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Cleaner energy for sustainable future

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A B S T R A C T

This special issue of the *Journal of Cleaner Production* focuses on "Energy for Sustainable Future". It is designed to mirror the increasing relevance of renewable energy sources and improved efficiency as crucial topics for practitioners in industry, for governmental policy makers, as well as for civic service providers, researchers, and educators. The purpose of this special issue is to serve as a catalyst for dialogue. The global warming related to CO_2 emissions, coupled with steeply rising energy prices and the recent global financial institutional melt-down are causing massive societal concerns and give rise to increasing demand for ways to improve societal and individual energy efficiency and for ways to shift increasingly to alternative, low or non-carbon based energy systems.

Until recently, industrial energy efficiency improvements have focused on improvements on efficiency rather than on the integration of renewable sources. The aim of this special issue is the identification of policies to support the development and implementation of technologies and management approaches we can employ to make the transition to more sustainable societies. The collection of papers in this special issue provide a foundation for students, researchers, scholars, practitioners and policy makers interested in making sustainable development more than a metaphor.

The papers include focus upon ways for:

(a) Improving industrial process to achieve improvements in energy efficiency.
(b) Minimising waste disposals and reducing their impact through better management.
(c) Reducing CO_2 emissions by making progress toward lower carbon, renewable energy based systems,
(d) Improving production of biofuels and hydrogen production systems, facilitated by employing cleaner production and novel LCA tools.
(e) Improving integration of advanced materials and energy efficient equipment in different industrial sectors.

Current and future developments in national and world economies are closely connected to sustainable, efficient and safe usage of raw materials and upon energy based on cleaner production concepts and approaches that are ecologically and economically appropriate for the short and for the long-term future of society.

These challenges have received considerable attention in the media and scientific journals over the last several years. The idea of developing a specialised conference focussed upon them was put forward on various occasions. Focus upon them became reality on the 5th and 6th May 2008 in the historic Castle of Veszprém, Hungary, the current premises of the Hungarian Academy of Science which hosted the Workshop.

The Workshop was a stimulating event and an overwhelming success, with nearly 100 contributors from Africa, North America, Asia and Europe, representing 28 countries. After a comprehensive selection and thorough reviewing procedure 11 papers were selected for this special issue.

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1. Introduction

The development and application of cleaner environmental technologies offer multiple benefits such as: reduced emissions, less waste and cost savings from reduced energy & resource use during production as well as due to improved systems of recycling and waste management. Many participants were concerned that cleaner technologies and cleaner production, in general are diffusing comparatively slowly, in spite of the great benefits that have been documented in systems that have implemented them.

There are numerous questions to be answered. In this special issue, the following issues are addressed:

(i) Is wide-spread application of biofuels thermodynamically sensible and can it really lead to progress toward sustainable societies?
(ii) What is the potential of the application of the environmental performance strategy map: an integrated LCA approach to support the strategic decision making process for cleaner production?
(iii) What potential can the new EU supported energy efficient technologies tool EMINENT offer in comparison with other energy technology assessment tools?
(iv) How can new reliability, availability and maintenance software tools contribute to improved and more efficient waste and emissions minimisation?
(v) What can/should be done to accelerate the implementation of novel, SuperSmart Grid system technologies designed to manage the collection of renewably produced electricity from multiple, decentralised sources, and its safe and efficient transmission over long distances?
(vi) What are key advances in 'waste to energy,' technologies and what is their place in perusing the transition to sustainable regions?
(vii) How can the 'pinch analysis,' energy saving methodology that has been applied to total sites [1] and industrial, civic and agriculture sectors [2] be used for carbon-constrained planning for sustainable power generation?
(viii) How can improved heat storage provide a cleaner and economically more sound option for the minimisation of energy use in multipurpose batch plants?
(ix) What cleaner production and energy efficiency improvements can be achieved by using improved 'plate heat exchangers' in phosphoric acid production?
(x) What are the most economical raw materials for fermentative hydrogen production and how clean are these processes?
(xi) Industrially, how widely applicable is the novel, non-equilibrium – biosorption column modelling on porosity effects?

A selection of papers presented at the conference was performed to provide suggestions and answers to these and related questions in this special issue.

At the start of the 21st century, rising energy costs coupled with increasing concerns about global warming related to CO_2 emissions, resulted in increasing interest in alternative, low and non-carbon based energy sources. In addition, there has been renewed interest in energy efficiency improvement methods compared to only a few years ago when energy was relatively inexpensive and abundant. Although, some small scale renewable energy systems have been developed to help satisfy industrial and municipal heating and cooling demands, most such efforts have been focused on individual family dwellings.

