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Editorial

Energy Policy and Climate Change: A Multidisciplinary Approach to a Global Problem

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1. Introduction

In the period between the end of the Second World War and the oil crises of 1973 and 1979, the most critical issues in the energy debate were the impending depletion of non-renewable resources and the level of pollution that the environment is able to sustain.

At the time, large investments in nuclear energy technologies were the answer to the growing energy needs, whereas local pollution was reduced by dilution in a wider environment. By the end of the seventies, it was clear that these policies and approaches were largely inadequate.

The Three Mile Island accident—the first of a series of catastrophic events—reduced the diffusion of traditional nuclear reactors around the world. Moreover, also as a consequence, the development of breeder reactors was abandoned in most countries.

Similarly, the attempt to reduce air and water pollution by using higher chimneys or by diluting emissions into larger river basins and lakes, while partially mitigating local problems, was giving rise to severe global issues, including the depletion of the ozone layer, the onset of acid rains and the eutrophication of coastal waters, among others.

Sustainability became the new paradigm that both the academic world and public opinion were ready to embrace. By that time, scientists all over the world were starting to raise concerns about climate change and its impacts at the global level. Research demonstrated the correlation between carbon dioxide emissions and increasing global mean temperatures. Over time, the need to reduce fossil fuel emissions to prevent serious climate change grew together with scientific evidence. Since then, innovation in energy generation, distribution and consumption has become inextricably tied up with climate change research.

Technology was called upon to improve energy efficiency by providing better building construction practices and improved industrial design procedures, to foster energy conservation by developing alternative, less energy-intensive products and to speed up the transition to a carbon-free energy environment by building up renewable energy sources.

Similarly, science has been committed to developing ever more refined models designed to predict the consequences of increasing carbon dioxide levels and other greenhouse gases in the atmosphere.

However, it soon became clear that science and technology alone could not provide the solutions for averting or partially alleviating the negative consequences of global warming and the conflicting objectives of economic growth, affordable prices and sustainability.

Indeed, an interdisciplinary approach including the natural and social sciences as well as economics and investment theory proved crucial to the development and implementation of mitigation and adaptation strategies.

What we are experiencing today is a real revolution that is transforming the global energy sector; it impacts all aspects on how we generate, distribute and consume energy. This revolution is not just a technological process; it is first and foremost, a societal and political process in which technology is one determining factor.

Thus, the role of different stakeholders, as well as societal needs and wants, are to be duly taken into account for the transition to be timely and effective. International agreements, as well as small and large-scale infrastructure projects to support the transition phase, all need to be based on a clear vision of the future and require laborious dealings and negotiation skills.

Finally, a strong juridical framework must be put in place at both the national and supranational levels to provide direction and reduce the risks for investors in implementing innovative solutions.

A multi-disciplinary approach is at the core of any serious action for sustainable development: any decision-making on energy issues should consistently pursue the parallel objectives of preventing serious climate change and protecting the natural environment. A partial or incoherent strategy could lead to ineffective and unsatisfactory results.

The goal of this Special Issue is to bring together a wide range of disciplines and technical fields under the same roof of a thematic area, which can be broadly defined as Energy Policy. Indeed, Energy Policy is called upon to solve some of the most pressing problems that our society is confronted with, *i.e.*, the prevention of dramatic climate change, the disruption of food supply chains, the onset of worldwide water stress and the collapse of political institutions.

As Guest Editors of this Special Issue, we were able to ascertain that this interdisciplinary position on fundamental issues of Energy Policy is now widespread among scientists and scholars, who are well aware that a wider and more embracing paradigm should be established for the Energy Policy Research.

The positive echo from the scientific community, reflected by the number and the quality of the contributions submitted, proves the significance of this general approach and the necessity of examining energy issues from a more general perspective, which should increasingly become part of the general public discourse beyond the strict framework of academic debates. Society at large needs to be actively involved in developing, suggesting and supporting possible and sustainable pathways, which are relevant at both the national and international levels. This will give decision makers the confidence and sense of urgency to develop and implement necessary policies. This is the main message being conveyed by this Special Issue.

