



ECOS 2018

Proceedings of the
**31st International Conference on Efficiency, Cost,
Optimization, Simulation and Environmental
Impact of Energy Systems**



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FOREWORD



On behalf of the Organizing Committee it is with great pleasure that we welcome you to the ECOS 2018 - the 31st International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems.

It is an honour to host such a distinguished venue whose excellence has been, for the last three decades, at the forefront of energy development. It is also recognition of the institutions that are engaged in organizing this event. In order to push novel frontiers and to keep in touch with the new trends in energy, additional topics are included into the scope of this conference. One feature we are excited about is the introduction of a special session on “Industrial Challenge”, a forum dedicated to discuss the energy problem from the industry perspective.

ECOS 2018 will take place in Guimarães, the first capital city of the Nation. It is a pleasant historic city awarded with the status of World Heritage of Humankind by UNESCO in 2001 and host of the European Capital of Culture in 2012.

José Carlos Teixeira
Senhorinha Teixeira

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KEYNOTE LECTURE



Professor Antonio Valero

CIRCE - University of Zaragoza
Zaragoza, SPAIN

Thermodynamic rarity, recyclability and loss of critical raw Materials in the energy transition including mobility: threats and limits

This paper is presented by invitation of ECOS'18 organizers to open a deep discussion among thermodynamicists. The book *Thanatia* opened a new thermodynamic vision of natural resources. I.e. the study of deterioration of planet Earth as a whole thermodynamic system and a new way to study the rate of loss of mineral resources of the Planet using exergy analysis. In this paper, I present and define in exergy terms the replacement cost, rarity, recyclability and downcycling, and is applied to the present automobile sector. A current conventional car contains 43 different metal elements, only 6 metals become recycled. The use of rarity as an indicator clearly shows that only the bulky is recycled, not the valuable. The foresight future of vehicles is towards an increasing demand of raw and sophisticated materials. Hybrid and battery electric vehicles have between 1.3 and 2.3 times more impact than conventional ones. This trend is also clear with new renewable energies. So the question is: to what extent the world can become dependent on these materials in a necessary decarbonized economy? We took for this purpose the 2DS scenario of the International Energy Agency for the year 2050. Considering the content of critical materials of these technologies, we found the replacement cost of the minerals used (9,355 Mtoe) is greater than the energy provided by all fossil fuels and nuclear energy (6,405 + 1,789 Mtoe), and even by all renewable energies (6,901 Mtoe). If materials demand grows exponentially, the required energy for its mining and smelting will also do it. This means that the cost of raw materials to decarbonize the economy could be unattainable. In other words, the Energy Transition could not be realized without a simultaneous Transition to Circular Economy. I.e. An In-Spiral Economy focused on separating techniques and promote circularity audits based on Thermodynamics.

KEYNOTE LECTURE



Professor Efstathios E. (Stathis) Michaelides

Texas Christian University (TCU)
Fort Worth, TX, USA

Transition to renewable energy - the need for energy storage

A common misconception for the substitution of fossil fuels with renewables for the production of electric power is that the amount of electric energy from wind and solar may be increased without limit. Because the production of electricity from wind and solar energy does not follow the power demand, the installation of large numbers of solar and wind units and the production of a higher fraction of the total annual energy from renewables in a region meets a barrier during periods of time when the power produced by the renewable sources is high and exceeds the demand of the electricity grid. At present, this limit is reached when solar and wind units produce 25-30% of the total energy used in a region. This is sometimes called U-shaped demand and has an adverse effect on the operation of base-load units operating with the Rankine cycle, such as nuclear power plants. Solutions to this problem include: a) the substitution of all steam units with gas turbines; b) central control of power demand (almost impossible in a market economy); and c) energy storage. The last option allows the operation of nuclear units that do not emit carbon dioxide and appears to be the best solution.

This presentation examines the causes and effects of U-shaped demand through a thermodynamics background. The analysis is based on hourly data on the supply (from PV cells and wind turbines) and demand for energy and power, which were collected over a period of an entire year. The hourly energy demand is analyzed and balanced with the supply of energy. Energy storage systems are used to ensure that sufficient energy is available to the consumers when the demand arises. Hourly data are presented for the demand, the supply, and the storage system capacity for the following cases:

1. A building with high air-conditioning demand in the summer.
2. A township that includes hundreds of buildings and industry.
3. A large geographical region, supplied by several electric power units.