Improving energy use efficiency is becoming increasingly important for combating rising energy costs and for fulfilling carbon emission tariffs in the industrial sector. Additionally there is increasing interest in improving energy use efficiency in the domestic sector, with most investments on insulation, energy efficient lighting, and energy efficient appliances. Although these efforts are helping societies to make slow progress towards a lower level of carbon based energy use and consequently to some reductions of CO_2 emissions, there has been little effort at systematic planning for producing an integrated energy system that includes industrial and domestic supply and demand. The design and implementation of combined energy systems for industrial, business and residential buildings has been limited to a few, isolated cases in which systematic design techniques were employed to produce a symbiotic energy grid system. One of the articles in this special issue addresses these challenges and opportunities.

2. Research opportunities highlighted in this special issue

Although there are several renewable energy sources that can provide individual family heating and cooling, and thus reducing the level of greenhouse gas emissions in comparison with fossil fuel based systems, the focus of this special issue is on sources that have been demonstrated or are operational on a regional scale. Domestic and industrial solid waste, after the recyclables have been removed, can be used as a valuable source of electricity and heat energy via CHP systems. The example of energy from sludges and solid waste demonstrates this. The CHP options, although not new are significant in multiple ways. Because in many cases waste contains a considerable proportion of biomass the use of waste helps society to reduce its greenhouse gas emissions due to reduction in usage of carbon based fuels.

A brief overview of keywords of the articles in this special issue, provides an overview of the topics addressed:

2.1. Energy/heat/power/electricity

Sustainable energy [3], energy efficiency [4], energy technologies [5], energy models [5], renewable electricity [6], electricity networks [6], waste to energy [7,8], power sector planning [9], clean electricity [9], heat integration [9], energy saving retrofit [10], heat recovery [10].

2.2. Cleaner production/LCA/sustainability/waste/CO_2

LCA [4], sustainable environmental performance [4], footprints [4], environmental burden reduction [4], early stage technologies [5], Smartgrid [6], SuperSmart Grid [6], thermal waste treatment [7], waste treatment technologies [7], carbon capture and storage [9], carbon footprint [9], CO_2 capture and sequestration [9], cleaner production [10].

2.3. Biofuels/hydrogen

Biofuels [3], biomass [3], hydrogen [12], hydrogen fermentation [12], biomass utilisation [12], biosorption column [13].

2.4. Production, industrial plants and advanced processing equipment

Supergrid [6], plate heat exchangers [11], phosphoric acid production [11], hydrogen fermentation [12], biosorption column [13].

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2.5. Advanced analytical software tools and methods

Assessment tools [5], EMINENT [5], reliability [8], availability [8], maintenance [8], RAMS software [8], pinch analysis [9], optimisation [10], MILP [10], partial differential equations [13], non-equilibrium model [13].

3. An overview of papers in this special issue

(i) The first group of papers highlights progress toward sustainability that can result from the use of cleaner production technologies. It assesses biofuels, environmental performance strategy and early stage energy efficiency methodology assessment.
(ii) The second group of papers is focussed on electricity transmission and delivery, including advances in converting waste to energy and in minimising waste by using software designed to assist in making improvements in system reliability, availability and maintenance.
(iii) The third group of papers is related to carbon/CO_2 related issues – minimising it during power generation, minimising emissions via improved heat storage and efficient usage due to improved technologies and planning of batch processes.
(iv) The last group of papers is devoted to advanced and compact heat exchangers and their application in production of hydrogen. A final paper addresses improved efficiency of biosorption columns.

3.1. Sustainability and cleaner production

The first paper of this special issue is an article titled, ‘‘Biofuels: thermodynamic sense – and nonsense’’ by Jack Ponton, from the University of Edinburgh, Scotland, UK [3]. He discusses issues about whether the current enthusiasm for biofuels ignores basic thermodynamics and other constraints. He considers the fundamental problem related to the combustible part of biomass being almost invariably solid, while the major demand for energy, except electricity, is in the form of gas or liquid fuels. Most current, conversion processes [14] are of low efficiency even for the convertible parts of the plant; the energy which could be obtained from burning a kg of wheat grain is about twice the amount that can be obtained via fermentation into ethanol. Furthermore all current liquid fuel processes can use only part of the plant. His paper identifies those biofuel technologies which make sense – as co-firing straw with coal in power stations, and those, which because of thermodynamic considerations, are nonsense – such as making ethanol from grain in Europe or from maize in the USA. Since arable land is a scarce resource in most of Europe, locally grown biofuels are unlikely to become a major replacement for fossil fuels. Jack Ponton highlights strategies which can help to maximise this contribution, as well as some promising, emerging technologies that can help societies make the transition to low fossil carbon systems.