Indeed, the articles submitted, as well as the ones finally selected to be published, cover a broad range of thematic areas: science and technology, economics, corporate finance, law, public policy, social analysis, national and international issues. As a matter of fact, several manuscripts straddle different subjects. We regard them as a sign of vitality in academic research and as a further confirmation of the necessary interdisciplinary character of innovative Energy Policy Research.

In the next section, we provide a brief review of the papers published, roughly classifying them according to the previously outlined thematic areas.

2. A Short Review of the Contributions in This Issue

A number of articles can be grouped under the broad heading of Science and Technology.

As far as energy efficiency is concerned, two articles address optimal building construction practices and adequate industrial design procedures respectively.

Kim *et al.* [1] show how the optimal design of shading installations can substantially affect the heating and cooling load for horizontal devices and venetian blinds in office buildings. The significant potential reduction of up to 13% of energy consumption that might be reached in Korea reflects the importance of this type of analysis in the construction sector.

In the article by Chew *et al.* [2], process integration is applied to the important case of non-negligible pressure drops between plant units. Indeed, process integration, based on pinch analysis, has become one of the most powerful techniques for efficient process design. Greeted as a veritable breakthrough in the eighties, pinch analysis has been successively extended to include the energy optimization of whole industrial sites and the energy interactions between industrial processes and the surrounding territory.

The role of technology in the development of renewable energy sources is analyzed in four articles dedicated to wind energy, energy from biomass and small hydropower.

While wind energy technology is approaching a level of maturity allowing it to be considered a well-established and economically viable source of energy, its very diffusion gives rise to new problems that the scientific community is called upon to solve.

Thus, the influence of the wind farm wake on the power production of neighboring wind farms is analyzed by Hasager *et al.* [3] using advanced methods based on satellite synthetic aperture radar observations. Furthermore, as shown by Van Ackere *et al.* [4], the inclusion of small and medium turbines in distributed energy systems, though reducing the overall impact of the spatial footprint, requires more detailed knowledge of the spatial distribution of the average wind speed.

As for the use of biomass in large centralized systems, Puigjaner *et al.* [5] show how an innovative adjustable design platform, conceptually derived from Process Systems Engineering, can be used for the optimal establishment of biomass-based supply chains, which constitute an essential requirement for the introduction of co-combustion/co-gasification projects in the current electricity production scenario.

Punys *et al.* [6] explore the potential negative impact of small hydropower systems on environmental aquatic systems due to sudden changes in the flow rate, especially during start-up and shutdown phases or as a consequence of changes in the electrical load. They provide an effective design method which includes the type of turbines employed and evaluate the largest ramping rate that does not strand or isolate fish populations.

Basic science and advanced engineering methods are employed by Bernardes *et al.* [7] to estimate the areas of profitable exploitation of gas hydrate fields in sub-seabed sediments. In addition to tapping methane hydrates, the technique might provide a suitable storage for a large amount of carbon dioxide sequestered in power plants and other industrial processes.

Contributions dedicated to corporate policies and investment decisions on energy issues include five articles.

In particular, Atlason *et al.* [8] show, on the basis of data related to Iceland's geothermal sector, how the establishment of a critical mass of local experts in the maintenance of innovative infrastructure can give rise to stable clusters based on knowledge and be beneficial to the further development of the sectors involved.

In the article by Thollander and Palm [9], the introduction of operational measures into the energy management system of production processes is recommended as an effective means of overcoming the barriers which reduce the propensity to the adoption of cost-effective measures. In particular, the authors recommend embedding additional models into the frequently used input-output analysis for improving the overall efficiency of energy management systems in the industry. Allowing for periodic adjustments would further enhance their reliability.

Similarly, Nasirov *et al.* [10] examine the barriers to the deployment of renewable energy technologies in Chile, despite the favorable political and economic climate. Using surveys and interviews, they identify these barriers as being caused by grid limitations, excessive red tape, scarce credit and uncertain regulations for the lease of physical commodities. The authors provide recommendations for overcoming these difficulties in the Chilean system.

Kiyar and Wittneben [11] analyze the portfolio management strategies of the four large electricity providers in Germany and come to the conclusion that the fossil fuel divestment campaign launched in 2012 (and presently including over two hundred institutions) is not at the root of their corporate decisions on reducing fossil fuel assets. Rather, they seem to be the result of a compromise brought about by dropping prices, the current composition of stockholder equity, political regulations, and the economic and social importance of lignite extraction in Germany.