A thermodynamic analysis of the hourly energy demand and supply is performed in each case and the hourly storage requirements are calculated and reported. Conclusions are drawn on the penetration and rated power of wind and solar units within a region; and recommendations are offered for the substitution of fossil fuels with renewables that would not compromise the reliability and flexibility of the electricity grid.

KEYNOTE LECTURE



Professor Noam Lior

University of Pennsylvania
Philadelphia, PA, USA

Sustainable energy development: the present (2018) situation, recent critical changes, and possible paths to the future

This invited keynote paper is the most recent among similar energy reviews in the sustainability framework published by the author, updated to year 2018 and is augmented by identifying and discussing some of the main game-changing developments in the extremely dynamical energy field. This dynamic transience often results in significant consequences for humanity and can seldom be foreseen or recognized early enough to allow timely correctional reactions.

Recent estimates and forecasts of the conventional fossil fuel resources and their reserve/production ratio, nuclear power, and renewable energy potential, and energy uses are critically surveyed. A brief discussion of the status, sustainability (economic, environmental and social impacts), and prospects of their energy use, and of power generation is presented. Some of the main ongoing and high probability energy game-changers discussed are:

1. Postponement of "Peak Oil"
2. Significantly increasing use of unconventional fossil fuels: shale and tight gas and oil
3. Ruinous effects of strong fluctuations of fuel prices, including their recent precipitous drop
4. Accelerated decoupling between energy consumption and economic growth
5. Transition to energy independence of the USA
6. Criticality of the future of coal
7. The nuclear disaster in Japan and nuclear power future
8. Market entry impact of electric cars
9. Criticality of the transition to renewable energy use
10. Harbingers of critical policy changes
11. Accelerated entry of the sharing energy economy
12. Important increase of support by organized religion for sustainable development

The author's view of the promising energy R&D areas, their potential, foreseen improvements and their time scale, and last year's trends in government funding are presented.

KEYNOTE LECTURE



Professor Paula Ferreira

University of Minho
Guimarães, PORTUGAL

Energy planning for smart and renewable systems

The share of variable output generation from renewable energy sources (RES) is increasing across the world and new approaches are required to keep system security at an affordable price. Whilst the transition towards high or even 100% RES systems is gaining increasing attention from policy makers, the technical and economic feasibility of these systems for operating at regional or larger scales is still far from being a consensual matter. It is however, recognized that a large effort is required to change historical planning paradigms, frequently relying on cost optimization planning models under a given set of assumptions and constraints. The inclusion of human behaviour and its relevance on long-term decision making has not been fully considered in such models, with climate experts already calling attention to the need to gain new insights into issues related to human behaviour and choices. Although this concern is not new, the popularity of the human centred decision making processes is growing, driven by the increasing opportunities that emerged with smart grid appliances and also by their potential to support the integration of variable renewable generation. In this session the transition towards low carbon energy systems will be debated, analysing how smart energy appliances may assist and improve the planning and operation of electricity systems with high RES share, by coordinating supply and demand and providing the required system flexibility.

KEYNOTE LECTURE



Professor Silvio de Oliveira Junior

University of São Paulo
São Paulo, BRAZIL

Exergy assessment of the human body: thermal comfort, physical activities and pathologies