His summary is as follows:

Nonsense: Attempting to produce ethanol from grain in northern climates. Diverting valuable arable land to the production of fuel oilseeds. Making special ‘biodiesel’ rather than using vegetable oil more directly.

Questionable: Encouraging large scale production of biofuels in Brazil, Indonesia, etc. Expecting biofuels to support transport at its present scale.

Sense: Burning agricultural by-products such as straw, and plastic waste, in existing power stations. Development of solid biomass technologies. Growing rapeseed for oil on set-aside land to blend with mineral oils. Carrying out research on: genetic modification to produce high biomass yielding plants on marginal land, algae, etc. as sources of biomass and processes for efficiently converting lignin and cellulose to liquids. Practically any energy conservation policy such as investments in insulation, improvements in lighting efficiency and efficient appliances, yield better economic returns than any renewables generation or fuel development.

In the second paper, titled, ‘‘The environmental performance strategy map using an integrated life cycle assessment approach to support the strategic decision making process,’’ by De Benedetto and Klemeš [4], the authors focus upon the main developments and limitations of LCA as a tool for strategic decision making. Because of this, they developed the environmental performance strategy map as a complementary tool. This graphical representation tool is designed to provide a single indicator – the sustainable environmental performance indicator – to expand upon the use of footprints (carbon, water, energy, environmental impact) as mere communication and awareness tools. The introduction of financial aspects within the tool, complements the environmental and work environment considerations and provides more holistic answers to comparative sustainability options. This tool can be successfully applied to provide an overall indicator of the environmental performance of existing applications or can be used as a supporting tool in comparing competing options in a strategic decision making process. Use of this tool is demonstrated with a specific case to illustrate the steps to find the optimal balance between cost and environmental impacts. Application of the tool offers the potential for balancing and minimising environmental impacts in performing and using energy, carbon, water footprints as well as in integrating the impacts of the system on emissions to air, water, soil and the impacts upon worker health and safety. The tool facilitates the integration of all of the parameters into a single indicator, a term that is valuable in making decisions among comparative options.

The third paper ‘‘Comparison between EMINENT and other energy technology assessment tools’’ is authored by Seguardo et al. [5] from Lisbon, Portugal. The early stage energy efficiency technology assessment tools can help decision makers in the identification and evaluation of sustainable energy solutions, in order to integrate them in long-term energy strategies. One of them is the EMINENT tool, developed with the support of the European Community Sixth Framework Programme to assess performance and market potential of early stage technologies (EST) in a predefined energy chain, under national conditions, in terms of financial feasibility, energy performance and environmental soundness. This paper presents a comparative study between EMINENT and other tools for energy technology assessment. The tools analysed were CO2DB, MARKAL, IKARUS and E3Database. Although, there are many different energy technology assessment tools, EMINENT seems to be the only one targeting EST. The EMINENT tool is described in details elsewhere [15,16]. EMINENT, besides having a database of ESTs that are low carbon technologies, can also support the EU in the assessment and selection of technologies that can help accomplish the objectives outlined.

3.2. Electricity, energy from waste and reliability

The paper of this group addresses the challenge of updating the European Electrical Grid. German and Austrian researchers report on research on ‘‘Development of SuperSmart Grids for more efficient collection, transmission and utilisation of electricity from multiple renewable sources’’ [6]. They emphasise that if Europe is serious about achieving its target to keep the global mean temperature increase below 2 °C, it has to strive for a 100% renewable electricity system by 2050. They describe a SuperSmart Grid approach, which combines what is often perceived as two exclusive alternatives: the wide area power generation and decentralised power generation. They argue that by combining these complementary measures, it is possible to address the crucial issue of renewable energy generation – fluctuating supply – in a comprehensive and technologically and economically viable manner. Their proposed SuperSmart Grid would simultaneously contribute to energy security, climate security, social security, and national security. There are several issues and open questions that must be thoroughly investigated. Most of them are connected with investment risks, often triggered by political uncertainties. They discuss seven of the most important aspects from the perspective of investors: (i) sheer magnitude of investment; (ii) poorly defined financial uncertainties; (iii) technologies uncertainties; (iv) policy uncertainties; (v) local political obstacles to transmission access rights; (vi) import dependency; and (vii) lack of political lobbying.

