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Editorial

Special Issue "Industry and Tertiary Sectors towards Clean Energy Transition"

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Abstract: The Special Issue "Industry and Tertiary Sectors towards Clean Energy Transition" is focused on technical, financial and policy-related aspects linked to the transition of industrial and services sectors towards energy saving and decarbonisation. These different aspects are interrelated, and as such, they have been analysed with an interdisciplinary approach combining economic and technical information. Collecting and analysing quantitative data would allow researchers to better understand the clean energy transition process, and how the international and national regulatory and policy framework are contributing to it. The papers within this Special Issue focus on energy efficiency and clean energy key technologies, renewable sources, energy management and monitoring systems, energy policies and regulations, and economic and financial aspects.

Keywords: energy efficiency in economic sectors; clean-energy technologies; energy policies and regulations; financial instruments; decarbonisation; renewable energy sources

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1. Introduction

The global economy should undergo an epochal and radical change in the next few decades to combat climate change. Clean-energy transition, the shift from the use of non-renewable energy sources to renewable sources, is part of the wider transition to sustainable economies using renewable energy, the adoption of energy-saving measures and green technologies development. This is a long and complex process, but it will allow us to safeguard the health of the environment in the long-run. The European Union is among the leading major economies in this process. In December 2019, with the European Green Deal, the objective of achieving a climate-neutral EU by 2050 was endorsed, alongside the target of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. Later on, Member States' presented Long-Term Strategies featuring national energy scenarios together with sectoral targets, which should be monitored to ensure that national contributions are consistent with the achievement of the European reduction path. The Commission presented its 'Fit for 55 package' in July 2021 to bring EU legislation in line with the 2030 goal. To reach these long-term targets, the contribution of everyone is required, from individual citizens to large multinationals, passing through SMEs. In this sense, national and international policies play a key role in paving the way for clean energy transition.

According to the well-known energy-efficiency gap, current energy-efficiency technologies may not be adopted due to different barriers; thus, several public policies exist to enhance and sustain their implementation. This Special Issue focuses on technical and policy-related aspects linked to the transition of industrial and services sectors towards energy saving and decarbonisation. These different aspects are interrelated; as such, they could be better analysed with an interdisciplinary approach, such as one combining economic and technical information.

Quantitative analysis of the main trends in the development and application of energy-efficiency technologies in different productive sectors can usefully complement policy monitoring and long-term policy planning. Collecting and analysing quantitative data would allow researchers to enhance their understanding of the clean-energy transition process, as well as how the regulatory and policy frameworks contribute and what improvements are required. The analysis focuses on energy efficiency and clean energy key technologies, renewable sources, energy management and monitoring systems, energy policies and regulations, and economic aspects.

2. A Short Review of the Contributions in This Issue

The articles included in this Special Issue address the topic of industry and tertiary sector energy transition from different perspectives. Some of these are purely related to technology development and analysis, while others focus on energy-efficiency policies and regulations. The role of different economic sectors in the clean-energy transition process is also analysed. What clearly emerges from the collected contributions is that different technologies and sectors could all play a significant role in the process, each with different impacts, and that energy-efficiency measures are critical for raising awareness and action, providing a useful information base to monitor policy outcomes and plan further actions.

The increased attention on energy efficiency, both at the national and international levels, has fostered the diffusion and development of specific energy consumption benchmarks for most relevant economic sectors. In this Special Issue, several articles examine energy consumption and the energy efficiency potential at sectoral level [1–4]. Energy audits (EAs) provide comprehensive information about the energy usage in a specific facility, identifying and quantifying cost-effective energy performance improvement actions (EPIAs). The crucial role of these tools in clean-energy transition is remarked by the European Energy Efficiency Directive (EED, Directive 27/2012), which introduces an obligation to implement EAs (art. 8). At member-state level, the database associated with mandatory energy audits could represent an important information basis to develop in-depth studies on energy consumption, energy performance indicators (EnPIs) and EPIAs. Basing on the database provided by mandatory EAs for large and energy-intensive enterprises in Italy (Legislative Decree 102/2014), Bruni et al. [4] developed a methodology to obtain energy consumption and energy-performance indicators, whereas Herce et al. [2] define a set of indicators to analyse EPIAs and the link between them and energy-consumption monitoring. The studies at sectoral level use the EAs information basis in different ways, and from different perspectives; moreover, two sectors are analysed using the methodology described in [4].