Ellenbeck *et al.* [12] question the widespread reliance on the sole market design for secure electricity supplies through the full development of capacity markets at national or regional level. Using an interdisciplinary approach based on economic analysis and sociological insight, they theorize that the market as a social institution is capable of shaping the investment behavior of its participants. The creation of a European Energy Union is proposed as a possible tool for positively influencing the four behavioral determinants identified by the authors.

A number of contributions can be classified as evaluations of policy responses to public problems or as proposals for the modification of existing regulations on energy issues. In other words, they fall under the broad definition of Public Policy.

Two articles consider the effectiveness of CO_2 mitigation measures adopted or recommended in China. Deng *et al.* [13] assess the consequences of the CO_2 reduction plan contained in the 12th five-year plan (2011–2015) in each of the 30 Chinese provinces by analyzing temporal and spatial variations of emissions. Taking into account the considerable differences encountered in the geographic distribution (mainly between coastal and internal regions), they suggest different targets for the geographical areas with a view of a more stringent future reduction of CO_2 emissions at the national level. Li *et al.* [14] use a general equilibrium model to forecast the consequences of the introduction of two mitigating measures by the year 2050. In particular, a carbon tax is shown to generate a strong reduction of emissions in the short term, but a decline of economic growth and innovation in the energy sector. On the other hand, the expansion of the emission trading scheme would lead not only to a significant emissions reduction but also to an increased deployment of renewable energy sources. A combination of the two measures is shown to be the optimal strategy.

Two more articles analyze energy issues in China and, using the resulting outcomes, recommend the adoption of suitable public policies. Sheng *et al.* [15] investigate energy efficiency in China using estimated shadow prices of energy and comparing them with market prices for the evaluation of the level of energy utilization. They show that although considerably higher since 1998, shadow prices are below the market value in eighteen provinces, which implies an inefficient use of energy. A reallocation of inputs is recommended to increase overall energy efficiency. Wang *et al.* [16] analyze the policies promoting the national industry which produces densified biomass solid fuel from agricultural and forestry residues in China. They recommend the use of a framework based on the supply chain steps to eliminate fluctuations in the availability of biomass feedstocks and consequently enhance the development of this industrial sector.

Benavides *et al.* [17] examine the implications of the present 5 US$/t$CO_2$e carbon tax in Chile and the possible consequences of its increase up to 50 US$/t$CO_2$e, using simulation models. They predict both an emission reduction and a price increase, which depend parametrically on factors beyond the control of policy-makers, including fossil fuel prices and non-conventional renewable energy investment costs. Alternative measures are considered and the resulting emission reductions evaluated.

In their article, Gutierrez-Escolar *et al.* [18] show that the regulations adopted by the Spanish government for the limitation of the impact of street lighting on the energy consumption of Spanish municipalities have missed the nationally set targets. By analyzing the performances of the various components which make up street lighting, the authors identify some aspects which should be considered for an efficient use of energy.

Reliable forecasts for the future development of national energy markets play a vital role in the correct formulation of energy policies by governments and other decision makers' bodies.

Reid and Wynn [19] investigate the solar power market in the United Kingdom and estimate that large-scale solar farms, as well as commercial and residential rooftop installations, will be able to compete in the market without subsidies in the next decade thanks to expected cost reductions due to technological innovation. The additional grid integration costs required by solar power variability could then be weighed against the advantages of using a secure, environmentally friendly and carbon-free energy source.

The literature meta-analysis carried out by Lilliestam and Patt [20] shows that the development of renewable energy sources would be beneficial to pave the way for a post-fossil fuel era in the Gulf States, but are hampered by inefficient bureaucracy and high fossil fuel subsidies. While overcoming these hurdles might be difficult in the short term due to inevitable conflicts with vested interests, policy solutions for future investments are considered possible.

The article by Sun *et al.* [21] has a strong methodological content and includes a new algorithm for the forecasting of fossil fuel consumption in the generation of electricity at the national level. Comparing the predictions of their model with the actual data of the Chinese market, they show the high reliability of their approach.