They stress the importance of the EU Directive on renewables, which permits importing of electricity from outside the European borders and the need of considering this contribution in the attainment of the national renewable energy targets. The vision of linking Northern Africa to Europe in an integrated, SuperSmart Energy Grid, may become a reality. This would be a very important step towards a decarbonised future, implying the possibility of developing a renewable energy-based economy in Northern Africa with positive implications not only for climate security but also for a substantial contribution to local development, job creation, sea water desalination facilities and potentially increased social stability. In Europe a link to North Africa through high-voltage DC lines combined with smart technologies would generate innovation in the electricity and engineering sectors and contribute to a decarbonised future in Europe. Therefore, large-scale investment in the construction of concentrating solar thermal plants in the Northern African deserts and on the Iberian Peninsula is urgently required, as well as the extensive construction of wind farms onshore and offshore. Additionally, the planning and construction of a unified regional SuperSmart Grid would enable the transport of renewable electricity from generation sites to load sites. High-voltage DC lines (aerial or underground depending on the terrain) can be designed with "smart" features that provide energy generation companies and consumers with sophisticated tools for load management, for conserving electricity, eliminating inefficiency and eventually for reducing energy bills. It is clear that the development of a SuperSmart Grid will require considerable research to develop a better understanding of the economic, commercial and technical challenges. This knowledge can only be gained through practical experience. As a consequence, large, commercial scale, pilot projects should be initiated as soon as possible.

The second paper in this group, titled, "Advances in waste to energy technologies," was written by Petr Stehlík from Brno, Czech Republic. The author provides an overview of recent advances in waste to energy technologies. The objective of his paper is the description of general and specific features of thermal processing of various types of waste. It is focused on new developments in technologies and units for the thermal treatment of waste. Ideas about new waste to energy-centres are outlined. Procedures for reliable design of units for the thermal processing of waste are summarised as follows: (i) input data should be verified; (ii) accurate balance calculations and optimisations should be performed with the support of scientific and research groups. Both heat efficiency optimisation and CO_2 emission mitigation (including the recently growing opportunity of sequestration) should be assessed [17]; (iii) mathematical modelling should be applied to key parts of technologies and equipment; (iv) experience and know-how should be exploited to the maximum extent possible, including expert systems and databases; (v) design of the processing technology should be performed in such a way as to facilitate future modernisations, technology upgrades or extensions made necessary either by obsolescence or tightening emission limits (e.g. strong limits for dioxin concentration); and (vi) selection of suppliers, manufacturers and contractors for the construction of thermal treatment units should be based on high expertise.

An integral part of the design of each 'waste to energy' processing plant has to be an economic evaluation. Based on simple economic criteria (payback period, net present value, and internal rate of return), it applies to both technical analyses (pre-selection of suitable alternative technologies) and environmental impact assessments (e.g. amount of emissions for each alternative design) to find the optimal solution. His conclusions are that: (i) environmental improvements are not accompanied by economic profits; (ii) the interests of investors are generally in contrast with findings of environmental impact analyses; and (iii) the economic analyses are location-dependent and different conclusions may follow if applied to different markets. It is generally necessary to consider constraints (limited funds) as well as investors' profit maximisation objectives.

The last paper in this group, titled, "RAMS contribution to efficient waste minimisation and management" written by Sikos and Klemeš from Veszprem, Hungary [8]. The paper analyses the potential benefits of using advanced software tools for the optimisation of reliability, availability and maintainability of waste minimisation and management. The significance of waste management systems has increased in recent years due to the growing problems of waste management chains affecting the daily lives of millions of people due to negative environmental impacts from improperly managed wastes; the new software makes it possible to model and to improve waste management systems. A key attribute of the software is that it can help to provide quantitative forecasts for various performance measures of waste management systems. This can include availability, downtimes, number of failures, and comparative costs. 'Waste to energy,' can provide sound economical solutions. Failure factors can be addressed by the advanced RAMS software. This can decrease or even avoid failures affecting the availability and reliability of waste management systems. An advantage of the RAMS software is its capability to model a system using various tools which can simultaneously integrate the relationships among data, equations, and diagrams. These tools can handle the influence of input data, failure tree, and reliability block diagrams on each other. This feature is helpful for decreasing the environmental impacts of waste incinerator plants. These software tools can optimise the equipment units, so as to avoid failures and to increase reliability. A further step in the detailed analysis is the cost optimisation that includes labour costs, space usage costs, downtime costs, and miscellaneous other factors that contribute to the total cost.

