuse solar radiation on horizontal plan (W/m²)
-atmospheric (air) pressure (mbar)
-relative air humidity (%)
-wind velocity (m/sec)
-wind direction (deg)

Meteorological data were monitored continuously through a Data Acquisition System for a 36 continuous month period, from 1/1/89 to 31/12/91. Values are monitored with a time interval of 1 min. The 1 min. values are then integrated over a time interval of 5 min. and 5 min. values are integrated over a period of 30 min. Invalid values are marked and excluded from further processing. If three or more data values are invalid the relevant 5 min. data values are marked as invalid. During the integration to 30 min. values, if more than three 5 min. values are invalid, the 30 min. value is marked as invalid.

The evaluation of SV-3 energy systems is based on the 30 min. averaged values. 5 min. averaged values have also been used occasionally, in order to check the systems operation and to have better knowledge of systems behavior.

The elaborated data presented in the paper are average, extreme maximum and extreme minimum monthly values, as well as daily variation of half-hourly values.

Comparisons of mean monthly values of SV-3 measurements with meteorological data derived from National Observatory of Athens are carried out. Regression analysis shows a very high correlation of air temperature and solar radiation and a lower, but high, correlation of relative humidity in both meteorological station measurements.

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A MODEL FOR ESTIMATION VARIABLE BASE DEGREE DAYS.
DEGREE DAYS FOR ATHENS AND THESSALONIKI - GREECE

K. T. Papakostas

*Aristotle University of Thessaloniki, Dept. of Mechanical Engineering, Energy Section,
Process Equipment Design Lab., 540 06 Thessaloniki, Greece*

A model for the estimation of degree-days above or below any base temperature is presented, which needs as input only the long term monthly-average temperature. The monthly degree-days and cooling degree-days for various bases were calculated for Athens and Thessaloniki, Greece, using hourly ambient dry-bulb temperature data of the period 1983-1992 and are presented in tabular form.

The heating and cooling degree-days of Athens and Thessaloniki and of other 12 greek cities are compared with the estimated degree-days of the model and the differences between the calculated and estimated values of degree-days are presented.

From the results of the paper is concluded that the model can be used, in case of lack of sufficient temperature data, for the exact estimation of monthly or annual heating degree-days or for a quick estimation of monthly or annual heating degree-days for any temperature base. The only input that is needed is the long term monthly-average temperature. The use of the model for the estimation of cooling degree-days must be further investigated.

METHODOLOGY TO CREATE TYPICAL METEOROLOGICAL YEAR FOR USE IN SOLAR SYSTEMS

M. Gazela, E. Mathioulakis, V. Belessiotis

Solar & Energy Systems Laboratory, NCSR «DEMOKRITOS»,

153 10 Agia Paraskevi, Attiki

Solar energy systems are weather-driven. Because of this, meteorological data for hourly periods are needed to simulate the performance of these systems. Unfortunately, weather varies, sometimes extremely, for one year to another. Ideally, predicting accurately the performance of a solar system would need many years of meteorological data. However, the computing effort required to simulate solar energy system performance with such a large set of data is very significant not to say prohibitive. As a consequence, the creation of a single year of «typical» data is needed in order to evaluate the performance of solar systems.

The most common ways to synthesize a «typical» set of hourly weather data for a year are three : T.M.Y (Typical Meteorological Year), T.R.Y. (Test Reference Year) and W.Y.E.C. (Weather Year for Energy Calculations). For T.M.Y. and W.Y.E.C. twelve «typical» months have been selected and then concatenated to make a complete year. This selection has been made according to specific criteria. For T.R.Y. a «typical» year has been selected and this «typicality» means no extreme in ambient temperature.

In this paper, each of the aforementioned «typical» set of hourly weather data is assessed with respect to the error of the predicted energy gain. Two solar domestic hot water systems were simulated and the energy gain in yearly and daily basis of each was estimated for 21 years and T.M.Y., T.R.Y., and W.Y.E.C. Comparing the results it was found out that the most suitable technique to create a «typical» set of weather data for use in solar systems is W.Y.E.C.

ENERGY CONSERVATION IN BUILDINGS
BIOCLIMATIC ARCHITECTURE

APPLYING THE NEW BUILDING ENERGY REGULATION IN EXISTING URBAN BUILDINGS

A. Papadopoulos, T. Theodosiou

Laboratory of Heat Transfer and Environmental, Department of Mechanical Engineering, School of Engineering, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece
Tel. +30 31 996015, Fax. +30 31 996012

The currently elaborated Regulation of Rational Use and Energy Saving in buildings is the most important development since the introduction of the Thermal Insulation Regulation in 1979, as far as energy conservation in the building sector is concerned. The first drafts of the new regulation give an impression on the methodological and practical challenges facing architects, engineers, contractors and owners.

A major novelty introduced is the energy renovation of new buildings, with measures like retrofitting of thermal insulation, substitution of windows and upgrading of the heating systems. In order to evaluate the effects of these measures, fifteen buildings have been monitored and their energy evaluation has been evaluated in the city of Serres. For every building the options and the effectiveness of these measures have been simulated and evaluated. The feasibility of the proposed interventions was examined, in order to determine their applicability.

POTENTIAL OF SOLAR CONTROL TECHNIQUES

C.A. Balaras, A.A. Argiriou, D.N. Asimakopoulos

Group energy Cosnervation, Institute of Meteorology and Physics of Atmospheric

Environment, National Observatory of Athens, P.O. Box 20048, 118 10 Athens, Hellas

Tel: +301-3490154, Fax +301-3490113, email: costas@env.meteo.noa.gr

Solar control has also a direct impact on the total energy consumption of the building. Proper shading of the building improves the indoor thermal conditions and reduces the cooling load during summer, while assuring that the beneficial solar gains during winter can still be utilized. Proper solar control can reduce the need for artificial lighting and reduce the need for electrical energy during the day, while maintaining acceptable visual comfort.

The work was performed during the Solar Control (Integrated Approach to Solar Control Techniques) project (JOULE, JOR3-CT96-00113), of the European Commission, DG XII. The project participants included 12 institutions from 10 European countries.

This paper presents a brief overview of the work that was completed during this project that included the development of new technologies and systems combined with smart automatic controls, with an emphasis on energy conservation and optimization of indoor conditions; experimental work for various types of internal, interpane and external shading devices for determining their technical characteristics and overall thermal and visual performance; evaluation of various shading types on natural ventilation, daylighting and indoor thermal conditions; development of simulation tools for the detailed study of shading devices in relation to thermal building simulations; potential of automatic controls for the optimization of daylight with reduced use of artificial lighting, while satisfying indoor visual comfort conditions; production of a Design Guidelines and Component Dictionary Handbooks (available in paper and a multimedia program) for architects and building professionals. The emphasis of this paper is to present an overview of the work carried out in relation to the impact of shading devices on natural ventilation and a short presentation of the Handbboks' contents.

EXPERIMENTAL AND NUMERICAL ESTIMATION OF THE DYNAMIC THERMAL CHARACTERISTICS OF BUILDINGS

K.A. Antonopoulos, *Professor N.T.U.A.*
M. Vrachopoulos, *Dr Mechanical Eng., Research Assistant*
E.P. Koronaki, *Mechanical Eng., PhD Candidate*
National Technical University of Athens,
Mechanical Engineering Department, Air-Conditioning Laboratory,
9, Heroon Polytechniou Str., 157 80 Athens, Greece
Tel: 7723673, Fax: 7721260, e-mail:kanton@central.ntua.gr

Research is carried out in the Air-Conditioning Laboratory of the National Technical University of Athens for developing experimental and numerical procedures, suitable for the estimation of the dynamic thermal characteristics of existing buildings.

The experimental approach is based on processing of temperature and heat flow measurements performed in a model house of floor area $1.50 \times 1.45 = 2.18$ m^2 and height 1.45 m, built in an insulated test chamber of internal dimensions $3 \times 5 \times 2.75$ m^3. Outdoor and indoor conditions are simulated within the test chamber and the model house, respectively, by use of electric resistances and cooling coils, receiving ON and OFF instructions from a controller connected to a PC, according to a developed computer code.

The computational approach is based on a finite-difference solution of a set of differential equations describing the transient thermal behaviour of the model house. The numerical results obtained are in good agreement with the experimental data, thus showing that the developed numerical procedure is reliable.

Various thermal characteristics of the model house have been estimated using the numerical approach supported by the experimental data. It is concluded that the developed procedures may be useful in the thermal characterization of buildings with applications concerning energy management and development of control strategies for energy conservation as well as improvement of passive and active systems.

ESTIMATION OF HEATING ENERGY REQUIREMENTS OF RESIDENCES WITH THE VARIABLE-BASE DEGREE-DAY METHOD

K. T. Papakostas

Aristotle University of Thessaloniki, Dept. of Mechanical Engineering, Energy Section,
Process Equipment Design Lab., 540 06 Thessaloniki, Greece

The variable-base degree-day method for the estimation of heating energy requirements in buildings is presented. Although the method is steady-state it continues to be important because the severity of a climate can be concisely characterized in terms of degree days. The variable-base degree-day method can provide a simple estimation of annual heating energy consumption in single-zone building, which can be accurate if the indoor temperature and the internal gains are relatively constant and if the heating system operates for a complete season.
A review of the method is given in this paper. The necessary equations for the calculation of the balance point temperature of a building, for the evaluation of heating degree days and for the estimation of the monthly and annual heating energy requirements are presented. All the factors which are involved in the calculations, such as the total heat loss coefficient of a building, the internal heat gains from occupants, lights and appliances, and the solar heat gains are analyzed and are adapted to apply to greek residences, in order that the estimation of heating energy consumption in such type of buildings can be as accurate as possible.
From the application of the method by various investigators it was found that the heating energy requirements of residence buildings predicted by the variable-base degree-day method fall within 10 percent of those computed by DOE-2. It was also found that the method predicts correctly the heating consumption of residential buildings when the average heating season temperature is at least 5°C greater than the balance temperature.

COST EFFICIENT PASSIVE HOUSES AS EUROPEAN STANDARD

Vourvoutsiotis Apostolos, MSc, Dipl. Ing.

Gartenstrasse 14

90571 Schwaig, Germany

E-mail: apostolosv@primus-online.de

Nowadays the passive house model is a more developed and in Central Europe accepted, way of cost and energy efficient building. Passive Houses are buildings in which a comfortable climate can be achieved without an active heating and air-conditioning system and with approximately zero CO_2 emissions. A passive house thus consumes in total, less energy than is required in average European buildings for household electricity and domestic hot water alone. The total final energy consumption of a passive house is thus lower by at least the factor 4 than the average consumption encountered in new buildings and pursuant to the applicable national regulations.

BREAKDOWN OF ENERGY CONSUMPTION WITHIN ENERGY AUDITS IN BUILDINGS AND ITS RELIABILITY COEFFICIENT

Michael Kteniadakis
Ass. Professor of Technological Educational Inst.(TEI) of Heraklion, Mechanical Eng. Dpt.,
Stavromenos, 71500 Heraklion, Crete, Greece

Zaharias Assariotakis
Mechanical Engineer, 7 G.Papandreou Street, 71306 Heraklion, Crete, Greece

Anna Lagkouvardou
Electrical Engineer, 7 G.Papandreou Street, 71306 Heraklion, Crete, Greece

Klearhos Sarikakis
Student of Mechanical Eng. Dpt., TEI of Heraklion, Crete, Greece

Breakdown of energy consumption, per energy system or per area, is one of the main purposes of an energy audit in large and medium size buildings. A documented and reliable breakdown will result to correct evaluations and choices involved with the possible actions of rational use of energy (RUE) and energy efficiency (EE) in the building. In this paper:

a) We examine methods of composition/creation of the breakdown of energy consumption, that relate to the variety and the goals of an energy audit.

b) We propose a way to estimate the reliability of a breakdown, by introducing two partial coefficients, which value the various factors that effect its composition. We define:

- **The compatibility coefficient (COC) of the breakdown.** The COCs' value is based on the quantitative comparison of the energy consumption that was theoretically calculated within the energy breakdown, to those that was actually measured and registered.

- **The completeness coefficient (COM) of the breakdown.** The COMs' value is based on the quantification of a number of factors, such as the completeness of the data (informations) that were taken into consideration, as well as the lacks, difficulties and limitations that appeared during the energy audit.

- **The reliability coefficient (COR) of the breakdown,** as the product of the (COC)·(COM).

For each one of the above coefficients, a rate of the acceptable values is set, out of which the energy breakdown is regarded to be unreliable and should be repeated or rejected.

c) We present two examples - implementations of the above method.

EXPERIMENTAL TESTING OF A ROOF COMPONENT WITH A WATER RADIATOR FOR NOCTURNAL COOLING

A. Dimoudi, A. Androutsopoulos, M. Vallindras

Passive Solar Systems Department, Center for Renewable Energy Sources

19° km Marathonos Ave., 19009 Pikermi, Greece

A prototype roof component was built and tested for the investigation of its cooling performance during the night period. The component was built in full scale and was tested under real outdoor conditions in the test facilities of the Centre of Renewable Energy Sources. The component comprises a water radiator connected to pipes embedded to a reinforced concrete slab forming a closed loop. The system was operational during the night period. The 4.97 m by 2.72 m wide roof component was continuously monitored for 22 days during the summer period (June-July 1998) and the outcome of this monitoring is presented.

Results showed that a cooling potential is feasible through heat exchange by radiation and convection. It was found that the system is greatly affected by the water flow rate, which has a major impact to the radiator's efficiency. Finally, the proposed roof is a feasible structure, which can be easily implemented to either new building structures or during renovation of existing buildings in covering their cooling load.

CALCULATED AND EXPERIMENTAL DEFINITION OF SOLAR CHIMNEY OPERATION

Vrachopoulos M.Gr., Filios A.E., Diamantidis F.
C.H.T.E.P.V.S./ T.V.T.T.I.S.E., Department of Mechanical Engineering

The solar chimney is considered as an economic, noiseless and physical method for cooling and the renewal of the air in buildings. Its application in building results in a reasonable reduction of the air conditioning loads during the summer and winter as the renewal air is replaced with fresh air, which is provided by underground space or ditch.

It has been observed that the temperature of the air in underground spaces remains almost constant during the whole year and it is equal to $20^{o}C$, approximately. The air masses from these spaces can be piped as a cold stream for the renewal of the air in rooms with a result the reduction of the cold loads during the summer time where the environment air temperature is quite high. The system effectiveness depends on the volume of the available underground spaces as well as the solar chimney geometry.

The present work studies the operation of a two dimensional solar chimney under real conditions of solar radiation and environment temperature. The transient two dimensional heat conduction problem in conjunction to the free convection problem are described by a system of partial differential equations which are solved simultaneously utilizing the finite differences technique. The solar chimney behavior is validated through the calculations, which are compared directly with experimental measurements performed in a full-scale model. Therefore, the prediction of the cooling effectiveness applying the solar chimney concept is provided with parameters the load, the chimney height and the area of the available underground spaces.

EXPERIMENTAL CONTROL OF THE VARIATION IN THE TEMPERATURE IN THE LAYERS OF A PLANTED AND A CONVENTIONAL ROOF AND EVALUATION OF ITS INFLUENCE IN THERMAL BEHAVIOUR

D. Aravantinos, F. Psomas, N. Tsakiris
Laboratory of Building Construction and Physics, Faculty of Civil Engineering,
Aristotle University of Thessaloniki, 54 006 Thessaloniki, Greece.

This work presents using experimental measurements the distribution of temperature in the successive layers of a structure and the planted part of the planted roof in comparison with a conventional roof. It also examines the influence on the internal climate of the building. The comparison is taken for the peak of the summer and the winter period when the most extreme climatic conditions are observed.

The investigation indicates a milder temperature situation in the planted roof than in the conventional roof. Hence the planted roof suffers smaller temperature variations and is subjected to smaller thermal distress. The larger variation presents the values of the external surface temperature, which shows in the conventional roof a daily range in the region of 25 °C in the summer period and of 10°C in the winter period, whereas the annual range of the external surface temperature approaches 50°C. In the planted roof the corresponding daily variation for both the summer and the winter period are about 5°C, whereas the annual range amount to just 16°C.

This is happening because the foliage of the plants offers a protective shading, which obstructs the penetration of the solar radiation and doesn't permit the development of high temperatures on its surface. Moreover the gross thermal capacity and the thermal inertia of the layers of the planted part contribute to the presence of the very small temperature variation in the layers of the structural element and is regarded as practically inert.

We take into account the fact that with the planted roofs are created new surfaces of vegetation, and these reverse the prevailing conception of the roofs, which is that roofs should remain bare and have only one purpose i.e. the protection of the construction from weather conditions, then the planted roofs can be the alternative solution to the search for new zones of vegetation in the densely constructed environment of the whole city.

ESTIMATION OF THE NATURAL VENTILATION CONTRIBUTION TO THE ENERGY BALANCE IN BUILDINGS IN GREECE

N. Papamanolis

Region of Central Macedonia

Kathigiti Rossidi 11, 54008, Thessaloniki

The paper attempts an estimation of the natural ventilation contribution to the energy balance in twenty-four (24) residential and commercial buildings in Greece for which air change rate measurements under real conditions accompanied by indoor- outdoor temperature difference records are available. For these buildings are calculated the thermal energy exchanges due to ventilation which are taking place during the experiments and the energy losses corresponding to the heating and cooling periods. The results are evaluated in comparison to the conclusions of similar studies conducted abroad as well as the prevailing in the country climatic conditions, in order to be used for the improvement of the information for the energy performance of the buildings in Greece.

BIOCLIMATIC INTERVENTIONS IN A TOLL-SHAPED, LIGHT-WHEIGHT CONSTRUCTION TV PRODUCTION STUDIO

Efterpi Tzanakaki, Eleni Lampropoulou, Eugenia Lazari
Ilias Sofronis, George Kanavakis
Centre for Renwable Energy Sources (CRES)
19th km. Marathonos Ave., 19009, Pikermi, Greece

The results of the energy design of an existing building which is going to be used as a TV production studio are presented. The studio is located near the Athens-Lamia National Road, 31 km outside Athens. It is a toll-shaped (semi-cylidrical) structure 25 m long and 8 m wide, constructed of a plastic membrane (the kind used for covering outdoor spaces) on steel beams. Aim of the energy design was to reduce the heating load and if possible, eliminate the cooling load of the building by interventions of a bioclimatic character and simultaneously provide adequate but controllable daylighting and acoustic insulation. Additionally, the application of low-energy HVAC systems and renewable energy sources for covering the resulting heating and cooling loads was explored. The heating load of the existing structure has been estimated to be 1972 GJ (1257 KWh/m^2) and the cooling load 233 GJ (155 KWh/m^2).