Two methodological studies were developed to fully exploit the database provided by the obligation to carry out an energy audit, enforced in Italy since 2014. Awareness of energy efficiency and sectoral benchmarking represents the first necessary step for companies to move towards energy transition. The novel methodology to assess energy performance indicators of productive and economic sectors presented in [4] could be potentially applied to all production sectors, providing key information needed to characterise various production processes from an energy perspective. Their paper provides details of the statistical method developed and a validation example on the NACE 23 division "Manufacturing of other non-metallic mineral products", with a focus on the cement industry.

Energy transition can only become a reality if everyone is involved: when energy efficiency is concerned, this implies that EPIAs are introduced in all sectors, reflecting the saving potential and specific conditions. The implementation of monitoring tools and energy-management systems (EnMSs) supports companies in their long-term energy-efficiency strategies and in the analysis of the effectiveness of EPIAs. Herce et al. [2] analyse the link between EnMSs (specifically ISO 50001) and EAs in the EED Article 8 implementation in two industrial and two tertiary sectors in Italy. Moreover, the impact of company size, energy-monitoring systems, and EnMSs on planned and/or implemented EPIAs is analysed. The findings show that, despite the complexity of the variables involved in the energy-efficiency gap, indicators such as "energy savings per company" and "EPIA per site" are higher in enterprises with an EnMS and monitoring system.

Both studies show how an obligation could become an opportunity at a twofold level: at company site level, EAs allow companies to better understand their energy-consumption structure and identify which EPIAs are most suited and where; meanwhile, at policy-making level, since the availability of reliable energy-consumption and saving information enables policy makers to better plan and monitor the strategies to reach long-term energy and environmental targets.

As far as studies at sectoral level are concerned, four single sectors are examined, one in the tertiary sector and three in the industrial sector [1,3–5]. In the second group, the refining sector is analysed; it is peculiar due to its key role in energy production [5].

Despite the high energy-consumption of hospitals and health structures, scientific literature lacks the presence of adequate energy-performance benchmarks, especially relative to the European context. Thus, Dadi et al. [1] aimed to define energy-benchmark indicators for the Italian private healthcare sector. EnPIs are calculated by considering the global energy-consumption of the different sites, based on the methodology developed in [4], and the sector's relevant variables are also employed. The results obtained are compared with those provided from the methodology adopted by the Environmental Protection Agency. In this way, the reliability of the proposed methodology could be validated, as well as the validity and future usability of the calculated indicators.

Looking at industries, the methodological contribution by [4] analyses cement as a case study, presenting results in terms of specific indicators based on an energy source. General results, methodological insights and validation of the proposed case study are discussed. The foundry industry is one of the most energy-intensive sectors; consequentially, many companies are trying to increase their energy efficiency. Choosing the most appropriate technological solution is a difficult task for several reasons, such as the high number of energy-saving technologies proposed by manufacturers and the literature, as well as rapid technological advances. Leoni et al. [3] investigated opportunities for reducing the energy consumption of Italian foundry companies and presents a list of available technological solutions validated by experts. Implemented and planned interventions were extracted from the EAs database, and the advantages of each technological solution were studied. It emerged that companies are strongly investing in increasing the efficiency of auxiliary systems such as compressors and motors. Petroleum refinement is very important in the European economy, and the continuous increase of energy efficiency is a key topic for this sector. Herce et al. [5] analyse ten Italian refineries based on mandatory EAs and public data, evaluating the primary, thermal and electrical specific energy-consumptions. Some insights into the impact of refined products mix and Nelson Complexity Index in energy consumption are also presented, together with an overview of EPIAs. This work presents a first step for the benchmark of Italian refineries.

In terms of specific technologies, those analysed by the contributions in this Special Issue mainly refer to energy use and electricity generation, namely waste-heat recovery [6,7], electricity storage and renewable electricity production [8,9] covering both energy efficiency and decarbonisation dimensions.