3.3. Carbon/CO_2 related issues

The third group of papers begins with a contribution titled "Carbon-constrained planning for sustainable power generation" [9] by Tan, Ng and Foo from the Philippines and Malaysia. They report on advances in the application of the 'pinch analysis,' approach applied to power generation. The authors developed a novel application of graphical pinch targeting methodology for preliminary planning of retrofits in the power generation sector. They suggest ways to aggregate carbon emission targets for the power generation sector which can be met while minimising the need for power plant retrofits. They present a scheme to adjust the solution so that power losses due to the energy demands of carbon capture systems can be offset by the addition of compensatory electricity generation from renewable energy or from efficiency improvements in existing plants. Their method provides rapid, intuitive insights on optimal retrofit allocations in a regional power generation facility. This is essential for preliminary planning purposes prior to the development and application of detailed mathematical programming models. The benefit of their approach is the potential to obtain substantial decreases in generation of CO_2 at the source.

Their future work is designed to address: (i) incorporation of different scenarios for generating compensatory power (e.g., using fossil fuel-fired plants and detailed process heat integration within CCS processes); (ii) use of a dynamic framework to plan for the gradual phase-in of both CCS retrofits and compensatory power plants; (iii) inclusion of a provision for annual growth in power demands in a growing economy; (iv) incorporation of life cycle analyses based on total carbon footprints; and (v) and the integration of the methodology as an initialisation step for detailed mathematical modelling that includes cost considerations.

The last paper of this group, titled "Minimisation of energy use in multipurpose batch plants using heat storage: an aspect of cleaner production," by Majozi from Pretoria, South Africa [10]. The author addresses the challenge of heat integration in batch plants with the objective of minimising energy usage as an important aspect of cleaner production that has received limited attention in the published literature. He developed a mathematical technique for the optimisation of energy use by means of heat storage in thermally integrated multipurpose batch plants. The storage of heat is implemented through the use of a heat transfer fluid. A mixed integer linear programming (MILP) approach yields a globally optimal solution for a predefined storage size. This approach is especially valuable when applied to systems with batch operations, like dairy and brewing processes which require dedicated techniques. The application of the proposed method to an agrochemical facility documented savings of more than 75% in external utility steam consumption.

3.4. *Advanced and compact production units*

The first paper of this group, titled, "Use of plate heat exchangers for phosphoric acid energy more efficient and cleaner production," by Kapustenko, Boldyryev, Arsenyeva and Khavin from Kharkiv, Ukraine, focuses on implementation of plate heat exchangers (PHEs) for cleaner and energetically more efficient production of phosphoric acid [11]. These researchers report on research designed to develop an ecologically sustainable, environmentally friendly, resource and energy saving production technology for a wide class of substances containing phosphorus. The essential feature of their work is that they document that replacement of tubular heat exchangers with compact PHEs effectively increases heat recovery and prevents or reduces pollution in other ways, as well. For such a corrosive environment as a phosphoric acid production plant, the Hastelloy G30 alloy is used as the material for the PHEs and synthetic rubber EPDMCT is used as the material for inter plate gaskets. There analyses reveal that using mixed groupings of plates with different geometries in the unit provide optimal solutions. Their simulation also reveals benefits from minimising wastewater pollution by closing the condenser cooling water circuits.

They developed software for calculation of the number size and locations of PHEs, by working with both mono-phase liquids and phase changing streams. They found that PHEs require much less material than is required for tubular heat exchangers. Additionally, they are more efficient in energy savings, which makes their implementation economically sound. Heat recovery with PHEs saves 25–30% of the energy normally consumed in the production of phosphoric acid.