The main proposed intervention was a double-envelope created by an air-gap and insulation on the interior side of the existing envelope, in order to combine thermal and acoustic protection of the building. Daylighting and passive solar gains in wintertime are achieved by creating an opening on the top of the building made of a diffusive polycarbonic sheet, which combines a moveable shading system. Night ventilation and earth-to-air heat exchangers are used as passive cooling means. All proposed interventions result in lowering the building heating load by 88% and in eliminating the cooling load. The heating load and occasional peak cooling loads may be covered by an air-to-air or air-to-water heat pump, which may operate in conjunction with the earth-to-air heat exchangers or a geothermal heat pump.

THE CONTRIBUTION OF THE PLANTED ROOF TO THE COOLING OF THE BUILDING

Th. Theodosiou, P. Amiras, Gr. Economidis
Laboratory of Building Construction and Physics, Faculty of Civil Engineering,
Aristotle University of Thessaloniki, 54 006 Thessaloniki, Greece.

This work investigates, based on the results of experimental measurements, the behaviour of a conventional roof during the hot summer period for both mild and high external temperatures. It observes the influence of the planted layers in the shaping of the temperature in the structural part of the roof and in the internal space and estimates its contribution to the cooling of the building.

From the study of the diagrams show that in the conventional roof during the summer period large thermal variations are present, which are especially intense during the peak period, whereas in the planted roof theses variations are more mild with minimum differentiation between the mild and peak periods.

In the conventional roof, in the external surface high temperatures appear, which rise to particularly high levels during the peak period. However in the planted roof the foliage of the plants protect the surface of the roof from solar radiation allowing much less penetration through the spaces between the leafs. This results in the surface temperature being lower than the temperature of the internal space during a 24 hour period of both wild and peak temperature variation.

The variations of the external surface temperature disappear completely in the separating water-proof layer and have virtually no affect on the structural part. The moisture in the planted part keeps the temperature at low levels, which are lower than those of the internal space.

The exploitation of these advantages of the planted roof can aid significantly the cooling of the building, particularly if is combined with food ventilation.

THE INFLUENCE DIFFERENT TYPES OF PLANTED ROOFS IN THE THERMAL BEHAVIOUR OF A BUILDING

E. Eumorfopoulou, N. Kalaitzidou, D. Tourtoura

Laboratory of Building Construction and Physics, Faculty of Civil Engineering,

Aristotle University of Thessaloniki, 54 006 Thessaloniki, Greece.

This work examines the thermal behaviour of a planted roof with low plants in comparison with one planted with higher plants, within the framework of a research program. The present figures concerning the first planted roof are derived from experimental measurements, while the figures concerning the second planted roof are simulation results.

The measurements were done on a roof, planted for that purpose, of a four storey building in Municipality of Stavroupolis. The measurements have shown that the different layers of the planted roof present small temperature variations. The foliage of the plants create a protective layer which doesn't allow the solar radiation penetration. So the temperature level in the roof is keeping low. As far as the temperature level is concerned the planted roof with higher plants present lower temperatures than those planted roof with lower plants. The thermal capacity of the ground contributes more towards the temperature decrease than sun shading offered the plants.

The increase of the width of the layers of the planted part doesn't step with the decrease of the thermal load. Hence a planted roof with low plants can correspond satisfactory to the decrease of the thermal distress of the roof. The choice of a higher planted roof is preferred when the thermal protection of the roof is combined with the ecological benefits achieved from the development of the vegetation, especially in the densely built areas.

EFFECT OF INDOOR MASS ON THE TIME CONSTANT OF BUILDINGS

K.A. Antonopoulos, *Professor N.T.U.A.*
E.P. Koronaki, *Mechanical Eng., PhD Candidate*
National Technical University of Athens,
Mechanical Engineering Department, Air-Conditioning Laboratory,
9, Heroon Polytechniou Str., 157 80 Athens, Greece
Tel: 7723673, Fax: 7721260, e-mail:kanton@central.ntua.gr

A numerical procedure is presented for the calculation of the transient heat transfer processes in the envelope, the indoor partitions and furnishings of buildings. The proposed method, which is based on a finite-difference solution of the set of the corresponding transient heat-transport differential equations, is used to examine the effect of indoor mass on the building time constant τ. The latter is analysed into components τ_{env} and τ_{ind} corresponding to the envelope and indoor mass. Function $\tau_{ind}(L_p, A_f)$ is developed, where L_p is the length of interior partitions and A_f the surface of the "equivalent furniture slab". A simple "time constant model" is also proposed, which is in satisfactory agreement with the developed rigorous numerical solution.

It is concluded that for houses and small buildings, the usual indoor mass increases time constant by up to 30%, which is analysed to 20% for interior partitions and 10% for furnishings. The effect of infiltration and ventilation on the time constant is found to be considerable and, under usual conditions may reduce the time constant up to 50%.

The τ-components introduced express the contribution of any indoor structural element or piece of furniture to the "total" time constant and are related to the corresponding components of the effective thermal capacitance. The analysis provides useful information for maximization of heat or cool storage in buildings.

LOW ENERGY PUBLIC HOUSING RETROFITS IN ATHENS, GREECE

ELIUS - A. Vei - Spiropoulou, architect

E. Triantis, architect consultant

L.D.K. - Technology and Development consultants

E. Kontomihalis, architect

This paper describes the basic principles of energy conscious **retrofitting** of two public housing units in the Municipality of Tavros on the outskirts of Athens, Greece. The project has been selected to be partly funded by the E.U. as part of the Program Thermie A.

It is composed of a combination of **renewable energy** and **energy conservation** systems including insulation, solar greenhouse and p.v. systems mostly integrated to the building envelope in an innovative way. The design process has been based on the principles of **participatory planning**, involving the users' views and following the recommendations of the E.U. Agenda 21 for sustainable development and carbon dioxide (CO_2) reduction.

It has a **high replication potential** because of the choice of building types which are representative of public housing all over Greece. Besides design and construction, the project includes a one to two year **monitoring period**, to record actual energy performance of the systems used.

REFURBISHMENT OF SCHOOL BUILDINGS USING TECHNIQUES FOR ENERGY CONSERVATION AND SOLAR ENERGY UTILISATION

K.Axarli[1], Th.Theodosiou[1], A.Papadopoulos[2], M. Papadopoulos[1], N.Tsakiris[1]

The age of the school building stock in Greece contributes to an increase energy consumption for heating and to a lower level of thermal comfort conditions inside the classrooms.

In the area of Thessaloniki, there are such aged school buildings for whom there is need for an extended energy refurbishment. The Laboratory of Building Construction and Building Physics of the Aristotle University of Thessaloniki has carried out a research program in order to analyze the energy performance of old school buildings and to propose technical solutions for their energy rehabillitation.

A school building built in the 70's was selected to be the case study for the research. In this building an extensive audit was performed. All the details concerning architectural structure, energy consumption and the installed heating system were recorded. Also some classrooms were monitored on an hourly basis during winter and summer period and measurements with infrared camera were taken. After the analysis of the collected data, specific refurbishment actions and various design options were discussed. The effects of these actions on the heating energy consumption were estimated through thermal simulations and finally the proposed interventions were technically evaluated.

[1] Kleo Axarli, Lecturer, Theodoros Theodosiou, Research Assistant, Michalis Papadopoulos, Professor, Nikos Tsakiris, Technical staff.
Laboratory of Building Construction and Building Physics, School Of Civil Engineering, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece. Tel. (+3031) 995777, 995616 - Fax: (+3031) 995603. e-mail: axarli@civil.auth.gr
[2] Agis Papadopoulos, Assistant Professor, Laboratory of Heat Transfer and Environmental Engineering, School of Mechanical Engineering, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece. Tel. (+3031) 996015 - Fax: (+3031) 996012, e-mail: agis@vergina.eng.auth.gr

THERMAL BEHAVIOR & OVERAL EVALUATION
OF APARTMENT BUILDINGS

C. A. Balaras, K. Droutsa, A. A. Argiriou

Group Energy Conservation, Institute of Meteorology and Physics of Atmospheric
Environment, National Observatory of Athens, P.O. Box 200 48, 118 10 Athens, Hellas
Tel. +301-3490154, Fax +301-3490113, email: costas@env.meteo.noa.gr

Considering the fact that operational costs of a building grow with time and that problems get worse unless some actions are taken, the necessity for maintening, refurbishing or upgrading actions becomes obvious. The overal evaluation of a building includes construction and functioning of the building, energy consumption and quality of indoor environment. The work was based on a European methodology (EPIQR) for the evaluation of the refurbisment / retrofit actions of residential buildings.

A total of 8 buildings have been audited, located at 3 major cities representative of the main Hellenic climatic zones. The buildings cover a representative range of typical constructions, size, conditions, and installed equipment. The audits included the building envelope, energy systems, some simple measurements (temperature, humidity, illuminance) with portable instruments and the indoor environmental conditions based on the occupants' answers to a questionnaire. The diagnosis of the overall constructional and functional condition of the audited buildings is average. The heating energy consumption ranges between 113-170 kWh/m^2 (north region), 64-73 kWh/m^2 (central region) and 40-80 kWh/m^2 (south region). Comparing the heating energy consumption with the average indoor temperature, reveals that high energy consumption does not always insure satisfactory indoor thermal conditions. According to the energy related calculations performed using the EPIQR software, there is a high potential for energy conservation in space heating and cooling, domestic hot water production and artificial lighting. The average indoor environmental quality of the residential buildings is average, since 45% of the occupants is satisfied and 44% are not satisfied.

EMBODIED ENERGY, A FACTOR OF ENERGY ORPTIMIZATION IN THE LIFE CYCLE OF BUILDINGS

D. BIKAS, S. MILONAS

LABORATORY OF BUILDING CONSTRUCTION AND PHYSICS

DEPARTMENT OF CIVIL ENGINEERING

ARISTOTLE UNIVERSITY OF THESSALONIKI, GR 540 06, GREECE

Buildings consume energy in their life cycle in direct and indirect ways. Direct energy consumption is understood as the heating and cooling operational energy of a building. Indirect energy consumption is generally understood in terms of "embodied energy" as the energy input in construction materials required by all the activities associated with a production process, including the relative proportions consumed in all construction activities. Integrated life cycle energy analysis should take into account the energy attributable to a building over its anticipated lifetime comprising optimal embodied energy and proving energy efficiency in building operation.

This paper examines the concept of embodied energy as a part of building materials and building elements and their composition into a building. Embodied energy analysis techniques are presented as well as the examination of their coefficients. The required data for embodied energy analysis is evaluated and classified in particular sets. Finally, a model based on life cycle embodied energy of the building shell is proposed as well as terms of application in typical buildings.

DYNAMIC AND STATIC BEHAVIOR OF AN OPAQUE WALL UNDER SOLAR RADIATION

P. Massouros, G. Athanassouli[*], G. Massouros

Department of Mechanical and Aeronautical Engineering

University of Patras

In this work, the dynamic behavior of an opaque wall under solar radiation is examined. By using an analytical method, the time delay of the phenomenon of the wall heating due the solar radiation absorption and the wall thermal restoration (i.e. cooling) after the interruption of solar radiation, were studied.

The transient phenomenon of the wall heating and the wall cooling describe the thermal inertial of the wall-room system, that acts as a thermal flywheel smoothing the thermal and temperature variations of the room-environment system.

The static behavior of the opaque wall i.e. his ability, been in thermal equilibrium, to attenuate the thermal and temperature variations, also was studied.

[*]Department of Physics

THERMAL BEHAVIOUR OF ISOLATED OFFICE SPACES DURING SUMMER PERIOD

Anna Kokkinaki – Daniil Civil Engineer PhD,
Lecturer, Aristotle University of Thessaloniki, Faculty of Civil Engineering,
Laboratory of Building Construction & Building Physics

Thermal behaviour of buildings during summer becomes more and more important these days, because of the conditions of structure and use of buildings. Due to this, the new German heat-insulation regulation (1995) contains requirements concerning summer thermal protection in non air-conditioned buildings.

Non air-conditioned office buildings with isolated spaces and big glass openings (windows) on their facades are a rather widespread -but interesting- case, which occurs in Greece. By means of thermal simulation methods and the Greek climate data fed into a computer processor, thermal behaviour of isolated spaces within non air-conditioned office buildings, specifically during the hottest summer season, is being tested below. The crucial thermal rates (temperatures) are calculated and the results of the influential factors are determined so that a comfortable inter-climate can be achieved within these isolated office spaces during the hottest periods of Greek climate.

ACTIVE SOLAR SYSTEMS

SOLAR WATER HEATERS WITH CURVED MIRRORS AND CYLINDRICAL STORAGE TANKS

M. Souliotis, Th. Nousia, Y. Tripanagnostopoulos,

Department of Physics, University of Patras, Patra 26500, Greece

Tel/Fax: +30 61 997446 / +30 61 997472 e-mail: msouliot@physics.upatras.gr

Solar water heaters for domestic use is widespread in many countries and most of these systems are of thermosiphonic type or Integrated Collector Storage Systems. The development of efficient ICS systems is mainly focused to the sufficient heat preservation by using selective absorbers, transparent insulating materials, double glazing, etc. In addition, most of the ICS units use cylindrical tanks and curved mirrors to collect more solar energy by the cylindrical absorber surfaces. In this paper we present two new ICS systems (DTS I and DTS II), which consist of two cylindrical tanks each one. These systems are based on the following design principles: (i) Use of two storage tanks for a better water temperature stratification, (ii) Achievement of thermal losses suppression by forming a hot air trap space between the inverted cylindrical absorber surfaces and the curved mirror, (iii) Effective use of the non uniform distribution of solar radiation on the absorber surfaces and (iv) Use of low cost materials. The two water tanks are connected with a pipe, with one tank (A1) operating as preheater and the other tank (A2) as main heater. The efficient operation of model DTS I is based on the higher water temperature increase during sunshine with significant water stratification from the top of A2 to the bottom of A1. Model DTS II is of less water temperature increase in both tanks, but tank A2 is an efficient heat storage and during draw off operation warm water from A1 enters in the tank A2. We used low cost materials for the construction of both ICS systems (polished stainless steel sheet for the mirrors and flat black painted absorbers), in order to achieve cost effective devices. Experimental results have shown that DTS I is more efficient during day compared to DTS II, but DTS II is more efficient in heat preservation during night. In addition, some improvements resulted to better performance for both ICS models.

SIDE BY SIDE COMPARISON OF TWO IDENTICAL SOLAR THERMOSIPHONS, WITH DIFFERENT CLOSED LOOP CIRCULATION.

Y. G. Caouris, N. Syrimbeis

Dept. of Mechanical Engineering & Aeronautics, University of Patras, 265 00 Patras, Greece.

Two identical Solar Thermosiphons (of the same type and same company), with different connection of the closed loop circuit, are tested under the same conditions. In the closed loop of the first thermosiphon (system No 1), the heat transfer fluid enters at the upper side of the mantle heat exchanger. In the second one (system No 2) it enters at the lower side of the mantle (as it is commercially available). The system No 2 appears to have lower performance in comparison with the system No 1. In addition, the final achieved temperatures of the system No 2 are lower than those of the system No 1. As much as higher is the daily Solar Radiation so the temperature differences are greater. As it is concluded, the choice of the entrance point to the lower side of the mantle results to a reduction of the output energy by an average amount of **10%**. In addition, the quality of the extracted energy is lower, because of the reduction of the final achieved temperatures by an average of **6,5 °C**.

Assessment of uncertainty in solar collector testing

E. Mathioulakis, K. Voropoulos and V. Belessiotis

Solar & other Energy Systems Laboratory - NCSR «Demokritos»

15310 Ag. Paraskevi - Greece

Tel.: ++301 5614592   Fax: ++01 5614592   E-mail: sollab@mail.demokritos.gr

The basic scope of solar collector testing is the determination of the collector efficiency by conducting measurements under specific conditions defined by international Standards. The experimental results of testing lead to determination of the parameters of a more or less complex model, usually a 2 or 3-parameter single node steady state model, which describes the collector behavior.

In the present study, a systematic analysis of the contribution of all the uncertainty components on the basis of the ISO 9806-1 test procedure is carried out in order to determine the final uncertainty in the characteristic equation parameters and the instantaneous efficiency of the collector.

A step-by-step methodology, based on specific statistical tools, for evaluation of the suitability of the collector models already in use, is proposed. This methodology allows not only evaluation of the reliability of the testing procedure itself, but also quantification of the goodness of fit.

Furthermore, if the uncertainty in the characteristic equation parameters is known, the uncertainty in the collector instantaneous efficiency to be predicted can be assessed. This is essential for the reliability of results of design tools, to which collector efficiency is a key parameter.

ANALYSIS OF SOLAR ENERGY HEATED AQUACULTURE UNITS

John Gelegenis[1] and Nicholas Koumoutsos[2]
[1]New Energy Techniques
[2]Professor Emeritus, National Tecnical University of Athens

The performance of solar energy heated aquaculture units is investigated. Storativity of the tanks and flexibility in pertinent with their temperature (as it is allowed by the biological characteristics of the cultivated species) are simultaneously taken into consideration for the evaluation of the system.

The possibility of applying available design methods (f chart, method Φ, and method Φf) is scrutinized and the appropriate introduction of the system parameters is further examined to this end. In the frame of a case study, estimations of the design methods are compared to analytical results arisen by simulation.

DYNAMIC METHOD FOR SOLAR DOMESTIC HOT WATER SYSTEMS TESTING

E. Mathioulakis, K. Voropoulos, V. Belessiotis

NSCR «Demokritos» - Solar and other Energy Systems Laboratory

15310 Agia Paraskevi Attikis

A new method for testing solar domestic hot water systems has been developed recently, the «dynamic method». The scope of this paper is to report on the results of the first systematic investigation of the dynamic method derived by testing in several types of systems according to ISO 9459-5 (DST) and the known ISO 9459-5, in the framework of a European Project which is still running. The predicted annual energy output of the systems was chosen to be the quantity for the comparison between the two methods. The results of the comparison are given and the problems presented by the use of the dynamic method are reported. Moreover, a discussion and proposals for the improvement of testing procedures and also proposals concerning the reliability of the method are given.

Through testing in the selected systems and the comparison between the two methods, several problems associated with the testing procedures and the elaboration of the experimental data have been found. The former concern mainly the testing conditions, which do not cover the whole range of operation of the system, leading to possible wrong results for its behavior. The latter are focused on the existing lack of enough documentation and the problem that no changes can be done in the software for data elaboration.

The main conclusion is that the dynamic method can become an interesting method for testing solar domestic hot water systems, due to its nature. But it is a fact that a number of important alterations and improvements are needed to be done, general or more specified, so that it can be able to characterize by a reliable way the behavior of solar systems.