Waste-heat recovery is one of the most promising options for improving the efficiency and sustainability of industrial processes. Although it is abundantly available and technologies for its exploitation are consolidated, the implementation rate of waste-heat recovery interventions is still low. Besides technical, economic, financial and regulatory factors, the lack or incompleteness of information concerning the material and energy flows within the companies, the types and characteristics of waste-heat sources and possible sinks for their internal or external reuse is another barrier. Giordano and Benedetti [6] proposed a methodology to systematic identify and characterize low-temperature waste-heat sources and sinks in industrial processes, which was based on the data gathered from the analysis of EAs carried out by large and energy-intensive enterprises in Italy. In order to demonstrate its feasibility, the methodology was applied to the Italian dairy sector due to its large energy-consumption and enormous potential for utilisation of low-temperature waste-heat sources.

Waste-heat recovery also has great potential in a productive context completely different from the Italian one: the Algerian economy. Hydrocarbons represent more than 90% of exports and natural gas power plants produce approximately 90% of electricity. However, the ambitious governmental program launched to foster renewable energy and energy efficiency reflects the commitment to exploit the existing potential. In this context, reliable and time-efficient optimisation tools are needed, considering technical, economic, environmental and safety aspects. Redjeb et al. [7] built a mathematical tool capable of optimising both steam and organic Rankine units. The tool could perform single or multi-objective optimisations of the steam Rankine cycle layout and of a multiple set of organic Rankine cycle configurations. To show the tool's potentialities and improve awareness of waste-heat recovery in bio-gas plants, the authors selected an in-operation facility as test case.

Another very important aspect of the current energy scenario concerns the operation of electric power-systems. This is becoming increasingly difficult, as the peak load demand is growing continuously, and the daily and annual load factors are worsening. One countermeasure to overcome these problems is a study of the operation method of electric power systems, including novel energy-storage systems such as secondary batteries, superconducting magnets (SMES) and flywheels, which have demonstrated astonishing improvements lately. In general, the cost of power generation can be reduced if the energy-storage system is charged during the off-peak time interval and discharged during the peak time interval. To promote the commercialisation of electrical energy-storage systems, an assessment of their environmental issues is essential, particularly in terms of CO_2 emissions. Tae et al. [8] tackled an evaluation method for CO_2 emission based on an optimal algorithm to identify the best-mix solution of power sources to reduce potential adverse environmental impacts of electricity generation.

Arena et al. [9] focused on photovoltaic electricity production and predictive maintenance, which has received increasing attention and is considered fundamental in industrial applications. In fact, it contributes to guaranteeing healthy, safe and reliable systems and avoiding breakdowns that could potentially lead to a whole system shutdown. The paper focuses on a use case of robust anomaly detection applied to an Italian solar cell production plant in Catania. They considered a Monte-Carlo-based pre-processing technique as a valid alternative to other common methods due to several advantages, such as outlier replacement and the preservation of temporal locality with respect to the training dataset. After pre-processing, the authors trained an anomaly detection model based on principal component analysis and defined a suitable key performance indicator for each sensor in the production line based on the model errors. The algorithm allows anomalous conditions to be isolated by monitoring the above-mentioned indicators and virtually triggering an alarm when exceeding a reference threshold. Testing it on both standard operating conditions and an anomalous scenario was successful, anticipating a fault in the equipment and demonstrating robustness to false alarms.

After contributions on the state of the art of sectoral energy consumption, energy-efficient and low-carbon technologies and technological assessment solutions, a final contribution provided an overall picture synthesising the general trend of green-technology development in the European Union. Technology is one of the main drivers in the clean-energy transition.

The European Union has recently approved an ambitious unilateral mitigation strategy known as the European Green Deal, leading the way in the negotiation process under the Paris Agreement. Caravella et al. [10] presented a novel approach based on the analysis of patent data related to climate change and mitigation technologies. At the global level, the pace of generation of new green technologies as measured by patent data has slowed in recent years. Moreover, the current EU technological positioning with respect to green areas appears to be problematic in terms of technological sovereignty, with serious risks of potential technological dependencies from other countries. Given the ambitious environmental targets in the EU, and the radical technological shift required to achieve them, additional and directed investments should be enhanced further.

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