One of the most fascinating and challenging applications of the Second Law of Thermodynamics is the attempt to study and understand the evolution of life and living organisms. It is well known that human life has a beginning, a development, and an end. Moreover, the evolution of living organisms is a typical example of irreversible process! Human body behaviour and performance are strictly linked/influenced by environment conditions: atmospheric pressure, temperature and humidity impose constraints to human life development. This is one of the best examples of energy system whose performance assessment requires information of the actual environment in which it is placed, being a good example and opportunity to apply exergy analysis in order to understand, assess and improve its performance. The application of exergy analysis to human body aims at determining the quality of the energy conversion processes that occur in the several systems, which compose the human body. By using this approach, it is possible to quantify the exergy destroyed rate and the exergy efficiency of these processes as well as of the whole body, under different operational and ambient conditions. The information obtained with this analysis allows comparing a healthy body performance with that of a body with a particular disease/pathology aiding to carry out the diagnosis of this type of disease, identifying the main sources of the irreversible processes caused by the disease evolution and estimating the impact on life expectancy (for instance, an aortic valve stenosis is an increase in the head loss of the cardiovascular system, overcharging the heart). Also, the exergy assessment of the human body can be a useful tool to establish thermodynamic thermal comfort requirements and to rank athletes under different level of physical activities. Based on simplified models of the human body, developed to represent the main energy interactions that take place in it, this lecture will describe and discuss detailed Exergy Analysis applications aiming to assess the quality of the energy conversion processes that occur in the body, its several systems and in biochemical reactions involved in these processes. These analyses are:

- Determination of the exergy behaviour pattern of the body and its respiratory system for a healthy subject under different environmental conditions and physical activity intensities. In order to achieve this target, destroyed exergy rate and exergy efficiencies are calculated for different altitudes, acclimatization periods, temperatures, relative humidities and exercise intensities. This procedure was applied to a thermodynamic model of human body for basal conditions and to experimental results of runners during different level of physical activities;
- The assessment of human body thermal comfort conditions by means of two terms of the exergy balance: destroyed exergy and exergy transfer to environment.
- The dependence of the life expectancy with the cumulative destroyed exergy throughout life. An exergy age index is proposed, allowing comparing the rate of life progression of a given subject under different conditions, based on the evidences that there is a maximum value of cumulative destroyed exergy throughout life. The impacts in the life expectancy of smoking, hypertension and cancer are assessed and discussed.

KEYNOTE LECTURE



Professor Yoshiharu Amano

Waseda University
Tokyo, JAPAN

Modeling Platform for Cooperative Energy Management Systems in Smart Cities

This keynote lecture introduces a platform which is composed of a model of electric distribution network connecting residential homes, commercial buildings and industries in a smart city. To overcome tough issues such as PV (photovoltaic) curtailment, massive penetration of electric vehicles, we have been investigated on our platform accommodating cooperative energy management systems (EMSs). With the software simulator, we can investigate performance of the distribution network connecting individual load at each end-point, which emulates typical demand profiles of residential, commercial, and industrial sectors. Then the dynamic performance can be confirmed on another hardware emulator. Smart home demonstration sites are also prepared for evaluating strategies implemented on each HEMS (home energy management system) connecting with digital communication to smart appliances. The platform virtually constructed as a cyber model of a smart city with a distribution network (DN). Parameters of each component model of residential state-of-the-art devices such as fuel cell cogeneration, CO₂ heat pump water heater, electric energy storage, and PV are identified on our test bed. The simulation platform involves models of demand-side EMSs and supply-side EMS which govern the distribution grid stable. The demand-side EMSs connecting to the end point of the DN manages appliances and distributed energy source such as HVAC system, PV, battery, fuel cell cogeneration, heat pump and so on. The supply-side EMS manages DN with changing parameters of SVR (step voltage regulator) and OLTC (on-load tap changer) under a certain constrained. Utilizing machine learning, each EMS has capability of forecasting the day-ahead demand profiles including PV output. Device/component model has its own local control loop implemented. The investigation on the simulation platform we confirmed that the cooperative management between supply-side and demand-side EMSs outperforms the conventional grid control. The power flow, electrical losses, and voltage profile on the DN model can be confirmed with vital visual images with reliable spatiotemporal resolution. In addition, indices measuring the sustainability of the model city, such as CO₂ emission, can be estimated from each scenario. Some results from case studies on massive PV installation and electric vehicle penetration can be demonstrated.

HONOURING SESSION: PROFESSOR SZARGUT



**Professor Jan Szargut, Full Member of Polish Academy of Science
Honoris causa doctor of Silesian University of Technology, Częstochowa University of
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Professor Jan Szargut – Obituary

Wojciech Stanek, Andrzej Szlek and Wojciech Kostowski

Teaching Exergy Thermodynamics

Ozer Arnas

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