PERFORMANCE CHARACTERISTICS OF ACTIVE SOLAR HEATING SYSTEM IN SPORTS CENTRE IN THESSALONIKI, GREECE

George Tsilingiridis, Panagiotis Pistikopoulos, Konstantinos Pattas

Laboratory of Applied Thermodynamics, Department of Mechanical Engineering

Aristotle University of Thessaloniki, 540 06 Thessaloniki, Greece

Tel: (031) 996084, fax: (031) 996019, e-mail: tsil@vergina.eng.auth.gr

The Solar Indoor Sports Centre (SISC), which was constructed during period 1987-91, is a demonstration project in Thessaloniki (north Greece, 40° N. Lat). SISC is a general-purpose indoor and outdoor sports centre designed to cover a variety of sports activities, as well social and cultural events for the local community. General objective of SISC design and construction was the exploitation of solar energy for the space heating of the building substituting all necessary conventional thermal energy. The applied systems include passive and active solar systems, which were designed and used for space heating as well for general-purpose hot water supply.

Space heating and hot water are supplied from a water storage tank, which is heated by a 588m² array of flat plate solar collectors mounted on the roof of the main Sports Hall. The heat store is an well-insulated concrete tank of 210m³, located in the basement of the building, where all the mechanical installation for heating and ventilation are located. The stored water is used for the heating system, for preheating the fresh air, inducted by the ventilation system and for heating the water for showers.

In this paper, elaborated data of active solar system performance are presented and a preliminary evaluation of active solar system is curried out.

ELECTRIC POWER GENERATION THROUGH SOLAR THERMAL SYSTEMS – THE 'THESEUS' PROJECT

Efrossini Kotsaki

Energy Policy and Planning Division

C.R.E.S. - Center for Renewable Energy Sources

19th km. Marathonos Ave., 190 09 Pikermi, Greece

Tel: 6039900, Fax: 6039904-5, email: kotsaki@cres.gr

Within the framework of the THESEUS project (1997-1998), under the E.C. DG XVII THERMIE Programme, the final design for a 50 MWe solar thermal power plant in Frangokastello, Crete, has been carried out. The scope of this project was the design of the parabolic through solar field and the power plant, the investigation of the legal framework as well as the determination of the economic parameters and the ownership status of the project.

In the present article, the current status of the main solar thermal power technologies is outlined. A general description of the THESEUS project is given. Furthermore, the operational design of the solar field (296.480 m^2) and the conventional Rankine steam cycle, as well as the overall plant performance indicators are provided. Finally, the benefits of the operation of such plants are discussed. These mainly concern the good match between the solar electricity production and the mid-day summer demand, the avoidance of conventional fuels imports and the CO_2 emissions reduction.

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SOLAR COLLECTORS WITH COLORED ABSORBERS

Y. Tripanagnostopoulos

Department of Physics, University of Patras, Patra 26500, Greece

Flat plate solar collectors with colored absorber are proposed for aesthetically sensitive solar thermal applications in buildings, as alternative to the monotony of collectors with black absorber. Experimental results from constructed and tested solar collectors, with or without glazing, and of black, blue and red brown absorber are presented and discussed. The lower efficiency of unglazed and colored solar collectors, compared to corresponding collectors with black absorber and glazing, can be partially overcome by using booster reflectors. Test results, showed that booster reflectors can increase the thermal energy output of unglazed and colored collectors, improving sufficiently their performance.

CONSTRUCTION OF A SOLAR COLLECTOR, USING RECYCLABLE AND CHEAP MATERIALS – DEFINITION OF PERFORMANCE

Y. G. Caouris, S. Pnevmatikakis

Dept. of Mechanical Engineering & Aeronautics, University of Patras, 265 00 Patras, Greece.

The purpose of this work is to supply technical advises and necessary details for the construction of a domestic solar collector, using recyclable (common glass bottles) and cheap material.

The process of construction is developed and the collector is tested according to the Hellenic Standard ELOT 388-1. The obtained diagrams are presented, from which it is concluded that the specific construction represents a worthy proposal, applicable by a wide range of people. Furthermore, if it were combined with a storage tank, would result to a cheap and efficient solution for domestic hot water production.

APPLICATION OF TAGUCHI METHODS IN QUALITY CONTROL OF FLAT PLATE SOLAR COLLECTOR

F. Batzias

Department of Industrial Management, University of Piraeus

80, Karaoli and Dimitriou str., 18534 Piraeus

Tel. 4142000, Fax. 4179064, e-mail fbatzi@unipi.gr

This work deals with the application of experimental design in quality control of flat plate solar collector. The specific algorithms used follow a certain simple version of the Taguchi methods. The control factors we introduced into a very simple orthogonal array with estimated values of the dependent variable (total thermal energy recovery over the life cycle of the solar collector) but without 'noise' were thickness of cover, distance between cover and absorption surface, material of absorber plate, material of encloser, material of back and side insulation, thickness of back and side insulation. After presenting the straightforward algorithm of (i) locating the control factors with the strongest effect on the dependent variable and (ii) estimating the expected target-value of total thermal energy recovery, we extended the control factors to include geometry of collector, number of covers and differentiation of back and side insulation as regards material and thickness. Subsequently, we introduced this enriched set of control variables into a new orthogonal array where we put also four noise factors produced via combination of two groups of workers (with their equipment) with two material providers. The performance of the algorithmic procedure showed that we can obtain valuable results and save time and effort on trying to optimize the quality paramaters of the flat plate solar collector.

AUTONOMOUS PHOTOVOLTAIC PLANTS FOR REMOTE ISLANDS. DESIGN PROPOSALS AND OPERATIONAL STUDY

Kaldellis J.K., Sotiraki K.

Lab of Soft Energy Applications & Environmental Protection

Mechanical Eng. Dept., TEI Piraeus,

e-mail: sealab@gdias.teipir.gr

Pontou 58, Hellinico 16777, Greece

The majority of small and medium size Greek islands use internal combustion engines to fulfil their local demands for electricity. These engines use expensive imported oil, therefore the electricity production cost of the existing autonomous power stations (APS) is extremely high. Consequently, the development of an autonomous photovoltaic (PV) power plant is examined, in order not only to face up to this problem but also to take advantage of the excellent solar potential of the Greek islands.

More precisely, the optimum size of the proposed photovoltaic station is defined first of all, taking also into account the possibility that any surplus of energy can be used for a corresponding desalination plant. Subsequently, the operational behaviour of the PV station is analyzed on an energy production-demand base. The present work is integrated with an interesting feasibility study. According to the preliminary techno-economical results the electricity production cost by the proposed PV power plant is significantly lower than that of the existing APS of Greek PPC.

STUDY AND APPLICATIONS OF HYBRID PV – THERMAL SYSTEMS

Th. Nousia, M. Souliotis and Y. Tripanagnostopoulos
Physics Department, University of Patras, Patra 26500
Tel / Fax : 061 997472, e-mail:tnousia@physics.upatras.gr

Buildings have needs in electricity as well as in thermal energy. Hybrid photovoltaic – thermal collectors can partially cover these requirements, by their integration on building roofs and facades. These systems convert solar radiation into electricity and thermal energy. We give experimental results of their electrical and thermal performance under steady state conditions, in different operating temperatures. We used an additional booster mirror in order to increase the electrical and thermal energy output of hybrid systems and we present results from this combination. We also propose combinations of PV – thermal systems with other types of solar thermal devices.

EFFICIENCY OPTIMIZATION OF SENSITIZED SOLAR CELLS: DEVELOPMENT OF FRACTAL TITANIUM OXIDE THIN FILMS

P. Falaras, A.P. Xagas

Institute of Physical Chemistry, NCSR "Demokritos", 153 10 Aghia Paraskevi, Hellas

N. Spyrellis, Z. Loizos

NTU, Chemical Engineering Department, Heroon Polytechniou 9, 157 80 Athens, Hellas

The photosensitization of wide band gap semiconductors (mainly TiO_2) with organic and inorganic dye molecules is being intensively investigated as a novel efficient and economic technique for direct solar to electrical energy conversion.

Central role to the whole process plays a TiO_2 thin film electrode. The texture and surface morphology of the semiconductor film are the most important factors that govern the cell efficiency. A net improvement of the overall conversion yield can be achieved by an increase of the real surface area of the TiO_2 film. With this clear objective in mind, a series of nanocrystalline TiO_2 thin films ($\sim$10μm) has been elaborated applying a sol-gel technique and characterized by atomic force microscopy (AFM). The examination revealed that the films present complex morphology, possessing a large number of surface features and moreover displaying fractal behavior. Their surface complexity was characterized by the fractal dimension D_f and reached a value of 2.36.

The fractal dimension parameter is an excellent tool for characterizing the surface complexity and estimating the film surface area. Since the resulting photocurrent is proportional to the effective surface area, we come to the conclusion that the photocurrent directly depends on the fractal dimension. This conclusion points to a new photoelectrochemical method for the calculation of the fractal dimension of a semiconducting film.

A further improvement of this parameter can be achieved via the development of rougher and more complex film surfaces. For that reason, a more efficient control of the hydrolysis and condensation steps of the sol-gel process is required.

OPTIMUM LOADS MATCHING IN DIRECT-COUPLED TO PHOTOVOLTAIC GENERATOR

A. Balouktsis, D. Themelis, Ch. Pallas, S. Tsakouridis & B. Ourdoudi

Department of Mechanical Engineering, Technological Educational Institution of Serres,

Terma Magnesias, 62123 Serres

In many stand-alone photovoltaic (PV) systems, the solar modules array is designed to power a specific single loads, such as lights (resistive loads), electromechanical loads that coupling with dc motors, water electrolyzer etc. Two-different PV system-load configurations are currently in use. The one is the directed-coupled systems that are simple and reliable, but do not operate at the maximum power operating point of the array, due to the continues variation of solar radiation. The other one uses a maximum power point tracker (MPPT) to maintain the PV array at a voltage for which it produces its maximum power and this is the most efficient configuration but less reliable in more cases. In any case an optimum matched system would lead to better utilization of the system and a reduction of the rating of the subsystems.

The formation of a study method of the load matching quality and the PV generator optimum design for direct-coupled systems are the subject of this investigation. The optimum design of the system based on the maximization of the matching factor that is defined by the ratio of the load input energy to the PV array maximum allowable energy over a time period. The advantage of the method lies in the fact that take account of the variation of solar radiation in a long time period and not only in one day as previous researchers have done.

The method applied to resistive loads using the program *Mathematica* and arithmetic analysis techniques. In order to generalize the results a per unit system based on the array maxim power point parameters is adopted. Results show that the theoretical optimum matching factor for an ohmic load is ~85% if it take account of the variation of solar radiation in one day and it's a function of clearness index if it take account of the variation of solar radiation in a long time period and any case less from 85%.

The Economics of PV Grid-Connected Residential Households

A. A. Lazou and **A. D. Papatsoris** University of York, Department of Electronics, Heslington, York YO10 5DD, United Kingdom. Email: adp@ohm.york.ac.uk

The cost-effective sizing and evaluation of residential grid-connected photovoltaic systems at various European locations is the subject of this paper. The grid-connected photovoltaic system is serving the energy needs of a medium-sized household inhabited by a typical four member family. A typical energy consumption daily profile is assumed, and the solar savings (SS) are estimated as a function of solar collector area and starting year of operation at each location. The calculations have been done assuming economic parameters and PV technology costs applicable to years 1998 and 2008.

The Economic Analysis of Stand-Alone Residential Photovoltaic Systems

A A Lazou and A D Papatsoris, Department of Electronics, University of York, Heslington, York YO10 5DD, United Kingdom. Email: adp@ohm.york.ac.uk

The cost-effective sizing and evaluation of residential stand-alone photovoltaic systems at various European and Mediterranean locations is the subject of this paper. The stand-alone photovoltaic system is serving the energy needs of a medium-sized household inhabited by a typical four member family. A typical energy consumption daily profile is assumed, and the solar array, battery and back-up generator -if necessary- are optimally sized to minimise the system life-cycle cost (LCC). The calculations have been done assuming economic parameters and PV technology costs applicable to years 1998 and 2005.

PHOTOVOLTAICS IN BUILDINGS

I.Charis

A. Charis and Partners, 2 Neofronos str. 161 21 Athens

Buildings play a fundamental role within the world energy balance. Photovoltaics have already demonstrated its efficient characteristics in electric installations. Building Integrated Photovoltaics can be a technology interesting for utilities with multiple advantages. PV can be an integral part of the building as a façade element, shading device, roofing material, etc. As it is shown this technology is already an option with numerous successful examples. In order for the market to be enhanced and make a difference in a global perspective further advancements need to be done regarding cost, quality and education.

WIND ENERGY

A 250 kW WINDTURBINE WITHOUT INPUT SHAFT

K.N. Pattas, E. Stapountzis, A. Michailidis, G. Tsilingiridis

Department of Mechanical Engineering, Aristotle University of Thessaloniki
540 06 Thessaloniki, Greece

A novel design horizontal axis 250 kW wind turbine, with three constant pitch rotorblades is presented. The power transmission system from the rotor to the generator consists of two independent gearboxes linked with a universal joint driveshaft. The first gearbox is planetary and its special characteristic is that it is assembled inside a slewing bearing with internal gear. The rotorblades' hub is directly mounted onto the inner ring of the bearing. Thus, the input shaft including its bearings can be eliminated. The achieved transmission ratio allows input torque reduction approximately equal to ten. Thus the second gearbox can be selected with a constant or mechanical variable transmission ratio, according to the wind capacity of the installation position, so that the accumulated energy can be optimised.

WIND FARM EVALUATION IN AREAS OF COMPLEX TERRAIN.

D. Kanellopoulos, G. Kapsalis. K. Kyriakopoulos, E. Manda

Public Power Corporation

Directorate of Alternative Energy Forms

10 Navarinou St. GR- 106 80, Athens, Greece

Areas of complex terrain are characterized by large variations of wind speeds. This natural phenomenon diversifies the energy output from wind turbines installed in such areas.

This work investigates the approach in evaluating wind farm performance when located in a complex topography. For this purpose the wind farm in Kalivari, Andros was used where seven wind turbines are located in a single row of 500 m in length. The machines are Vestas V27-225kW with a tower of 30.5 m and a diameter of 27 m.

Data such as active power, wind speed from the nacelle, and wind speed and direction from an independent meteorological tower(30.5 m AGL) were evaluated.

Statistical models were used in the analysis of this experimental data in order to investigate the correlation among the various parameters. The variation of wind potential between wind turbines was deduced from measurements. A high positive correlation was observed among the locations of the machines. In most of the cases this exceeded 0.9.

EXPERIENCE WITH THE OPERATION OF R.E.S. SYSTEMS
IN GREECE

G.Betzios Dipl.Mech.Ing. – Dipl.Econ.Ing.
PPC/DPN Sigrou 112 11741 Athens
Tel. 9249451, Fax 9242977, e-mail: gbetj@tee.gr

PPC is the first European electricity utility, which following the 70's oil crises begun its activities successfully in Renewable Energy Sources (RES) exploitation in Greece. The first RES pilot and demonstration projects were installed in the early 80's, such as the Photovoltaic Station and the Wind Park in Kythnos, the Ag. Roumeli Photovoltaic Station etc., to be followed in the coming years by more projects, both in the photovoltaic and wind energy sectors.

By 1992, PPC had installed windturbines (W/T) of 25 MW total installed capacity. A number of problems and faults which developed in the W/T equipment resulted in the majority of W/T's ceasing operation for large periods of time, leading to all the undesired consequences this development could have had for the future of RES in Greece.

The experience and knowledge acquired from tackling these problems, from the operation of W/T's and the cooperation problems with the Autonomous Production Stations, are invaluable and should be utilized towards exploiting RES in Greece.

POTENTIAL AND PERSPECTIVES FOR R.E.S. EXPLOITATION IN AUTONOMOUS GRIDS

G.Betzios Dipl.Mech.Ing. – Dipl.Econ.Ing.
PPC/DPN 11741, Sigrou 112 Athens
Tel. 9249451, Fax 9242977, e-mail: gbetj@tee.gr

The excellent wind potential in the Aegean islands coupled with the high cost of the electricity generated by PPC's oil-fired Autonomous Power Stations in these islands, favour if not dictate the exploitation of Renewable Energy Sources (RES) for electricity production in these islands.

On the other hand, however, the stochastic intermittent character of RES in general and of Wind Energy in particular, in conjunction with the islands' large load variations, on a 24 hour as well as on a yearly basis and the power stations' diesel engines' minimum technical operating limits, restrict presently, to a high extent, RES penetration in the autonomous islands grids, to figures of the order of 10%.

In order to tackle permanently and effectively this deadlock, viable solutions have been sought and studied, based on the development and implementation of appropriate in each case hybrid systems combining RES and traditional oil-fired stations.

The first intelligent-hybrid system of this type has already been installed in Kythnos in 1998 and it is expected to begin operating in 1999. RES penetration with this system, which utilizes special batteries for short term energy storage (a few minutes), is expected to exceed 50%.

Second generation hybrid systems are at the design and study phase. It is anticipated that these systems will match wind energy to demand, to approximately 80% penetration level, using two reservoirs for intermediate energy storage. The two reservoirs located at different altitude, will comprise a reversible hydroelectric station, where at low demand periods water will be pumped up and during load peak periods electricity will be produced from the hydroelectric plant.

ENERGY EFFICIENCY OPTIMISATION BY PARALLELING INVERTER MODULES

G. Sergiadis

ILPRA sa

Industrial area of Thermi, PO Box 355, 57001 Thermi, Greece

Renewable energy installations, mostly solar, require high efficiency systems to deliver ac power to the utilities, from accumulated energy in batteries. Recently, bigger installations in hotel resorts, or monasteries where the power demand varies heavily within the day, showed that usual dc/ac inverter systems offer a poor total energy efficiency.

The reason is attributed to the fact that the dispersion in the power demand is high and that the duration of the low demand period is very important, compared to the duration of the high demand period.

Given that the inverter is required to provide power for the highest possible load, the inevitable inherent losses to the conversion process within the inverter, which are partly independent from the load, though low compared to the nominal load, are very important compared to the long term low power demand.

The intelligent paralleling of inverter modules seems to be the only feasible technical solution to overcome this problem. This work proposes an optimum inverter module size, both to keep the total losses low and to provide ample load demand margin.

It is shown that in a typical installation in a Holly Mount Athos Monastery, the total power efficiency may rise to more than 85 % adopting this technique, compared to a maximum 60 % in the single inverter system.