The analysis of global phenomena and global governance institutions constitutes the basis of any consistent energy policy capable of tackling the problems to be solved at an international level.

Scott and Sugg [22] examine, using national and global data, the strong interactions between water scarcity caused by energy generation in several large and diversified economies and, conversely, limitations to energy development due to water shortage (especially in arid areas and small island states). They estimate that a virtuous water-energy-climate cycle is possible and that it should be fostered through institutional arrangements. To this purpose, they suggest a number of coupled energy-water policies.

Jänicke's [23] attempt to ascertain mechanisms for the global diffusion of climate-friendly technologies leads to the identification of three interactive, partly overlapping processes based on virtuous policy-market cycles, the emulation of best practices from domestic markets and pioneer countries and the integration of vertical and horizontal dynamics in multi-level systems of governance. Even if the focus is on the European system of multi-level climate governance, general recommendations are addressed to policy makers.

A strong juridical framework is a prerequisite for any efficient and consistent energy policy. On the other hand, creating the necessary consensus for the establishment of international institutions with the appropriate authority to produce binding rulings becomes more and more arduous with increasing extension of the territorial jurisdiction.

Two articles consider the role of European legislation and the conditions for its enforcement.

Considering a number of European directives and regulations, Ferrara [24] shows that the progress of smart cities in Europe is critically dependent on the further development of energy efficiency and renewable energy sources. However, he finds that for the current pledges for an efficient development of smart cities to be transformed into binding rules at national level, a clear legal framework should be established.

Klimscheffskij *et al.* [25] analyze the reliability of the guarantees of origin of sold electricity by considering the residual mix resulting from the combination of implicit disclosure systems and explicit tracking procedures. They identify a number of double-counting errors related to implicit electricity disclosure and suggest the use of a new residual mix calculation methodology developed in RE-DISS project.

Energy-related decisions have a considerable impact on a number of societal issues, including a direct influence on peoples' lifestyles, as well as negative externalities. Indeed, energy can contribute to the solution of many severe social problems, but it can also aggravate some of them, reinforcing the necessity of involving all stakeholders in the decision-making procedure on energy strategies.

This Special Issue contains three articles on energy-related societal issues.

Stenner and Nwokora [26] question the general validity of Inglehart's post-materialism theory even in affluent countries. Using a large cross-sectoral data set, they argue that particular interests, rather than broad value systems, determine global trends in environmental attitudes. Accordingly, the environment's future champions are expected to be the citizens of the developing nations most at risk of real material harm from climate change and environmental degradation.

Similarly, Frederiks *et al.* [27] regard the variables frequently employed to explain household energy usage as inconclusive. Instead, they suggest that a multitude of factors should be considered to avoid inconsistent interpretations, which might lead to questionable conclusions. Understanding the nature and the mechanisms of these factors might provide useful guidance to policymakers.

Komendantova *et al.* [28] examine the concerns of local stakeholders affected by the construction of electricity transmission infrastructure. Since several thousands of kilometers of new lines have to be constructed and upgraded at the European level to accommodate growing volumes of intermittent renewable electricity, the dialogue between transmission system operators and non-governmental organizations, as exemplified by the BestGrid approach, is crucial. The stakeholders' concerns disclosed in four pilot projects constitute the main subject of the article. The authors present an analysis of the reasons underlying them and evaluate the BestGrid process on the basis of the attitudes of the stakeholders involved in the four projects.

3. Conclusions

It has been argued by the authors of "Limits to Growth" [29] in the 30-Year Update of their book that "*humanity is in overshoot*", *i.e.*, it has exceeded the limits, beyond which any further evolution can lead to collapse, unless "*the damage from overshoot [is] reduced through wise global policy, changes in technology and institutions, political goals, and personal aspirations*". Sustainability in energy generation and consumption is one of these limits.

Over the following ten years, more and more evidence has been accumulated suggesting this program is more pressing than ever. The task of energy policy research is to identify means and tools of this "*wise global policy*". As reflected by the content of this Special Issue, ingenuity and commitment among members of the scientific community have proven to be equal to the task: the political institutions are now called upon to urgently put the resulting knowledge into practice.

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