The next paper titled "Raw materials for fermentative hydrogen production" by Urbaniec and Grabarczyk from Plock, Poland, reports on evaluation studies of diverse raw materials for fermentative hydrogen production [12]. The authors investigated the critical parameters of hydrogen production by thermophilic fermentative and photo fermentative micro-organisms. They reviewed various types of biomass, which can be used as raw materials for hydrogen production, as well as the methods of biomass pre-treatment prior to being fermented. They developed a new approach for the technical assessment of biomass suitability and compared several promising raw materials with respect to hydrogen yield. They state that due to a low mass fraction of water – about 10% – the highest yield of H_2/kg of biomass is obtained from wheat bran and wheat straw. Both materials are very good candidates for hydrogen production without adverse effects on food production. Their availability for hydrogen production is difficult to determine, but the order of magnitude of potential hydrogen output from these materials in Europe was estimated at 1 Mt/y. The prospect of usage of these raw materials for fermentative hydrogen production is uncertain. The hydrogen yields per kg of wet raw materials from sugar beet, potato and beet pulp, is considerably lower on a kg basis, however, the highest yield in kg H_2/ha can be obtained from potato and sugar beet. To avoid conflicts with food production, low-cost by-products from food processing, such as potato steam peels, can be promising raw materials for hydrogen production, rather than using the crop itself. Compared to wheat straw, the availability of such by-products in Europe is limited, but is sufficiently large to justify hydrogen production at locations close to potato processing plants. Sugar beet constitutes an interesting raw material option because of its potential availability on a large scale without conflicting with food production. After the recent EU sugar market reform, the growing area of sugar beet in the EU decreased from 2.1 Mha in 2005 to 1.6 Mha in 2007; this resulted in a 24% decrease of sugar beet production. The authors calculate that if the sugar beets were grown in the previous areas of production, that would produce sufficient biomass for hydrogen production to yield up to 0.48 Mt/y.

The last paper of this group is titled, "Non-equilibrium biosorption column modelling with porosity effects" by Reverberi, Dovì, Fabiano and Maga from Genoa, Italy [13]. Their study was motivated by the need for predicting the dependent variables of biosorption columns, which is an important process in cleaner production technology. They determined the pollutant concentration in the bulk phase in the liquid filling the pores and in the solid biomass along the axial coordinate of the column for a wide range of parameters by adjusting the physics and chemistry of the global process. The hypothesis of instantaneous chemical reactions was replaced by a more realistic expression taking into account chemical kinetics and fluid advection timescales separately. The system of partial differential equations was solved by a reliable, numerical algorithm based on the method of lines. They anticipate that the use of this model can be advantageous in the context of a cleaner production strategy for two different aspects. The first is related to building a software interface between the present algorithm and specific flowsheeting packages, which have been proposed in a recent publication [18]. Adopting this synergy, they estimated that a 10–20% energy efficiency improvement could be obtained in the management of a biosorption plant on a pilot scale. The second aspect concerns the field of process control, since the use of a robust and efficient model has strong implications in terms of environmental and health safeguards [19].

4. Conclusions and contributions to the state of the art

There are numerous problems, which modern society must face in seeking to secure a sustainable energy supply while also seeking to reduce energy use induced climate changes and species diversity

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losses or competition for human food production. The rapid increase in energy consumption globally makes the problem more complicated. Recent oil and gas crises have shown, only too well, how societies are extremely vulnerable to geo-political and climatologically influences to their energy supplies. This special issue is based on a workshop held in Hungary that targeted some of the relevant problems. The full texts of all contributions have been published elsewhere [20]. The Workshop, was fortunate to have had delegates from nearly 30 countries who contributed much from their wisdom and extensive experience. However, due to the complexity of the global challenges we are facing, we realised that each person or team had limits to the issues that they could effectively address. Therefore, this special issue was developed, based upon the specialised inputs from these skilled scientists and technologists. Taken as a whole, these papers address many of the challenges pertaining to global climate change and to the impacts the choices we make in energy types/sources and investments in energy efficiency in production and consumption have upon societal sustainability.

Although, new insights are emerging on some energy-related problems, which seem to be rather straightforward, most of them have not yet been satisfactorily solved.

Many of the problems have been addressed annually at the "PRES" – "Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction" conferences [21] held during the last 12 years. The following issues have been addressed in those conferences:

(i) Diversification of energy sources and supply chains; regional energy sustainability zones and interzone integration.
(ii) The mass storage of energy – especially of electricity and heat.
(iii) The energy efficiency and energy saving attitude being accepted as a priority by society.
(iv) The change of the societal approach away from wasting energy.
(v) Sustainable energy solutions for transport – technology, management and societal acceptance.
(vi) Sustainable energy solutions for developing countries.
(vii) Sustainable energy for securing fresh water for the world's growing human population.

These are a few of the issues addressed; the list could and should be considerably extended. It is encouraging that some of the big players are researching these issues [22]. However, much more collaboratively orchestrated work is needed to find proper answers to these and many other challenges. This special issue was designed to widen and deepen the discussion and to make available the contributions for which the Journal of Cleaner Production offers an ideal platform.

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