APPRAISAL OF THE RETURN ON INVESTMENT
IN THE CONSTRUCTION OF WIND PARKS

A. Kravaritis* and N. Stavridis**

*Assistant General Manager for Development

**Director of Alternative Energy Forms

Public Power Corporation

PPC's long experience of investing in the development of Wind Energy applications is presented in this paper. The report gives a comprehensive account and evaluation of the activities involved from start to finish. Furthermore, it describes the framework (legal, fiscal, environmental, administrative etc) within which this development takes place. Preliminary steps, data collection and evaluation, site selection criteria, limitations imposed and generally all factors influencing the implementation process, are described in detail. The appraisal of investments in wind energy applications, is completed by the detailed examination of two of PPC's Wind Parks and the conclusions drawn are presented therein.

GEOTHERMAL ENERGY

INHIBITION OF CaCO3 SCALE FORMATION -
A LABORATORY INVESTIGATION

N. Andritsos[1], A.J. Karabelas[1], G. Chitanu[2] & A. Carpov[2]

1 CPERI & Dept. of Chemical Eng., AUTh, P.O. Box 1517, GR 540 06 Thessaloniki, Greece

2 Macromolecular Chemistry Institute, 41 G. Ghica Voda St., 6600 Iassy, Romania

There are several methods to eliminate or suppress the formation of scale in geothermal systems. One of the most common techniques involves the use of chemical additives, which are usually moderately large molecules that are readily adsorbed on the growth-active sites of the crystal surfaces, thus retarding nucleation and crystal growth and distorting the crystal structure of the scale Crystal growth inhibition is considered the most efficient method of controlling carbonate scale formation in geothermal installations. It is well known that for these scales there are numerous inhibitors in the market, employed with various degrees of success. The objective of the present work is to assess the capability of several chemical additives to prevent or to reduce the formation of calcium carbonate scales.

The experiments were carried out under conditions partially resembling the sudden supersaturation (with respect to $CaCO_3$) of geothermal fluids caused by the flushing of CO_2-rich gas phase at low pressures. Three of the additives tested were maleic anhydride copolymers, synthesised in the Macromolecular Chemistry Institute (Iassy), while the fourth was a commercial inhibitor. The experimental results demonstrated that for intermediate $CaCO_3$ supersaturation ratios, almost complete scale inhibition was possible with all additives. At higher supersaturation ratios, the deposition rate seemed to be unaffected by the introduction of these inhibitors, despite the fact that bulk precipitation suppression was obtained. However, crystal distortion was observed, resulting in weakly cohesive deposits, which could facilitate their removal by the fluid flow.

INHIBITION OF CARBON STEEL CORROSION IN A GEOTHERMAL FIELD

P. Klepetsanis[1,2], N. Harmandas[1,3], I. Ignatiadis[4] & P. Koutsoukos[1,3]

1. FORTH / ICEHT, P.O.BOX. 1414, 26500 PATRAS

2. Dept. of Pharmacy, University of Patras, 26500 PATRAS

3. Dept. of Chemical Engineering, University of Patras, 26500 PATRAS

4. Department of Geotechnical Engineering and Mineral Technology, BRGM, Avenue de Concyr BP 6009, 45060 ORLEANS, FRANCE

The effectiveness of maleic acid copolymers and commercial products as corrosion inhibitors of carbon steel were examined in geothermal field at Melun l' Almont in south of Paris. The examination was done using a sequence of DC and AC electrochemical techniques. This sequence of electrochemical techniques is used for the rapid evaluation of various compounds as corrosion inhibitors for a given metallic material in a given environment. The concentration of tested additives was 10 ppm and the temperature of geothermal fluid was 72°C.

The commercial products Solamine 129 and Aquaprox MMC 7300 showed the best performance as corrosion inhibitors. The commercial products Mexel 432 and Busperse showed a small effect on carbon steel corrosion at the same conditions. Their action is difficult to interpret because their exact compositions are commercial secrets. The copolymers of maleic acid did not affect the corrosion process of carbon steel. This effect is probably due to negligible adsorption of maleic copolymer molecules on carbon steel surface.

GEOTHERMAL ENERGY DEVELOPMENTS IN THE PREFECTURE OF SERRES

G. Karydakis[1], N. Andritsos[2] and M. Fytikas[3]

[1]IGME, Dept. of Geothermal Energy, Mesogeion 70, GR 115 27, Athens

[2] CPERI & Dept. Chemical Engineering, AUTh, P.O Box 1517, GR 54006, Thessaloniki

[3]Dept. of Geology, AUTh, GR 54006, Thessaloniki

The work deals with the developments of geothermal exploration and utilisation in the prefecture of Serres, in Central Macedonia. During the past 5 years, 18 new productive wells were drilled in the Strymon basin, and more specifically, 9 in the geothermal field of Nigrita, 6 in the Angistro field and 3 in the Sidirokastro field, further extending the areas of the known reservoirs. The physicochemical characteristics of waters from several new wells are reported and an assessment is given on the scaling and corrosion tendency of the geothermal fluids. Despite the significant progress made in the geothermal exploration, the growth of uses in the prefecture was slow. The total area of "geothermal" greenhouses is 9.5 ha (up from 7.8 ha in 1994), while and area of 3 ha with subsurface heating for asparagus cultivation was put in operation last year.

EVALUATION OF THE POTENTIAL OF THE GEOTHERMAL FIELD OF N. KESSANI IN THE PREFECTURE OF XANTHI IN GREECE.

A. Bekas & Z. Agioutantis

Department of Mineral Resources Engineering, Technical University of Crete
73100 Hania, Greece

The geothermal reservoir at the N. Kessani area in the Xanthi Prefecture (Greece) is described using appropriate diagrams and charts based on the results of the drilling program in the area. These diagrams include curves of equal temperature drawn for four different elevations below the surface topography, curves of equal geothermal gradient and curves of heat flow. Thus, the distribution of the energy potential with depth can be estimated and the corresponding heat source and heat transfer systems may be identified. Also, a rough estimate of the geometric volume of the reservoir is presented as well as an estimate of the total energy stored and the energy that can be utilized through pumping of the geothermal fluids. Finally, the total power supply of a number of drill holes that can be utilized as production wells is calculated.

COVERAGE OF A DISTRICT HEATING SYSTEM NEEDS BY USING GEOTHERMAL ENERGY

John Gelegenis[1] and Nicholas Koumoutsos[2]
[1]New Energy Techniques
[2]Professor Emeritus, National Technical University of Athens

The use of geothermal energy for district heating is investigated and evaluated through the use of two principal factors, the coverage ratio and the load factor.

A heat exchanger scheme is considered (indirect use) combined with conventional radiators, as this case seems to be especially important for Greece. Primary attributes of the geothermal system are its quality (temperature of the fluids) and its available quantity (flow-rate), which are conveniently expressed in a dimensionless form.

A simplified algorithm is developed for the estimation of the coverage and load factor of the above system. Processing of detailed temperature data is no more required, as the heating degree-days are only needed, which can be estimated from the monthly average temperatures. The algorithm is next demonstrated in three examples, the last of which deals with a geothermal field to the North of the Country.

A FEASIBILITY STUDY FOR A DISTRICT HEATING APPLICATION UTILIZING THE GEOTHERMAL FIELD OF N. KESSANI IN THE PREFECTURE OF XANTHI IN GREECE.

Z. Agioutantis & A. Bekas

Department of Mineral Resources Engineering, Technical University of Crete

73100 Hania, Greece

The geothermal potential of the N. Kessani field in the Xanthi Prefecture (Greece) can be used for developing a district heating system to heat neighboring villages. This paper presents a feasibility study for such a project based on geothermal, climatic, and topographic data. Geothermal data available for the area enable thermal power estimations and the designation of a number of boreholes as production boreholes. The thermal demand for an average house in the study area is calculated based on actual climatic data for a ten year period. The design of the network allows for distribution pumps, heat exchangers, a backup heating system, pumping and re-injection of geothermal fluid as well as heat losses in the pipelines. Design data are given for both the primary and secondary distribution networks (pipelines). Additionally the projected annual energy production, the decrease of CO_2 emissions, as well as economic indices comparing the geothermal district heating system to a conventional heating system are calculated and presented.

UTILISATION OF GEOTHERMAL ENERGY IN GREECE:
PRESENT STATE, TECHNICAL PROBLEMS AND PROSPECTS

N. Andritsos[1], A.J. Karabelas[1] and M. Fytikas[2]

[1] *CPERI & Dept. Chemical Engineering, AUTh, P.O Box 1517, GR 54006, Thessaloniki*

[2] *Dept. of Geology, AUTh, GR 54006, Thessaloniki*

Greece holds a prominent place in Europe regarding the existence of promising geothermal resources, which can be economically exploited. Geothermal fields producing fluids which can be used for the production of electricity (T>150°C) are limited along the active volcanic arc in the South Aegean Sea, but no activities are reported during the past 5 years in this area. Regarding low enthalpy areas significant progress in the geothermal exploration has been made, by extending already known areas and identifying new ones.

The main use of geothermal energy in Greece, apart of the use of geothermal water in balneology, is the heating of greenhouses in Macedonia, Thrace and some islands. There are about 18 ha of active geothermal greenhouses (up from 16 ha in 1995), but the main development during the past 3 years is the subsurface heating of 11.5-ha fields with asparagus cultivation using geothermal water. The installed capacity of the geothermal greenhouses is about 20 MW_t and the oil savings for the cultivating period 1998-99 are estimated to be 4400 toe. The first large-scale space heating project has just been completed in the Spa of Trayanoupolis, in Thrace. The use of geothermal heat pumps, despite their widespread potential, is limited to three installations.

Despite the limited growth and utilisation of geothermal energy in Greece, it is believed that with the proven technology and the abundance of low-enthalpy resources in Greece the geothermal energy can play a more active role in the future.

INHIBITION OF IRON(II) SULFIDE PRECIPITATION IN A
GEOTHERMAL FIELD

N. Harmandas,[1,2] P. Klepetsanis,[1,3] I. Ignatiadis,[4] P. Koutsoukos[1,2]

1. *FORTH / ICEHT, P.O. BOX. 1414, 26500 PATRAS*
2. *Patras University, Dept. of Chemical Engineering, 26500 PATRAS*
3. *Patras University, Dept. of Pharmacy, 26500 PATRAS*
4. *BRGM, Avenue de Concyr BP 6009, 45060 Orléans, Cedex France*

Three polyelectrolytes, one organophosphorous compound and two commercially available additives were tested regarding their ability to inhibit iron (II) sulfide precipitation in simulated geothermal fluids and in a geothermal brine. Most of the additives tested proved to efficiently retard iron pyrite precipitation in the laboratory experiments. On the contrary, only one of them gave positive results regarding the inhibition of mackinawite precipitation in the geothermal field experiments. The interpretation of the results obtained was based on theoretical calculations using molecular simulations in conjunction with models explaining adsorption of the additive molecules on growing crystal surfaces. The effectiveness of the organophosphorous additive was attributed to strong electrostatic interactions between the crystal surface and the additive molecule combined with matching of interatomic distances between ions on the crystal, and charged groups of the additive molecule. It was also concluded that the effectiveness exhibited by the polyelectrolyte additives was rather due to sequestration of Fe^{2+} ions, which caused reduction of the solution supersaturation, than poisoning of the active growth sites on the crystal surface. No conclusions could be drawn explaining the effectiveness or ineffectiveness of the commercial products, since their exact composition is covered by patents.

OPTIMUM ENERGY MANAGEMENT OF ANAEROBIC WASTEWATER TREATMENT PLANTS, USING LOW ENTHALPY GEOTHERMAL FLUIDS

Sigalas J., Kaldellis J.K.

Lab of Soft Energy Applications & Environmental Protection

Mechanical Eng. Dept., TEI Piraeus,

e-mail: sealab@gdias.teipir.gr

Pontou 58, Hellinico 16777, Greece

In the present work a complete model of the heat flux exploitation of the several existing geothermal fields of low enthalpy in Greece is developed. The model takes also into account the energy requirements of anaerobic wastewater treatment plants for municipal sludge.

The basic idea investigated here is the usage of low quality (low exergy) geothermal energy to fulfil the energy needs of the wastewater treatment installation (bioreactor), instead of the consumption of the biogas produced. According to this strategy the high exergy biogas can be utilized in high temperature energy applications, increasing the economic benefits of the plant. The present analysis is completed by carrying out a techno-economic evaluation study of the proposed solution for selected cases in Greece.

HYDRODYNAMIC BEHAVIOR OF A HOT LEAKY AQUIFER UNDER PUMPING SITUATION AT THE GEOTHERMAL FIELD "AGISTRO" OF THE SERRES AREA .

I. DIAMANTIS * , Gr. KARIDAKIS ** & Ar. SARANTEAS **

*Assoc. Prof. , Department of Civil Engineers ,
University of Thrace, 67100, Xanthi*

*** Department of Geothermal Energy,
Institute of Geology and Mineral Exploration, Mesogion 70, 11527, Athens.*

The thermal springs of the Agistro area as the superficial expression of the homonymous geothermal field, spouting at the northern border of the Agistro mountain (Serres area) and are exploited for therapeutical uses.

In this paper is examined the behavior of the aquifer system in a dynamic situation, such as the pumping of a well that is situated in a small distance southern of the springs.

From the pumping data we have as a result the stabilization of the water level at the first minutes of the hour. In the same time we have the decrease in the temperature of the pumping water and an increasing in the temperature of the springs. This lead as to assume the existence of a vertical supply from the overlying cold aquifer, using the Hantush's relation concerning leaky aquifers.

BIOMASS

BIOMASS PRODUCTION FROM *EUCALYPTUS* SPECIES AND PROVENANCES IN THRACE

K.P. Panetsos, Professor of Aristotle University of Thessaloniki

Department of forestry and natural environment, Aristotle University of Thessaloniki, Greece

Since the oil crisis during 1970's, much research has been focused on the utilization of biomass as an alternative source of energy, able to substitute fossil fuels and at the same time to be friendly to the environment.

A source of biomass production is the establishment of plantations, with fast growing forest species in short rotation. Species of the genus *Eucalyptus* have been used successfully in such biomass plantations in various countries of the world and in Greece. The success of a plantation depends not only upon the choice of the proper species, but also of the best adapted and productive provenance of each species for a given site.

In north Greece it was determined that the most important limiting factor for *Eucalyptus* cultivation is the low freezing temperatures. Three species: *E. bicostata, E. viminalis* and *E. dalrympleana*, proved to be able to combine tolerance to cold and biomass production. These three species, represented by a number of provenances and open pollinated families were used to establish a comparative plantation in the spring of 1995, near the village Magana of Xanthi prefecture in Thrace. Four growth periods later, it was found out that *E. dalrympleana* and *E.viminalis* are the best performing species in the plantation. It was also recorded significant variation within each species, a fact that favours the application of selection programme.

CATALYTIC PYROLYSIS OF BIOMASS FOR IMPROVED LIQUID FUEL QUALITY

M. C. Samolada, A. Papafotika, D. Patiaka and I. A. Vasalos

Chemical Process Engineering Institute (CPERI), P.O. Box 361, 570 01 Thermi, Thessaloniki, Tel: 498146, fax: 498180

Biomass pyrolysis liquids are generally characterized by a high water content and a low stability even under mild heating conditions. Their instability was primarily attributed to the existence of unsaturated oxygenated substances, especially carbonyls and acids. Commercial catalysts were evaluated based on their ability to improve the liquid product quality. The primary evaluation criteria were: (a) to maintain the high liquid yields (b) to decrease the amount of carbonylic compounds and (c) to minimize water production. The latter is generally a difficult goal to be realized, because most catalytic reactions produce water and coke, thus decreasing the amount of the liquid organic product. Catalysts evaluation was performed in a laboratory scale fixed bed reactor unit using synthetic bio-oil as a feedstock. The considered catalysts fall in three general categories: (a) zeolites, (b) aluminas and (c) Fe/Cr catalysts. The performance of selected optimum catalysts was further studied using solid biomass. Comparable results were obtained with both procedures.

IRRIGATION OF ENERGY PLANTATIONS WITH PROCESSED URBAN LIQUID WASTES

J. Vourdoumbas, Chemical Engineer, M.Sc.
J. Kaliakatsos, Physicist, PhD
T.E.I. of Heraklion, Branch of Chania, Romanou 3, Chania, 73133
Tel. 0821-28188, FAX 0821-28190, e-mail: gboyrd@tee.gr
G. Kazakis, Forester
S. Doulis, Forester, Ph.D.
P. Kefalas, Chemist, Ph.D.
MAICH, Agrokipio, Chania, 73132, Tel. 0821-81151, FAX 0821-81154
Ch. Kotsifaki, Chemical Engineer
DEYACH, Municipality of Chania, Chania, 73132, Tel. 0821-45268

Disposal of processed urban liquid wastes can be combined with irrigation of energy plantations where the produced biomass can be used for heat or power generation. In the following work a pilot unit is described where the outlet of a treatment plant is being used for irrigation of a plantation with fast growing species. Results concerning the growth of the plantation, the quality of the effluent and the rate of irrigation are presented.

FLEET TESTS IN GREECE BY USING BIODIESEL BLENDS

A.Serdari, K.Fragioudakis, E.Lois, S.Stournas

National Technical University of Athens, Department of Chemical Engineering,

Laboratory of Fuel Technology and Lubricants

Iroon Polytechniou 9, 157 80 Zografou Campus, Athens

ABSTRACT

Biodiesel is a mixture of fatty acid methyl esters, prepared from vegetable oil triglycerides and can serve as an efficient substitute of conventional diesel fuel. In Europe, the most commonly used raw material for biodiesel production is rapeseed oil. In recent years, several other raw materials are being considered as viable candidates for biodiesel production.

This study includes fleet tests in Athens by consuming blends of typical diesel fuel with biodiesel produced from sunflower oil, corn oil, olive oil and used frying oils, marked the first actual utilization of biodiesel in Greece, and has served to illustrate the attractiveness of this renewable and environmentally friendly fuel in the day to day operation of a variety of vehicles. Nine diesel powered vehicles were employed for the purposes of the project, circulating in the greater Athens area and performing their normal tasks. They were fuelled either with typical greek diesel fuel or with mixtures with 10% or 20% by volume biodiesel. The tests included emission and fuel consumption measurements and lubricating oil analyses.

The four types of biodiesel performed in a similar way: they decreased exhaust emission of black smoke, resulted in a limited change of nitrogen oxide emissions, did not affect significantly the rate of lubricant deterioration and probably resulted in slightly increasing the detected amounts of some wear metals in the used lubricating oil. It is important to note, that the drivers of the vehicles expressed enthusiasm for the new fuel.

URBAN WASTE

SAMPLING, SORTING AND ELABORATION OF HOUSEHOLD WASTE
- THE CASE OF THE MUNICIPALITY OF PILEA / THESSALONIKI -

G. Koufodimos, K. Verganelakis, Z. Samaras

Laboratory of Applied Thermodynamics, Mechanical Engineering Department,
Aristotle University of Thessaloniki, 540 06

The results from a one-year domestic waste sampling in the Municipality of Pilea, in Thessaloniki, are presented. The paper describes (a) the sampling method, which was conducted four times during one year (once per season) in selected regions, (b) the qualitative analysis of the collected samples and (c) the waste processing method, which consisted of drying, grinding, calorific value measurement and incineration. The procedure that was followed in this sampling study is analysed and compared with other methods that have been applied in other regions of Greece and worldwide.

INVESTIGATION OF MUNICIPAL SOLID WASTES' THERMAL TREATMENT PERSPECTIVES WITH A LOCATION-ALLOCATION MODEL AND MULTICRITERIAL ANALYSIS FOR THE REGION OF EAST MACEDONIA-THRACE, GREECE

G. Perkoulidis, A. Karagiannidis, N. Moussiopoulos

Laboratory of Heat Transfer and Environmental Engineering

Department of Mechanical Engineering, Aristotle University Thessaloniki,

University Campus, Box 483, GR-54006 Thessaloniki, Greece

tel.:+30 31 861078, 996011, fax: +30 31 887210, 996012

e-mail: gperk@aix.meng.auth.gr

In this paper, a study of the management system for post-consumer, municipal solid wastes of the Eastern Macedonia-Thrace Region is conducted. The study focuses on the evaluation and comparison of certain thermal treatment technologies with mechanical separation and landfilling. Rotary kiln and pyrolisis are evaluated as thermal treatment technologies.

A linear mixed integer programming model was implemented for facility location and waste allocation to them, taking into account objectives as: (a) waste finally disposed in the ground, (b) emissions contributing to the greenhouse effect, (c) recovered materials, (d) recovered energy and (e) total cost. After the parametric solution of the aforementioned model, mono-criterial optimal solutions result, which are then ranked with the use of a multicriterial method from the Electre family, on the basis of a proper designed library with evaluation criteria.

RATIONAL USE OF ENERGY
IN GREENHOUSE POT PLANT PRODUCTION SYSTEMS

P. Giaglaras [1], A. Baille [2] & C. Kittas [1]

[1] *University of Thessaly, Department of Agriculture, Animal and Crop Production,*
Laboratory of Agricultural Constructions and Environmental Control
Pedio Areow, GR-38334, Volos, Greece
[2] *INRA, Unite de Bioclimatologie, Domaine St. Paul, Site Agroparc,*
84914 Avignon Cedex 9, France

In this paper, a mathematical simulation methodology is presented for flower pot plant production systems. The simulator was developed to explore the behavior of the system and to evaluate climate management systems in order to optimise the use of energy.

The first results show that artificial lighting can increase the productivity and the efficiency of energy used for greenhouse climate regulation.

USE OF THE SLUGDE FROM THE LIQUID WASTES TREATMENT PLANTS AS FERTILIZER AFTER DRYING USING BIOMASS AS A FUEL

J. Vourdoumbas

TEI of Heraklion, Branch of Chania, Romanou 3-Chalepa, 73132 Chania
E-mail : gboyrd@tee.gr

The use of the sludge from the liquid treatment plants in agriculture has not found yet broad applications in Greece. After processing the sludge in bioreactors for biogas production, the water is removed by filtering in a final concentration of approx. 75%. Further reduction of the water content of the sludge can be obtained with drying in rotating dryers where biogas or olive Kernel wood can be used as biomass fuel. The final product having a water content 12-15% can be used in agriculture if its concentration in heavy metals is in the limits of the current regulations.

In the following work, the possibilities of using the sludge from the treatment plant of Chania in agriculture after processing and drying using biomass as a fuel are presented.

OPTIMISATION OF ENERGY PARAMETERS
IN AGRICULTURAL PRODUCTS DRYERS

S.J. Babalis (*), E. Mathioulakis (*), V.G. Belessiotis (*), V. Sotiropoulos (**)

(*) Solar & other Energy Systems Laboratory, NCSR "Demokritos", 15310 Aghia Paraskevi
Attikis, Greece, Tel. +301 6544592, Fax +301 6544592, E-mail: sollab@mail.demokritos.gr

(**) Aristotle University of Thessaloniki

In order to determine the best drying scenario, in respect of the product quality characteristics and energy saving, a number of drying tasks were carried out under different drying conditions in an experimental apparatus developed for this purpose. Two basic parameters which influence the drying performance were considered: the drying air velocity and temperature. Firstly the influence of air velocity was investigated while the air temperature was kept constant. Secondly the influence of air temperature was investigated keeping constant the air velocity. Furthermore it was examined the influence of the pre-treatment with sulphur vapours on the drying time and the dried product quality. The optimal conditions during the drying period were determined in order to achieve the best drying performance.

This approach allowed us to develop a series of methods and tools, leading consequently to the elaboration of certain optimisation rules of the drying process. The application of those rules ensure about the quality of the final product, with the minimum of waste energy.

POSSIBILITY OF HEATING HUDROPONIC GREENHOUSES USING BIOMASS AS A FUEL

J. Vourdoumbas

TEI of Heraklion, Branch of Chania, Romanou 3-Chalepa, 73132 Chania

E-mail : gboyrd@tee.gr

C. Economakis

Institute of olive and subtropical plants, Agrokipio, 73132, Chania

In a greenhouse with hydroponic culture (Nutrient Film Technique) there is the possibility of heating the nutrient solution to the desired temperature.

In this work reference is made in the possibility of using olive Kernel wood for heating a hydroponic greenhouse. The olive Kernel wood is used for heating simultaneously the interior of the greenhouse and the nutrient solution in which the plant roots are immersed.

STUDY OF VARIABLES DETERMINING AIR TEMPERATURE IN A DYNAMIC VENTILATED ROSE GREENHOUSE COVERED WITH PVC

C. Kittas, M. Karamanis, N. Katsoulas

University of Thessaly, School of Agriculture, Crop and Animal Production,

Pedion Areos, GR-38334, Volos, Greece.

Forced ventilation for greenhouses cooling was expanded in Mediterranean areas. It is used not only to prevent overheating but also to regulate air humidity in greenhouses. The examination of the variables which determine the greenhouse air temperature and the development of a simplified model for the prediction of internal greenhouse temperature, which will incorporate the outside climatic conditions and the greenhouse parameters, will contribute to a better estimation of forced ventilation systems. The aim of this study was to investigate experimentally the variables and their interaction, which affect the greenhouse forced ventilation. We carried out measurements of greenhouse ventilation rate simultaneously with measurements of climatic variables (air temperature, humidity and solar radiation inside and outside the greenhouse and outside wind speed) in a multi-span fan-ventilated greenhouse with roses located at Karditsa, central Greece. Data analysis showed that the difference between inside and outside air temperature is proportional to ventilation rate and to incoming solar radiation. This allowed us to suggest a simplified form of greenhouse energy balance and finally an equation relating greenhouse air temperature with the outside climatic variables (air temperature, solar radiation and wind speed) and greenhouse parameters (cover material transmission and ventilation rate). The equation calibration gave satisfactory results and showed that it can be incorporated in greenhouse climate control algorithms and it can also be used as a tool for more accurate estimations of ventilation needs.

OPTIMUM GREENHOUSE ENERGY MANAGEMENT
USING LOW ENTHALPY GEOTHERMAL FLUIDS

Kodossakis D., Garofalakis J., Vlachou D., Kaldellis J.K.
Lab of Soft Energy Applications & Environmental Protection
Mechanical Eng. Dept., TEI Piraeus,
e-mail: sealab@gdias.teipir.gr
Pontou 58, Hellinico 16777, Greece

The necessity of using external heat sources to cover the energy deficit of greenhouses under contradictory climate conditions is dictated either for survival or for efficiency improvement reasons of the crops cultivated. Taking into account the plethora of the existing low enthalpy geothermal fields in Greece, the optimum procedure to fulfil the heat requirements of a greenhouse by using geothermal energy is extensively investigated in the present analysis. According to the results obtained the economic efficiency and competitiveness of similar applications are greatly improved, mainly due to the minimization of the conventional energy consumption by the greenhouse installations.

UNIT OPERATIONS IN ENERGY SYSTEMS

MODELING OF PREMIXED FLAME PROCESSES
FOR THERMAL TREATMENT PURPOSES

H.H. Liakos[1], M.K. Koukou[1], M.A. Founti[2] and N.C. Markatos[1]

[1]National Technical University of Athens, Chemical Engineering Department,
Section II, Zografou Campus, Athens 15780

[2]National Technical University of Athens, Mechanical Engineering Department,
Thermal Section, Patision 42, Athens 10682

The work investigates the effects of varying the fuel (propane and methane), the pressure of the mixture reactants and the angle of impingement on the performance characteristics of a turbulent premixed jet flame impinging on a solid surface. These effects are important for the design of torches and flaming machines used for material cutting and forming. The combustion and flow characteristics are modeled using a finite volume computational approach. Based on the simulation results, it is shown that increasing the pressure of the mixture reactants modifies the flame-surface interaction mechanisms. Both fuels have the same thermal yield. Changing the impingement angle modifies the reaction area while the maximum temperature and reaction rate values remain the same with the case of a normal flame.

STUDY OF NATURAL CONVECTION IN A GLASS MELTING TANK

N. Katsavos, I. Lekakis and N.S. Vlachos

Department of Mechanical & Industrial Engineering

University of Thessaly - Pedion Areos, 38334 Volos, Greece

The physics of simulated glass flow in a laboratory model of a glass melting tank are studied using methods of flow visualization, particle image velocimetry (PIV) and computational fluid dynamics. An order of magnitude dimensional analysis of the Navier-Stokes equations is presented to determine the important parameters of the problem. The main goal is to find the optimum arrangement of the burners in the glass furnace that results in the best homogenization of the glass melt with corresponding savings in the energy requirements of the glass furnace.

USE OF LDA AND PIV FOR THE FLOW STUDY OF A TIME VARYING CONSTRICTION

K.Maras, S.Tzouanakis and D.S.Mathioulakis

NTUA, Department of Mechanical Engineering, Fluids Section

The flow field of a time varying constriction in a square duct was studied through LDA and PIV for mean Re in the range 300 to 800 and St from 0.05 to 0.3. The three separated zones appearing when constriction increases were examined as well as the flow field far from it. Most probably due to the three dimensional model used, there was no vortex formation observed like that one mentioned in literature for two dimensional flows.

MATHEMATICAL SIMULATION OF AIR FLOW IN SINGLE – SIDED VENTILATED BUILDINGS

K. Papakonstantinou, C. Kiranoudis, N. Markatos

Department of Chemical Engineering, National Technical University of Athens
Heroon Polytechniou 9, Zographou Campus, 15780 Athens

The present paper refers to the numerical simulation of the air's velocity and temperature flow concerning naturally single - sided ventilated buildings – the special case in which the air from the external environment is brought inside the building from openings which all have the same direction -.

The paper draws attention to the physical procedures leading the air's movement during the single – sided natural ventilation and presents a mathematical model, implemented in a general computer code, that can provide detailed information on velocity and temperature prevailing in three-dimensional single – sided ventilated buildings with openings of any geometrical complexity, for given external meteorological conditions. The model involves the partial differential equations governing flow and heat transfer, in large enclosures. Turbulent flow is simulated and buoyancy effects are taken into account. The model is used to assess the environmental conditions in a test cell designed and constructed by the National Observatory of Athens with external conditions corresponding to their measurements. The results reffering to the use of the numerical code, give a good accordance compared with the experimentally measured values of air velocity, temperature and pressure, in various sites inside the test cell.

CYLINDER WAKE-AIRFOIL INTERACTION FOR APPLICATION TO A DOWNWIND HAWT.

H. Stapountzis, K. Yakinthos, A. Goulas,
G. Charalambous

Department of Mechanical Engineering, Aristotle University of Thessaloniki

540 06 Thessaloniki, Greece

The influence of a cylinder wake on the loading and flow field of a downstream positioned airfoil is studied experimentally and numerically. Both the lift and the airfoil wake are modified by the cylinder presence. The airfoil loading is reduced and its wake broadened due to the slow decay of the cylinder wake. Wind shear in the spanwise direction is more effective when the cylinder is present and it acts in the direction to restore the airfoil pressure distribution which was altered by the cylinder. Numerical calculations have been performed to simulate the experiment. A Navier-Stokes solver was used to calculate the velocity and pressure field using the pressure correction technique on a co-located variable arrangement in a C-type curvilinear grid simulating both the cylinder and the airfoil. The results showed that when the cylinder is placed in the symmetry plane upstream of the airfoil the lift coefficient is reduced. When the cylinder is placed in a distance from the symmetry plane upstream of the airfoil, the lift coefficient tends to be slightly over the "design" lift coefficient of the airfoil with no existence of a cylinder.

PITCHING PLATE WAKE INTERACTION WITH A STATIONARY PLATE

J.Noussis and D.S.Mathioulakis

NTUA, Department of Mechanical Engineering, Fluids Section

The wake of a pitching plate and its interaction with a stationary one was studied by means of PIV. When the produced by the pitching plate vortices interacted with the stationary plate they forced the flow to separate alternately from its two sides, producing new vortices of opposite sign. The circulation of the new vortices becomes stronger and that one of the original weaker, the closer the latter pass over the stationary plate.

THE TRANSIENT 1-D PROBLEM OF THERMAL CONDUCTION-CONVECTION IN A MULTI-SHELL PLATE WITH BOTH SIDES EXPOSED

N. J. Siakavellas & D. P. Georgiou
Department of Mechanical Engineering & Aeronautics
University of Patras, GR-26500 Patras, Greece

The study investigates the one-dimensional transient heat fluxes on both sides of a plate composed of two parts, a relatively thick metal plate and a thinner non-conducting coating. The configuration simulates the flow separator plate in the constant volume, countercurrent heat exchanger (CVCHE). The flow countercurrents on the two walls of the plate develop step changes in the heat transfer coefficient concurrently or with a phase difference.

The study develops the analytical solution for both the thermal field and the resulting heat fluxes on the walls in non-dimensional terms in the steady state. The transient solutions were done numerically. The solution of these equations for conditions similar to those expected in a CVCHE show that a delay (dimensionless) time of order 2 appears in such a step change. The phase difference effect does not influence this value appreciably.

ESTIMATION OF POLLUTION FROM AN INDUSTRIAL CHIMNEY USING A THREE DIMENSIONAL NUMERICAL MODEL

D.K. Feidaros, I.E. Sarris and N.S. Vlachos

Department of Mechanical & Industrial Engineering

University of Thessaly - Pedion Areos, 38334 Volos

A simulation is presented of the dispersion and deposition of gaseous and particulate pollutants in the atmosphere from an industrial chimney using a numerical model which is based on the solution of the Navier-Stokes equations in an Eulerian frame and a Lagrangean description of particle dynamics. The turbulent boundary layer of the atmosphere is considered neutral and the pollutants chemically inactive. The distribution of temperature and concentration of the gaseous pollutants as well as the trajectories of the particles are calculated. The results of the study allow comparisons to be made and conclusions to be drawn for the dispersion and deposition of pollutants in three-dimensional geometries. The increased wind speed results in lower escape heights and smaller dispersion widths. All particles escape from the present three-dimensional field, while corresponding two-dimensional calculations showed that the larger particles deposit in the region downstream of the chimney.

OPTIMIZATION OF TRANSPORT COEFFICIENTS IN IMPINGING JETS ON FLAT AND CYLINDRICAL SURFACES

H. Stapountzis, K. Yakinthos, D. Tsipas, A. Goulas

Dept of Mechanical Engineering, University of Thessaloniki
BOX 443, Thessaloniki 540 06, Greece

D. Valougeorgis, A. Gikas

Dept of Mechanical and Industrial Engineering
University of Thessaly, Volos 383 34, Greece

Transport phenomena induced by an axisymmetric circular turbulent jet impinging on a flat plate and a circular cylinder were examined experimentally for a range of jet Re numbers between 15000 and 80000. Relevant parameters studied were the geometrical position of the jet like distance from the surface and impingement angle. The bulk of the present work addressed heat transfer by a cold incompressible air jet impinging on a heated surface. Mass transfer experiments included the dissolution and disintegration of waterpaint layers by impinging water jets and erosion of cylindrical aluminum specimens by impinging air-solid particle jets.

It was found that transport coefficients are improved if the jet nozzle - surface separation distance is about half the length of the potential core of the jet in unconfined (free jet) conditions. Curved surfaces exhibited better transport coefficients in the immediate region of the stagnation point.

There were cases in which the maximum Nusselt numbers occured close to the stagnation regions, i.e. the stagnation point did not always coincide with the maximum heat transfer point. The best angles of incidence for maximum heat transfer appeared to be between 90 degrees (normal impingement) and 75 degrees.

Similar behaviour was noticed for mass transfer processes, but for erosion additional factors like the composition of the impinging particles and the mechanical / physical properties of the test specimens are of great importance.

Comparison of some of the present experimental data with those prdicted by the CFD code FLUENT indicated good agreement for pressures and poor for transport coefficients.

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INTENSIFICATION OF TRANSPORT PHENOMENA IN THIN FILMS BY A CORRUGATED WALL: THEORY AND EXPERIMENTS

M. Vlachogiannis & V. Bontozoglou

Department of Mechanical & Industrial Engineering, University of Thessaly

Pedion Areos, GR-38334 Volos, Greece

Gravity induced flow of a liquid film over a corrugated wall is studied analytically, computationally and experimentally. Linear analysis indicates that corrugations with length around 2 mm lead to wall-free surface resonanse. Computer simulation by a pseudospectral method predicts the nonlinear characteristics of flow over finite-amplitude corrugations. Preliminary results are presented of a fluorescence imaging method, that will be used in the experimental investigation of the problem.

HEAT TRANSFER AND FLUID FLOW MODELLING IN DIRECT METHANOL FUEL CELL STACKS (DMFC)

P. Argyropoulos, K. Scott, & W. M. Taama

Department of Chemical and Process Engineering, University of Newcastle upon Tyne, Merz Court, Newcastle upon Tyne, NE1 7RU, UK.

Direct Methanol Fuel Cell systems are an attractive potential power source for the new generation zero emission vehicle. These systems have a number of advantages over their main competitor hydrogen operated fuel cells. These include the absence of a fuel processing unit, resulting in a simpler system with lower volume and weight, the liquid form of the fuel, that makes it more safe and easier to handle, and the potential to use the existing fuel supply and distribution system infrastructure. Many issues remain to be solved as the design of the system itself is carried out semi-empirically and the mode of operation (i.e. vapour vs. liquid fed systems, pressurised vs. ambient pressure cathodes, feed concentration and flow rate etc.) are still a subject of dispute.

A large scale prototype DMFC stack has been built at Newcastle University (25 cells of 270 cm^2 active area per cell, nominal power output 500W) based on a flow bed design developed by the authors with the aid of a flow visualisation study and fluid flow modelling. In addition a series of engineering models were developed for predicting the fluid distribution from the stack manifolds, the overall system pressure, the chemical equilibrium in both anode and cathode flow beds and the thermal management of the stack.

PREPARATION OF THIN CdS LAYERS BY THE CONTINUOUS FLOW OF A SUPERSATURATED SOLUTION

N. Andritsos, M. Kostoglou & A.J. Karabelas

Department of Chemical Engineering, Aristotle University of Thessaloniki, and

Chemical Process Engng Research Institute, P.O. Box 1517, GR 540 06 Thessaloniki, Greece

The most common method for preparinf thin CdS filmw, used in photovolataic applications, is the chemical bath deposition (CBD) process. Despite being fairly simple and convenient method, this method exhibits some disadvantages concerning mainly the use of large concentrations of ammonia. The objective of this work is to develop an alternative to CBD method, using a simpler chemical system. The method lies in the wall crystallisation of CdS on glass or glass/SnO_2 substrates by the flow of a solution supersaturated with respect to CdS

With this method, rather uniform films on SnO_2 superstrates were produced so far, of thickness 200 to 500 nm, exhibiting good adhesion characteristics especially after annealing at 400°C for 30 min. The best results are obtained in a narrow range of supersaturation ratio between 6 and 8.

MODELLING THE CHEMICAL BATH DEPOSITION PROCESS OF CDS

M. Kostoglou, N. Andritsos & A.J. Karabelas

Department of Chemical Engineering, Aristotle University of Thessaloniki, and

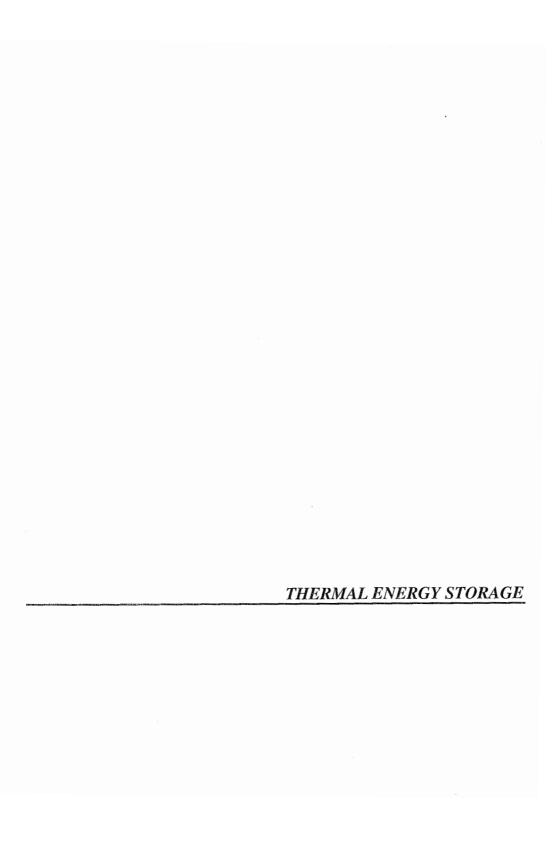*Chemical Process Engng Research Institute, P.O. Box 1517, GR 540 06 Thessaloniki, Greece*

Among the available techniques for preparing CdS films, deposition from solution and, more specifically, the *chemical bath deposition* (CBD) appears to be a fairly simple and convenient method for large area coverage. Such a CBD process involves the slow release of sulphide ions via the controlled hydrolysis of thiourea in the presence of a cadmium salt and a chelating agent (commonly NH_3) resulting in the precipitation of CdS on glass substrates

A chemical engineering type analysis of the CBD process is carried out in this paper to aid its design and optimisation. Model equations are developed (based on a population balance formulation) for the temporal variation of reactant concentrations as well as of the solid phase, both in the bulk and on the substrate. A possible sequence of elementary mechanisms (i.e. nucleation, surface reaction etc.) is suggested and the resulting comprehensive model is solved numerically. Computational results show that the model is consistent with available experimental data on film thickness evolution. Furthermore, the influence of the process parameters on the results is studied theoretically and discussed for several cases. The model may prove very useful for optimising the CBD process with respect to its design variables (reactant concentrations, process time etc.), as well as for efficient experimental determination of presently uncertain or missing parameter values.

EXPERIMENTAL FLOW STUDY OF A PULSED AIR JET

A.Panorgias and D.S.Mathioulakis

NTUA, Department of Mechanical Engineering, Fluids Section

The flow field of a pulsed air jet (1Hz) was studied with a hot wire and the results were compared with a steady jet of the same $Re=1.3x10^5$. Basic differences between the two jets were the increased flow rate, increased jet diameter and changing momentum flux in space of the pulsed jet, whereas time mean velocity profiles were of similar same shape.

THERMAL ENERGY STORAGE

THERMAL ENERGY STORAGE IN PHASE CHANGE MATERIALS-EXPERIMENTAL INVESTIGATION

I. Zoudiari[*], E. Mathioulakis[*], V. Belessiotis[*], D. Yfantis[*]
Solar and Energy Systems Laboratory
NCSR "DEMOKRITOS" 153 10 Ag. Paraskevi Attikis
**NTUA, Department of Chemical Engineering*

The experimental investigation of a latent heat storage system utilising paraffin as a phase change material is presented. At a first stage the phenomenology of the melting and solidification process has been studied. The influence of inlet temperature and flow rate of the heat transfer medium on the duration of charging/discharging process is investigated at a second stage.

Paraffin was selected as a heat storage material because of its advantages such as, high latent heat, chemical and thermal stability, low cost and availability. The experimental unit consists of a cubic tank connected with heat charge and removal systems at desired temperatures. The tank is filled with the paraffin in which a heat exchanging system with Copper make finned tubes is embedded. The heat transfer fluid is water that flows inside the aforementioned tubes.

Experimental results showed that the melting front is a slow moving cone which proves first the poor thermal conductivity of paraffin secondly the existence of natural convection in the melt and that the problem cannot be considered as one dimensional. The basic mechanism of heat transfer during melting is natural convection while, during solidification in the vicinity of the pipes is conduction.

The inlet temperature of the heat transfer fluid has more significant influence at melting rates rather than solidification. On the other hand flow rate in the range that we have tested has very little effect especially at the discharge rates.

NUMERICAL SIMULATION OF HEAT STORAGE IN PHASE CHANGE MATERIALS (PCMs)

I. Zoudiari, J. K. Statharas, E. Mathioulakis, V. Belessiotis

Solar and Energy Systems Laboratory

NCSR "DEMOKRITOS" 153 10 Ag.Paraskevi Attikis

In the present paper a numerical model for the simulation of latent heat storage is presented. The storage system utilises paraffin as a phase change material, which melts/solidifies in a temperature range. The result of the aforementioned behavior of paraffin is the existence of a mushy region during phase change. Modelling of a melting/solidification problem is very complicated mainly due to nonlinearity and the a priori unknown location of the phase change boundary. The model that is being developed, is a 3D enthalpic one with fixed grid and it takes into account not only conduction but also convection in the liquid phase. Latent heat evolution and fluid flow in the mushy region and natural convection are represented via suitable source terms in the corresponding conservation equations. More specific flow in the mushy region is modeled using Darcy approximation for porous media and natural convection is induced via a Boussinesq buoyancy source term. The derived equations are being solved with PHOENICS code. The overall computations are in progress. They have not yet completed due to long computational time.
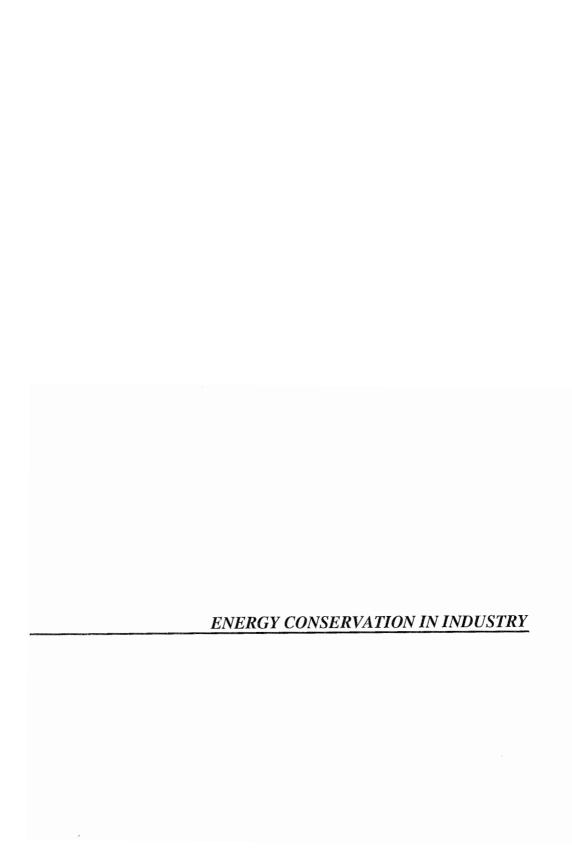
EVALUATION OF ALTERNATIVE METHODS
FOR SOLAR ENERGY STORAGE

V. Lygerou

Department of Chemical Engineering, National Technical University of Athens

Zografou Campus, GR-157 80 Athens, Greece

In this work the basic systems for solar energy storage are examined, with emphasis on the applications to the domestic sector. After a brief presentation of the conventional thermal energy storage systems, the possibilities of conversion to electricity and/or hydrogen are discussed. It is pointed out that there are several alternative routes for matching the supply to the demand of a solar house. Advanced technology opens new opportunities for a widespread exploitation of solar energy in small, distributed collection units.

ENERGY CONSERVATION IN INDUSTRY

THE INFLUENCE OF COMBUSTION ON OPTIMUM FLOW OF GLASS MELT

I. E. Sarris, N. Katsavos, I. Lekakis and N. S. Vlachos
Department of Mechanical & Industrial Engineering
University of Thessaly - Pedion Areos, 38334 Volos

The heating of glass melt in an industrial glass furnace is achieved with burner arrangements placed above its free surface. In the old furnaces, the burners were placed with their axis along the length of the furnace and above the entrance of the raw materials. In recent years, the burners are placed with their axis in the transverse direction and with each one of the burners on the opposite site displaced in the melt flow direction. The number and the arrangement of the burners affect the flow of glass melt and the quality of the final product. In the present work a parametric study is carried out of the glass melt flow in a melting tank for different number and arrangement of burners using computational fluid dynamic. The results show that the temperature distribution above region of low velocities (worse mixing region) in the melting tank produces a flow acceleration.

TECHNO-ECONOMIC EVALUATION OF ENERGY SAVING TECHNIQUES IN GREEK INDUSTRY

Kaldellis J.K., Exintaris Ant., Kiousi V.
Lab of Soft Energy Applications & Environmental Protection
Mechanical Eng. Dept., TEI Piraeus,
e-mail: sealab@gdias.teipir.gr
Pontou 58, Hellinico 16777, Greece

The Greek industry is responsible for nearly the 29% of national energy consumption. Besides there is almost no energy management strategy for the majority of the small and medium size Greek enterprises, resulting therefore to an energy consumption per product which is twice the corresponding one, according to the international standards.

The proposed analysis is focused on simple energy saving techniques for the industrial sector, which may obtain a 20% energy preservation in case they are adopted. In addition to the numeration of the technical specifications and peculiarities of the suggested applications, the present work investigates the evolution with time of the installation cost, the maintenance and operation cost and the resulting economic benefits due to the energy saving achieved.

SUBSTITUTION OF ENERGY-CONSUMING PROCESSES BY MEMBRANE SYSTEMS

Pan. Ignatiadis, Vas. Gekas

Dep. of Environment, Technical University of Crete

Membrane Technology could be used in the Industry with the aim to replace energy-demanding processes for separation, preconcentration and microbial removal, to give some typical examples. Traditionally used unit operations such as multistage evaporation, simple evaporation and pasteurization (or even sterilization) carried out at temperatures higher than 70 °C and with high energy costs could be replaced (at least partly) by mechanical and cold membrane unit operations such as Reverse Osmosis, Ultrafiltration, Cross Flow Microfiltration and Pervaporation.

Comparison data will be given in typical cases, that demonstrate the application potential of Membrane Technology in the Dairy industry, Food and Drinks industry, Production of Electrical energy and Waste water treatment.

SURFACE ALLOYING OF SiC POWDER ON METALLIC SUBSTRATES USING SOLAR ENERGY

D.I. Pantelis*, A. Griniari**, A. Choundri*, Ch. Sarafoglou*, S. Chionopoulos*

National Technical University of Athens (NTUA), Greece
* Department of Mechanical Engineering
**Department of Naval Architecture and Shipbuilding Engineering
9, Heroon Polytechniou st.,Zografou Campus, 157 80 Zografou, Athens, GREECE

In this work is studied the possibility of surface alloying formation with pre-deposited SiC powder on metallic alloys (steels and cast iron), using concentrated solar energy, in order to enchanch their surface properties (hardness and anti-wear resistance).

More specifically, the use of solar energy resulted in treated zones, the microstructures of which depend on the solar exposure duration. Thus, for similar values of energy density, long exposure time gives greater depths of the treated zones, lower values of hardness and a great amount of porosity, whereas, sort heating time results in smaller depths, greater amount of undiluted carbides and increased hardness. Generally, there was good adhesion between treated zones and substrates. Finally, these results were compared to similar results obtained by Laser surface treatment, and the differences between the two methods are presented.

OPTIMIZATION OF ENERGY CONSUMPTION IN PERLITE EXPANSION PLANTS

M. A. Founti[1] and K.N. Laskaridis[2]

[1] *National Technical University of Athens, Mechanical Engineering Department,*
Patission 42, Athens-10682

[2] *Institute of Geology and Mineral Exploration, Department of Economic Geology,*
Messoghion 70, Αθήνα-11527

The paper investigates and proposes measures for optimization of energy consumption in perlite expansion furnaces. The characteristics and the factors affecting the expansion process are briefly discussed. A typical perlite expansion plant is presented together with relevant operational parameters.

The work focuses on the energy balance during a typical operational period of a furnace. It is shown that the flue gases leaving a vertical expansion furnace together with the expanded perlite particles carry out with them a significant amount of energy that could be otherwise exploited. The energy content of the flue gases and of the expanded perlite particles is about 42.5% and 16.5% respectively, of the energy supplied to the system by the fuel.

It is concluded that the energy performance of a typical perlite expansion plant can be significantly improved if the heat losses to the environment and via the furnace walls are minimized. Heat exchangers can be used for the preheating the combustion air and/or of the raw material.

BEST APPLICATION METHOD OF COMBINED HEAT AND POWER SYSTEMS (CHP) IN TEXTILE INDUSTRY.

J. N. Katsanevakis

Engineering and Consultancy Dep., Enervac-Flutec Ltd

Ionia Thessaloniki, tel: 031/783572 Fax 031/781824 E-mail: Flutec@Flutec.gr

G. Hasapis

Technical Dep. Colora S.A

Thermi, Thessaloniki tel 031/463002 Fax 031/461063

This presentation concerns the basic parameters that strongly influence the optimised application of CHP systems in textile industry. A brief description of the dyeing plant gives initial information on the energy characteristics, and the essential energy consumption data that are needed. The most suitable CHP methods for the textile industry and their energy balance is given. The basic alterations to the electromechanical equipment of the plant are defined and the alternative scenarios of CHP application are determined. Several financial criteria for the comparison of the scenarios are determined and the final selection is being done. Finally some best practice guides for the effective application of CHP are given.

SOFTWARE DEVELOPMENT FOR THE ENERGY CONSUMPTION OPTIMIZATION OF INDUSTRIAL COOLING TOWERS

N. Yiourniezakis and D. Valougeorgis

Department of Mechanical and Industrial Engineering, University of Thessaly
Pedion Areos, GR-38334 Volos, Greece

ABSTRACT

Industrial processes produce excess heat, usually in the form of hot water that must be cooled and reused. Cooling towers dissipate this heat quickly, by circulating hot process water in the presence of air to maximize evaporation. They are designed to expose the largest surface area of transient water to the maximum airflow for the longest period of time. Process water is delivered to hot water inlets located at the top of the towers. It is allowed to flow down through the heat transfer media in the tower by either gravity or by pressurized nozzles. The type of airflow varies with tower design. Airflow usually is mechanically induced by a series of motor driver fans.

As with other piece of equipment, cooling tower performance can be optimized if the operating parameters are rigorously specified and controlled. The heat transfer process involves latent heat transfer owing to vaporization of a small portion of the water and sensible heat transfer owing to the difference in temperature of water and air. Theoretical possible heat removal per pound of air circulated in a cooling tower depends on the temperature and moisture content of air. The enthalpy difference between the enthalpy of saturated air at water temperature and the enthalpy of the air stream provides the driving force for the cooling process. An indication of the moisture content of the air is its wet bulb temperature.
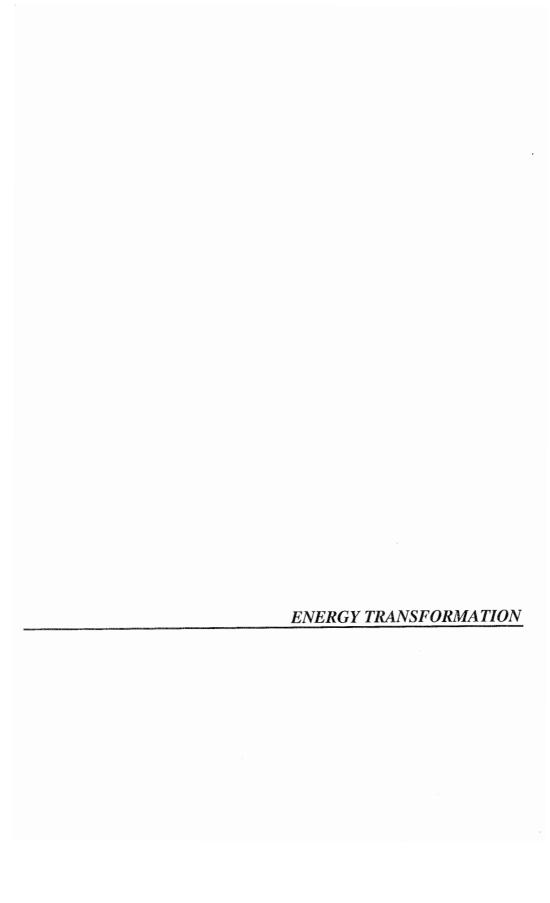
The main parameters involved in the design of cooling towers include the air wet bulb temperature, hot and cold water temperatures and the volumes of water and air. The hot and cold water temperatures and the water flow rate are specified from the plant process engineers to cover certain needs and must be always satisfied. Cooling tower manufacturers determine the size of the tower and the air flow rate based on the above specifications and the wet bulb temperature anticipated at site. Usually design wet bulb temperatures have set not to be exceeded more than 5% of the total operating hours during a normal summer.

Cooling towers are built to produce design conditions based on the design wet bulb temperature. As a result cooling tower motors and fans are engineered to produce design conditions of 100% air volume flow rate all the time. However by definition design wet bulb temperature does not occur more than 3% of the time on the average. Therefore 97% of the time the tower is over producing on air and cold water production, thereby wasting power consumption (during fall, winter, spring and evenings).

Introduction of variable frequency speed control is the most common method of adjusting the speed of the motor and driven equipment and alter the air flow rate. This is done however, in such a way as to continuously satisfy the cooling load requirements and at the same time consume minimum energy.

In this paper a software package is developed to provide the necessary correlation between the instant wet bulb temperature and the variable frequency controller, keeping the tower characteristic constant and optimizing the energy efficiency. From basic cooling tower thermodynamics it is seen that in an enthalpy – temperature diagram, the area on the graph between the saturation curve and the operating line must always remain constant. This criterion is important to ensure, all the times, the specified cooling load. A reduction in the wet bulb temperature leads to an enlargement of this area, which results to waste power consumption.

A relatively simple algorithm is developed, based on the Merkel integration formula to modify the airflow according to the wet bulb temperature modifications on a 24-hour basis keeping however constant the area of integration between the saturation curve and the operation line. Numerical results indicate energy savings up to 75%. Implementation of this approach to new cooling tower installations as well as to revamping of existing ones, leads to tremendous money savings and also to improved environmental protection, without jeopardizing the reliability of the cooling tower performance.

ENERGY TRANSFORMATION

DEVELOPMENT OF INDUSTRIAL CATALYST
MIXED IRON-NICKEL OXIDE FOR THE WATER-GAS CONVERSION
AND HYDROGEN PRODUCTION

J. Chandrinos, D. Dimotikali, H. Papaharalampos and G. Petroutsos.

National Technical University of Athens, Chemical Engineering Department, Material Science and Engineering Section, Iroon Polytechniou 9, 15780, Athens, Greece.

The aim of this work is the development of industrial catalyst mixed iron-nickel oxide for the shift reaction using as row material a greek product (iron-nickel of LARKO).

In a previous work the activities of mixed catalysts of Fe_3O_4 and Cr_2O_3 , CoO and NiO in the water gas conversion were examined.

The promotion of the catalytic activity of Fe_3O_4 found by the added admixtures was ascribed to the p-semiconductivity of the oxides Cr_2O_3 , CoO and NiO, to the electronic structures of the cations of these transition elements, as well as to the spinel structure of the mixed oxides.

We found a very high activity (70% conversion against 43-46% of three commercial catalysts at 380 °C) for the catalyst with 12-13% Ni atoms. This high activity was ascribed to the unstable electronic structure of the cations Ni^{2+} ($3d^8$) and Ni^{3+} ($3d^7$) and to the disordered structure of the mixed inverse spinel with this Ni concentration.

In the present work we prepared and measured five mixed catalysts of Fe_3O_4 and NiO in the above region of Ni concentration and a mixture of three from the above catalysts which has been impregnated with solution 0,5M CrO_3. We measured also for comparison an industrial catalyst (G-3 of SUD-CHEMIE). The procedure used was the same as in the previous works (coprecipitation with NaOH solution from chloride solutions), but the starting material was iron-nickel from the Greek Company LARKO. The catalysts were tabletted with 1% graphite as binder. The composition and structure of the catalysts were checked by chemical analysis, X-ray diffraction, surface area measurements and Mössbauer spectrography.

METHANE CATALYTIC AND ELECTROCATALYTIC COMBUSTION IN SOLID OXIDE FUEL CELL.

S. Douvartzidis, K. Kiriakopoulos and P. Tsiakaras

Department of Mechanical and Industrial Engineering, University of Thessaly,

Pedion Areos, 383 34 Volos, Greece. E-mail: tsiak@uth.gr

The present study is concerned with the catalytic and electrocatalytic behavior of the perovskite-type oxide with chemical formula $La_{0.6}Sr_{0.4}Co_{0.8}Fe_{0.2}O_3$ for application as anode electrocatalyst of a solid oxide fuel cell. The perovskite was deposited on Yttria Stabilized Zirconia (YSZ) in the form of a thin layer. Experimental measurements were conducted during the reaction of methane combustion in a continuous stirred tank reactor with various methane to air ratios in the feedstream, at atmospheric total pressure, and in the temperature range of 500-900 °C. The results of the experimental measurements revealed that the electrochemical supply of oxygen anions through the YSZ-electrolyte affects drastically the conversion percentage of methane. Moreover, it was observed that the specific catalytic system might operate in a wide range of experimental conditions maintaining adequate catalytic activity and practically constant thermal stability.

APPLICATION OF THE ENVIRONMENT-FRIENDLY STIRLING CYCLE IN THE PRODUCTION OF ELECTRICITY

Katherine Marketaki & Vassilis Gekas

Department of Environmental Engineering

Technical University of Crete Campus, GR-73100, Chania

One of the most environmentally friendly thermodynamic cycles, the Stirling cycle may be combined with a reflector/collector of solar energy for the production of electric energy. A number of these units could be used and compose a solar park for the peak needs of places presenting plenty of sunlight hours per year, such as Crete. The first estimations are presenting in this paper and they allow the extraction of some optimistic conclusions.

In our days the problem of energy consists a major problem, because of the well known effects of the air contaminants, the danger of accidents in the approach ports and the long term threats from the sanitary landfill of nuclear wastes, when the solution of the energy problem is the use of nuclear energy. In Crete the energy problem is very intense in the summertime when the population of the island sharply increases because of the tourists. The tourism consumes half of the consumption in the tertiary section. On the other hand Crete appears to have big proportions of sunlight, which in some areas in south - east of Crete averages 3000 hours/year (European record), with a mean monthly solar radiation in the levels of 130-150 KWh/m^2. These data consist a challenge for the application of solar energy in Crete and there have been studied some systems that exploit solar energy with the use of photovoltaic cells in Fragokastelo in Sfakia.
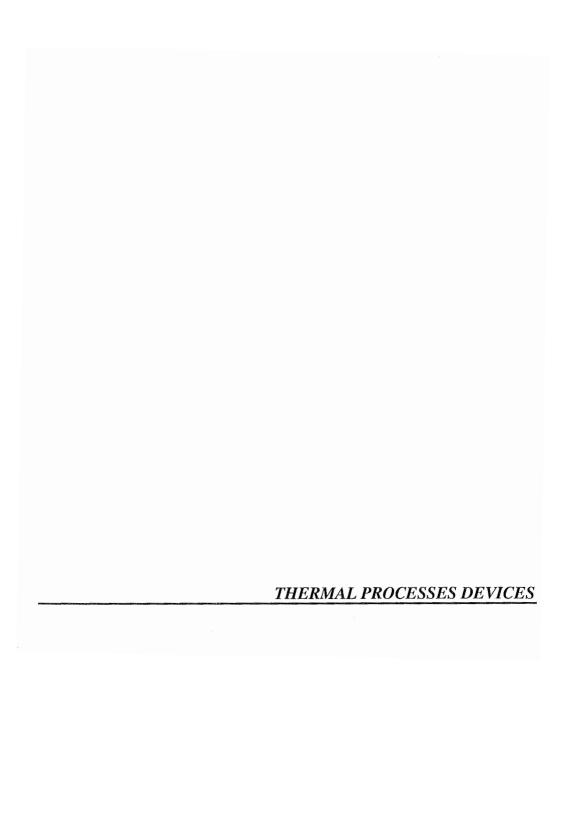
The object of this paper is the investigation of a new technique, which is based in the zero-waste discharge cycle of Stirlring. There have already been developed units of 25 kW for the production of solar energy. Solar parks of these units (more than 1000 units) operate in California USA, and in Almeria Spain with cost price close to the cost of conventional energy production units.

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DESIGN AND DEVELOPMENT PEROVSKITE TYPE CATALYST FOR COMBUSTION AT LOWER TEMPERATURE: CASES OF CH$_4$ AND CO COMBUSTION

N. Georgakakis, S. Douvartzides and P. Tsiakaras

Department of Mechanical and Industrial Engineering, University of Thessaly,

Pedion Areos, 383 34, Volos, Greece. E-mail: tsiak@uth.gr

La$_{0.6}$Sr$_{0.4}$Co$_{0.8}$Fe$_{0.2}$O$_3$ perovskite was separately tested as a catalyst for the reactions of methane and carbon monoxide combustion in a fixed bed tubular flow reactor. Experiments were carried out at relatively low combustion temperature values (300-600°C for CH$_4$ and 100-300°C for CO) and at atmospheric total pressure. Low concentrations of CO were selected in order to approximate real combustion conditions of various engineering applications. The complete conversion of CH$_4$ and CO was obtained at 580°C and 260°C, respectively. The apparent activation energy for the combustion of CH$_4$ was found to be 23.5±1 kcal/mol, while for the combustion of CO was found equal to 12±1 kcal/mol.

THERMAL PROCESSES DEVICES

AIR-WATER TWO-PHASE FLOW IN A PLATE HEAT EXCHANGER

G. Karagiannis, P. Argyropoulos, P. Vlasogiannis & V. Bontozoglou

Department of Mechanical & Industrial Engineering, University of Thessaly
Pedion Areos, GR-38334 Volos,

Performance of a plate-and-frame heat exchanger is studied experimentally under two-phase flow conditions. Long-term goal is the correlation of heat transfer to flow regime. Preliminary analysis of thermal performance indicates that the addition of air results in a significant increase of the heat transfer coefficient, particularly at high water flow rates. Visual observations, made possible by replacement of the mobile cover place with one by plexiglass, indicate the existence of multiple flow regimes.

THE DESIGN OF A NOVEL HOT GAS PARTICULATE FILTER UNIT

G. Macheridou[1], E. Skaperdas[1], P. Stobbe[2], J. Hoej[3], A.G. Konstandopoulos[1]*

[1]*Foundation for Research and Technology Hellas,*
Chemical Process Engineering Research Institute,
P.O. Box 361, Thermi, Thessaloniki 57001, Greece
[2]*NOTOX International S.A., Sandtoften 10, DK-2820, Gentofte, Denmark*
[3]*Department of Chemistry, Materials Science Group*
Technical University of Denmark, DK-2800 Lyngby, Denmark

State of the art hot gas particle clean-up technology is typically based on ceramic candle filters (rigid and soft), and to a lesser extend on smaller, one piece honeycomb cross flow filters. The technology is still in states far from providing reliable and cost effective particulate removal from hot gases. Major problem areas involve: mechanical failure due to ash particle bridging, filter thermal stability and material compatibility issues, system price due to a high candle filter weight and manufacturing cost, and an appreciable pressure drop, to name a few.

The objective of the current research is to develop a compact hot gas particulate clean-up system by integrating specifically tailored, advanced high temperature ceramic materials into a novel and cost effective filter design, so as to overcome problems with current candle technology. The proposed hot gas filter system is constructed combining individual filter elements to create an assembled honeycomb structure.

The filter system has been simulated computationally with respect to its structural and flow characteristics during normal operation and reverse pulse jet cleaning. In addition, filter coupons have been constructed and tested under simulated conditions in a flow rig with respect to their permeability to provide data for scale-up.

*Tel. (+30 31) 498192, Fax (+30 31) 498190, E-mail: agk@alexandros.cperi.forth.gr
http://www.cperi.forth.gr/en/particle.shtml

EXPERIMENTAL INVESTIGATION OF THE FOSSIL FUELS COMBINED COMBUSTION WITH BIOMASS IN A LAB-SCALE FLUIDISED BED COMBUSTOR.

Prof. KAKARAS E.,

Dipl.-Ing. VOURLIOTIS P. and Dipl.-Ing. GRAMMELIS P.

Mechanical Engineering Department, National Technical University of Athens

28 Octobriou Str. 42, 10682 Athens, GREECE

The use of low calorific value or high sulphur content coal mixed with biomass is interesting due to the complementary properties of the two fuels since biomass has low ash and sulphur contents and a high volatile concentration that is favourable to a clean combustion of the coals under consideration.

Within the scope of this concept, NTUA's Steam Boilers and Thermal Plants Laboratory (NTUA-LSB) performed a series of experiments in a lab-scale Atmospheric Bubbling Fluidised Bed Combustor (ABFBC), using the fossil fuels of Megalopolis pre-dried lignite and Göttelborn hard coal with biomass material, i.e. Wood matter from pressed oil-stone (WPOS) and straw. During the trials, the applicability limits of the coal partial substitution by biomass as a function of the excess air ratio were determined, taking also into account the special features of the combustion technology used. In this way, the effects on combustion behaviour, flue gas emissions, volatiles release, residual matter and the ash tendency for agglomerates and deposits formation were thoroughly examined.

As a general assessment from the results of the co-combustion trials, it can be said that WPOS and straw act as supporting fuels when burning with lignite, by improving its combustion behaviour. On the contrary, they do not cause any significant alterations to the combustion process during the co-combustion with Göttelborn, where they behave as substitute fuels.

HORSESHOE VORTEX CONTROL BY SUCTION THROUGH A SLOT IN THE WALL CYLINDER JUNCTION

D. P. GEORGIOU, V. A. PAPAVASSILOPOULOS

Department Of Mechanical Engineering & Aeronautics
University Of Patra
Rio, 26500 Greece

The present study investigates experimentally the influence of suction on the horseshoe vortex. The vortex is generated in the junction between a flat wall and a bluff body formatted by a 600x200 mm^2 rectangle with a 60mm diameter half-cylinder in front of it.

The height of the body was 0.3m and the tests were done in a low speed wind tunnel with a 0.2x0.3 m^2 test section.

The incoming boundary layer thickness was 30mm, while the Re number based on the bluff body width was 5.36x10^4.

Three slot configurations were employed. The first two had a slot width of 3mm and formed arcs of 180° and 60° in the body-wall junction, while the third was around the plane of symmetry wall junction with a cross-section of 5x20 mm, just in front of the bluff body).

The velocity, static and total pressures were measured by a miniature (1.2 mm O.D.) five hole Pitot tube. Traverses were made in four radial planes (30°, 50°, 70°, 90° with respect to the center of the bluff body front section.

The evolution of the horseshoe vortex parameters and the modifications imposed on the secondary flowfield (when compared to the solid wall data) were deduced from the data analysis. In general a sharp reduction in the vortex strength and size was observed.

«INPUT-OUTPUT» METHOD FOR SOLAR STILL MODELING

K. Voropoulos, E. Mathioulakis, V. Belessiotis

NSSR «Demokritos» - Solar & other Energy Systems Laboratory

15310, Agia Paraskevi Attikis

In this paper, a simplified methodology for the evaluation of the operation of a solar still and for the prediction of its long-term production using available climatic data of is proposed. Several equations which describe the thermal behavior of the still are evaluated by making comparison of the predicted values of the model with the experimental data.

The evaluation of the model was done on a greenhouse-type solar still using experimental data derived after a series of continuous operation of the still over a period of more than three months with high variability of the climatic data.

The proposed «input-output» model which describes the daily and the night production of the solar still has been found to be very reliable, predicting water production values very close to the experimental ones. Moreover, the mean temperature of the water inside the still, being one of the most important parameters of the «input-output» model, can be also reliably expressed as a function of the climatic data of the present and the previous days.

The combination of the above has led to a model, used not only for the design and optimized evaluation, but also for the prediction of the total water production of the still, which can be easily applied in practice. By conducting a short-term period of testing in a specific solar still, the characteristic parameters of the model equations are derived using a parameter identification procedure. Following this, the same model is applied for the long-term water production prediction using commonly available climatic data, such as mean daily values of solar radiation and air temperature.

Desalination by mechanical compression of humid air

M. Vlachogiannis[a*], V. Bontozoglou[a*], C. Georgalas[b], G. Litinas[c]

[a]Department of Mechanical & Industrial Engineering, University of Thessaly, Gr-38334 Volos, Greece,
Tel: +3042174069, fax: +3042169787, e-mail: bont@mie.uth.gr
[b]Department of Physics, University of Patras, 26500 Patras, Greece
[c]Ingenierbüro Litinas, D-76137 Karlsruhe, Germany

A novel desalination concept is described, combining the principles of humidification-dehumidification and mechanical vapor compression. Thermodynamic analysis indicates the effect of operating conditions on water production capacity and compression energy. A laboratory prototype was built to prove the above concept. Preliminary experiments indicate successful operation and point to improvements in a future design.

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF THE PERFORMANCE OF A HEAT PUMP

M. Vlachogiannis, Ch. Panoutsos, V. Bontozoglou & A. Stamatellos

Department of Mechanical & Industrial Engineering, University of Thessaly,

Pedion Areos, GR-38334 Volos, Greece

The steady and transient performance of a heat pump is investigated. Measurements are taken in a properly modified comercial unit and the coefficient of performance is evaluated as a function of outdoor conditions. Computer simulation of steady operation is undertaken and the predictions are compared with manufacturer's specifications. A modification of the control scheme is proposed which permits efficient heating operation at vey low outdoor temperature.

ABSORPTION HEAT PUMP IN COMBINATION WITH SOLAR ENERGY AND FLOOR HEATING/ COOLING SYSTEM

C. A. Balaras, A. A. Argiriou, S. Kontoyiannidis

Group Energy Conservation, Institute of Meteorology and Physics of Atmospheric Environment, National Observatory of Athens, P.O. Box 200 48, 118 10 Athens, Hellas

Tel. +301-3490154, Fax +301-3490113, email: costas@env.meteo.noa.gr

This paper summarizes the first experimental and simulation results regarding the industrial construction of a small European absorption heat pump (10kW) used for space heating and cooling in residential buildings, coupled with solar collectors and a floor heating / cooling system.

The initial experiments in order to study and control the overal performance of the floor heating/ cooling system were carried out in a Climatic Cell. In addition, a simulation model for the entire system is developed under TRNSYS 14.2. The floor heating / cooling model was validated and its accuracy is considered satisfactory, taking into account the experimental errors in boundary conditions of temperature as well as the assumption of the homogeneous indoor temperature.

Simulations were performed for the complete system both in heating and cooling mode, in order to study the influence of various parameters on the efficiency of the system's components, so as to optimize their development, avoid common problems (i.e. high indoor humidity during the summer) and achieve indoor thermal comfort conditions. Validation and sensitivity analysis results will be performed in the coming months.

TEMPERATURE FIELD PREDICTION AROUND A VERTICAL EARTH HEAT EXCHANGER

Vrachopoulos M.Gr., Filios A.E., Stylianou S.K.
C.H.T.E.P.V.S./ T.V.T.T.I.S.E., Department of Mechanical Engineering

In Hellas, the energy demands of the buildings for heating, cooling and hot water in use are covered in a high percentage by fuels that beyond of their contribution to the environmental soiling, they are not renewable and moreover they aggravate the national economy. The 40% of the energy consumption is due to the buildings demands which require temperatures lower than 60 °C and they can be provided by the available environmental temperature. One of the existing environmental energy sources is the normal or natural geothermal energy. The heat pumping is achieved via underground water or rocks utilizing earth exchangers. Experimental studies indicate that the heat pumping through a vertical earth heat exchanger follows an exponential reduction, which is a function of the thermophysical properties of the underground.

The theoretical study includes a method, which is referred to the transient, three-dimensional problem that is described by a system of differential equations which describe the heat conduction into the underground domain and the convection of the heat from the cooling water. The experimental study has been carried out in a vertical earth exchanger with a 60m in length, which is connected with a water-water heat pump and a fan coil.

ENVIRONMENTAL ISSUES

RECENT DEVELOPMENTS IN COMBUSTION GENERATED EMISSIONS ABATEMENT AND CHARACTERIZATION

D. Zarvalis[1], E. Skaperdas[1], E. Papaioannou[1], G. Macheridou[1], C. Altiparmakis[1], M. Kostoglou[1], P. Stobbe[2], R. Zahoransky[3] & A.G. Konstandopoulos[1,*]

[1]*Foundation for Research and Technology Hellas, Chemical Process Engineering Research Institute*

P.O. Box 361, Thermi Thessaloniki 57 001, Greece

[2]*NoTox International A/S*

Sandoften 10, DK-2820 Gentofte, Denmark

[3]*Wizard Zahoransky KG*

Schwarzwaldstr. 3, D-79674 Todtnau, Germany

Emissions legislation worldwide makes imperative the need to reduce and control combustion generated particulate emissions. In the present paper we review the activities of the Aerosol and Particle Technology Laboratory of FORTH/CPERI in the area of pollution control technology for mobile and stationary combustion sources. In particular we present results from the following topics :

1. Optimization of reductant dosing system upstream of a DeNOx catalytic converter
2. Optimization of the design and regeneration of ceramic soot particle filters
3. Real time nanoparticle measurement

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*Tel. (+30 31) 498192, Fax (+30 31) 498190, E-mail: agk@alexandros.cperi.forth.gr
http://www.cperi.forth.gr/en/particle.shtml

NATIONAL STANDARD FOR THE MEASUREMENT OF WIND TURBINE' NOISE, AT THE RECEPTOR'S LOCATION

D. Theofiloyiannakos,
Center of Renewable
Energy Sources

D. Skarlatos,
Department of Mechanical &
Aeronautics Engineering
University of Patras

K. Iliopoulos
Public Power Corporation

Although the sound power levels emitted from new generation Wind Turbines are considerably lower than in the past, they still constitute sources of noise pollution and the sound power emission should be taken into account for the planning of Wind parks or individual Wind Turbines. The need of rules for the noise impact, as a guide for the wind park developer and the nearby inhabitants is obvious. There is a need for relative legislation and for it's implementation there is a need for standard measurement procedures. Standards or guides concerning noise from industrial plants exist in several countries. Generally these procedures cannot be applied in the case of Wind Turbines where the measurements have to be performed under special and difficult meteorological conditions for several values of wind speed.

The Greek standard for the measurement of noise emitted from Wind Turbines at the receptor's site, was the main work of Working Group 5 : "Acoustic noise from Wind Turbines" under the Technical Committee ELOT-CRES/TC-81: "Wind Turbines". The standard describes two methods for the measurement of W/T's noise at the receptor's site. Special attention has been given on background noise correction and also in techniques for improving the signal to noise ratio. These techniques and methods have been prepared so that they can be used for the verification of compliance with noise legislation regarding noise limits and for the verification of noise propagation models.

TONALITY IN ACOUSTIC NOISE EMISSION FROM WIND TURBINES

D Skarlatos
University of Patras

D Theofilogianakos
CRES

The acoustic noise annoyance is a major environmental problem. The annoyance of noise depends upon many parameters, as for example, the level of the noise, the impulsive character of it, the presence of high level tones (known as tonality) etc.

The tonal character of noise is essential in the determination of the total annoyance, for this reason in many countries according to their standards, a penalty is added to the totally calculated noise level.

Although in the modern wind turbines the tonality of the emitted noise is reduced, the problem is still remaining. The decision if the existing tones in the spectrum of noise is dominant or not, sometimes is very difficult case and sometimes is depending upon the experience of the acoustic engineer.

With this paper we try to present one (generally accepted) method for the determination of the tonality, which is proposed in the Greek standard: Measurement of noise immission from Wind Turbines at noise receptor locations. A reference on the existing methods, which all of them is based on the Zwicker's critical bands theory for the tonality calculations, is also presented.

ANALYSIS OF RESULTS DERIVED BY EXHAUST MEASUREMENTS AT CENTRAL HEATING FURNACES

Gregoriades Yiannis

Organization for the Master Plan and Environmental Protection of Thessaloniki

4 Angelaki St., 54636 Thessaloniki, Greece

The analysis results derived by various exhaust measurements at central heating furnaces are presented in the paper. This was a study task included in the framework of the Project: "Control of atmospheric pollution produced by local combustion sources" as a part of the URBAN EU Initiative.

The measurements mainly dealt with the central heating process at residential units as well as public and municipal buildings and covered a period from October 1997 to March 1998 (municipalities of Evosmos, Menemeni and Polihni). The measurements were realized by using portable electronic gas exhaust analysers at stationary sources included. Gas Temperature, Temperature of environment, Oxygen (O_2) and calculation of Carbon dioxide (CO_2), Carbon Monoxide (CO), Nitrogen Oxide (NO), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Draft, efficiency. Interesting enough is to observe that is the first time field measurements of CO, NO, NO_2, SO_2 parameters was taken.

The study groups also filled out a survey check list dealing with various attributes of each individual derive such as: building insulation, manufacturer, type, age and horsepower of furnaces and burners, maintance level of device, fuel consumption etc.

EDUCATIONAL ISSUES

INTERDEPARTMENTAL EDUCATION IN RENEWABLE ENERGY SOURCES: POSSIBILITIES, DIFFICULTIES AND PERSPECTIVES

K. Axarli, A. Papadopoulos, M. Papadopoulos

Laboratory of Building Construction and Physics, Department of Civil Engineering, School of Engineering, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece Tel. +30 31 995616, Fax. +30 31 995603

The tasks carried out by engineers in the environmental and energy sector are changing rapidly and so are the requirements set to their education. In this paper are presented the experience obtained and the results drawn within the frame of an interdepartmental course, carried out as a pilot project, by the Departments of Civil Engineering and Agriculture.

The requirements set by the market, regarding educational and environmental management by engineers, have been analyzed and quantified, in order to determine educational gaps and overlaps. As a result, the necessity for interdepartmental courses was underlined, in order to provide a complete approach on specific topics.

Two courses on rational use of energy and on renewable energy sources are carried out, incorporating a series of lectures on theoretical and applied issues. The experience obtained in this way will be utilised in the revision process of the syllabuses of the two departments.

DEVELOPING A DATA-BASE FOR ENERGY AND THE ENVIRONMENT
THE HEPHAESTOS PROJECT

D. Sanopoulos, A. Kungolos, Z. Kiparissidi & B. Keramaris

FORTH / Chemical Process Engineering Research Institute

6th km Harilaou-Thermi Rd., P.O.Box 361, 57001 Thermi, Thessaloniki, Greece

The exploitation of scientific and research activity in important areas, such as Energy, is substantially supported through collection, organization and diffusion of its results. Modern development in the sector of Telematics and Electronic Information make electronic organization and diffusion of information necessary. In the present study, the **HEPHAESTOS** project is presented, which is supported by General Secretariat for Research and Technology, of the Ministry of Development of Greece, in the frame of programme *EPET II, Measure 2.4 (National Information System, Creation and Development of Information and Databanks for Science and Technology)*. Chemical Process Engineering Research Institute (CPERI) develops the project since 1.9.98. **HEPHAESTOS** is a databank with information concerning Energy and Environment. The main goal of the work is the collection and utilization of information concerning these two scientific fields as well as the exploitation of relevant information sources, scattered in Greece. The databanks that will be developed will be of four different categories. Directories of research groups and activities, bibliographical databases, numerical databases and images databases. Main subjects that will be covered include legislation, standardization, research results and presentation of research groups and of offered services in the environmental sector as well as presentation of enterprises active in the field. In the current study, the methodology of the development of Hephaestos is presented and the potential utilization and benefits that will come out of its use are explained. It has to be emphasized that in Greece the development and distribution of on-line databanks is still in an initial stage and, therefore, significant benefits will come out of this effort. Obviously, some of the expected benefits will satisfy existing needs for information of both scientists and business people.

INTERNET BASED, ENERGY AND ENVIRONMENT INFORMATION CENTERS

K. Karatzas, A. Papadopoulos, N. Moussiopoulos

Laboratory of Heat Transfer and Environmental Engineering

Department of Mechanical Engineering, Aristotle University Thessaloniki,

University Campus, Box 483, GR-54006 Thessaloniki, Greece

tel.: +30 31 996139, 996011, fax: +30 31 996012

email: kostas@aix.meng.auth.gr

The need for redefining the relationship between the building, their users and the environment leads to the demand for reliable and easily to use information in energy and environmental issues. Thus, information supply in issues of environmental and energy management for buildings can be achieved by making use of World Wide Web applications. These applications should supply technical instructions, while accessing information relevant to atmospheric environment of the buildings. In this paper a generalised architecture of such an application is presented. In addition, technical details of these applications are discussed focusing on the use of remote sensing, and a short example of an operational application is introduced.

ENERGY POLICIES

INNOVATION POLICY FOR RENEWABLE ENERGY SOURCES

Y. Stamboulis and C. Edippidi

Department of Mechanical & Industrial Engineering, University of Thessaly

Pedion Areos, GR-38334 Volos, Greece

Until now the renewable energy policy has focused on two critical points (technology development and investment in energy production capacity), ignoring a third critical one, equipment production. In this paper an alternative approach is suggested, which integrates the approach to both supply and demand.

Initially we list the problems that have occurred during the development of renewable energy systems and their deployment in energy production and management.

Follows an analysis for the different nature of renewables as technological systems and also of the need of a different approach as an innovation process.

Finally, we are suggesting directions of action, aiming to integrate a policy system based on the innovation approach.

The point of view of this analysis should contribute substantially to the design of a policy in order to develop successful applications in the field of renewable energy sources, as well as in the production of corresponding products.

CENTRAL COGENERATION UNITS IN ATHENS - AN ECONOMICAL APPROACH

Fotios E. Karagiannis

PUBLIC POWER CORPORATION of GREECE
Strategy and Planning Department
Tel.: +301-3825369   Fax: +301-3847568
E-mail : do.spd@dei.gr

The work presented in this paper concerns a computer model for the economical assessment of investments in the cogeneration field. All economic elements of the investment are taken into account and, in combination with the necessary technical data, the model calculates the cashflows of the whole investment and of the equity as well as some basic indices for the economic assessment such as the Net Present Value, the Internal Rate of Return, the Discounted Payback Period and the Benefit - to - Cost Ratio of the cashflows above.

A prefeasibility study has been performed on the operation of central cogeneration units (CHP) in Athens. The obtained results were encouraging and the above mentioned model has been applied. A parametrical approach has also been realized.

The results that the model gave show that the Project is economically viable under certain conditions. Basic parameters directly affecting the Project's viability are the initial investment cost, the fuel cost and the sales price of the produced electricity.

The following table contains some of the obtained results that show the influence of the above parameters on the Project's viability.

NG price	Basic		Basic-20%	
$/kW	1000	600	1000	600
Project casflow				
NPV at 10% (M. of GRD)	92.9	609.7	291.3	808.1
Rerurn on Investment (%)	10.9%	18.1%	12.8%	20.5%
Equity cashflow				
NPV at 10% (M. of GRD)	-56.8	313.9	72.2	442.8
Return on Equity (%)	8.7%	20.5%	11.7%	24.9%

THE STRATEGY OF THE PUBLIC POWER CORPORATION FOR THE PROMOTION OF THE GOGENERATION IN GREECE

Dr. D. Papakonstaninou   **Dr. F. Karagiannis**

PUBLIC POWER CORPORATION of GREECE
Strategy and Planning Department
Tel.: +301-3825369   Fax: +301-3847568
E-mail : eus.spd@dei.gr   and   do.spd@dei.gr

The electricity sector is in the phase of restructuring. Within the European Union the Directive 96/92/EC guides this restructuring. New rules will be applied concerning the production, transmission and distribution of electricity, taking into account the need that the transition to an Internal Electricity Market be progressively done in order that the Electricity Companies can be adapted to the new environment. Within the broader European enregy policy content, Combined Heat and Power (CHP) is promoted, as it contributes to the security of supply, the competitiveness of the economy and the reduction of environmental pollution. The Directive also foresees priority in the dispatching of CHP units. A draft of the Law for the restructuring of the Greek electricity sector has been recently published for the adaptation of the Greek legislation to the Directive. In Greece there exist actually CHP installations of 223 MW$_{el}$. The Public Power Corporation has several activities in the field of District Heating in the areas of Ptolemais, Kozani, Amyntaion, Florina and Megalopolis. The Greek legislation promotes CHP by giving economic incentives and simplifying the procedures for the installation and operation of such units. About ten applications in the CHP field have up to now been done from both public and private sector. The possibility of long-term agreement is also foreseen. It concerns an agreement between PPC and a consortium, for the construction and/or operation of a CHP plant whose the electric production will be sold to PPC under agreed terms. Another possibility is the creation of subsidiary companies with third parties, such as the company COGEN HELLAS S.A., which has been created recently in collaboration with Gas de France International. It is the intention of PPC to sustain the effort to promote CHP in Greece by the use of all possible means available in the existing and future legislation.

THE PROGRESS OF THE OPERATIONAL PROGRAMME FOR ENERGY

Dr. Panos Liveris

Dep. Head of the Management Consultant of O.P.E.

Georgia Laskari, M.Sc.

Head of the Secretariat of the Monitoring Committee of O.P.E.

Ministry of Development, Michalakopoulou 80, GR 10192 Athens

tel. +301-7488648,-9, fax +301-7717609

The Operational Programme for Energy (O.P.E.) was a fundamental design and implementation tool for the national energy policy during 1994-1999, as a part of the "Community Support Framework II". The objective of O.P.E. regards:

- the support of projects for facing of energy demand
- improvement of energy efficiency
- enlargement of the penetration of Renewable Energy Sources (R.E.S.)
- exploitation of the rest indigenous energy sources.

The total budget is 1116 Meuro, of which 41% constitutes national contribution, 32% Community support and 27% private investments. The O.P.E. succeeded to attract investments for R.E.S. projects, which amount installed power three times the installed R.E.S. power in Greece till today.

The strengths and the weaknesses of O.P.E. proved useful for the design of the new Programme for Energy and Natural Sources, which is going to be implemented during the period 2000-2006.

ELECTRICITY PRODUCTION COST IN GREECE

Kodossakis D., Mosxovaki St., Vlachou D., Kaldellis J.K.

Lab of Soft Energy Applications & Environmental Protection

Mechanical Eng. Dept., TEI Piraeus,

e-mail: sealab@gdias.teipir.gr

Pontou 58, Hellinico 16777, Greece

After the EU Electricity Directive came into force in 1997, each EU country has had to open up its local electricity market in stages by 2003. This electricity market liberalisation is going to impose seismic changes on the electricity production industry, during the next three years. In an effort to support the competitive position of Greek electricity producers, the energy production cost (social cost excluded) from various available resources in Greece is investigated. The results obtained are analytically compared to the existing prices of the international (european mainly) electricity market, for a time horizon of twenty years.

Finally, a comparative study, for various geographical regions of Greece, is carried out, concerning the electricity production cost by wind, solar, hydro and oil power stations. Using the above mentioned piece of information a more rational planning for the Greek electricity production system is proposed.

INVESTMENT VIABILITY ANALYSIS OF RENEWABLE ENERGY SOURCES

G. Christodoulou

Mechanical Engineer, 14 Gazias Street, Ano Ilisia 15771, Athens

The evolution of energy investments of Renewable Energy Sources, render them as energy production facilities and make them competitive to conventional energy sources. Its also considers an evaluation of their viability.

A renewable energy source facility, operating in the existing Greek legislative framework, gives the capability to any independent investor to produce and sell energy to PPC with predetermined price, this represents an investment which we are going to examine if and under what circumstances it will be viable.

THE PHOTOVOLTAIC MARKET IN GREECE
MARKET RESEARCH

Ioannis Mavrogiannis, Theocharis Tsoutsos, Efstathios Tselepis

Centre for Renewable Energy Sources (CRES), 19th km Marathonos Ave., 19009 Pikermi, Attiki, Greece

This specific paper, presents the results of a National research study, which took place in December 1998, within the framework of THERMIE-B programme STR-938-96-HE/IT: "PV markets in the Mediterranean-Assessment of potential barriers. Action plan for development", of the D.G. XVII of the European Commission.

The study depicts the current situation of the (PV) market in Greece, including the segmentation of the PV applications (independent applications for households, agricultural uses, external lighting, telecommunications-transceivers, lighthouses of the Greek Navy, demonstration and training projects, etc.).

Furthermore, the following aspects are also presented in respect to the PV market:
- the current legislative framework (laws, European-National programmes, etc.)
- the predictions for the next 5 years according to market actors' estimations
- the critical parameters for the wide speed promotion and dissemination of PV technologies.

INVESTIGATION OF POWER PEAK LOAD OCCURRENCE IN SELECTED REGIONS OF NORTHERN GREECE

George Tsilingiridis

Laboratory of Applied Thermodynamics, Department of Mechanical Engineering
Aristotle University of Thessaloniki, 540 06 Thessaloniki, Greece
Tel: +30-31-996084, fax: +30-31-996019, e-mail: tsil@eng.auth.gr

The seasonal variation of electric power peak load in representative regions in Northern Greece is analyzed, and the factors that influence the power demand are investigated.

Main factors that influence power demand and govern peak load occurrences are: summer activities in agriculture (pumping) and tourist services, tariffs policy of Public Power Corporation (affecting heating in buildings), and summer air conditioning in major urban areas. According to the main characteristics of each geographical region, e.g. agricultural, industrial, urban, tourist services, these factors have, separately or in combination, a major predominant influence on power peak load.

The examination of historical evolution of seasonal variation of power peak load for the years 1990, 1994 and 1997 reveals a shift of peak load from winter months to summer.

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