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Editorial

Cogeneration Economics

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1. Introduction

This editorial provides a synopsis of the contributions published during 2020–2021 in a Special Issue of *Energies* entitled "Cogeneration Economics". An initial call for papers was held, which is described below.

Cogeneration (combined heat and power (CHP)) and/or trigeneration (combined cooling, heating, and power (CCHP)) are widely recognised solutions for energy efficiency and greenhouse emissions reduction. During the last decade, new policies and financing schemes have been developed to support and promote cogeneration solutions. However, the recognised need for rapid decarbonisation of the energy system has instigated developments in policies, regulations, and energy markets, which will affect the economic viability of cogeneration solutions and the conventional valuation methods and tools. This Special Issue aimed to provide appropriate state-of-the-art methods, tools, and data for the changing business case of cogeneration accounting for the wider investment environment and legislation impacts. Thus, all topics related to cogeneration economics were eligible.

Potential topics included but were not limited to the following themes:

- Cogeneration/trigeneration technologies;
- Equipment cost: data and estimation;
- Operating and maintenance cost: data and estimation;
- Energy prices;
- Existing system evaluation and capacity expansion;
- Process design and optimal operation;
- Project valuation methods: levelised cost, discounted cash flow, real options, etc.;
- Investing and operating viability criteria, performance indicators;
- Third-party financing schemes, energy services companies;
- Regulatory and legal framework;
- Incentives policy and supporting schemes;
- Electricity markets participation strategies;
- Market diffusion and adoption;
- Utility-scale applications, district systems;
- Industrial applications: paper, dairy, bakery, brewery, sewage sludge incineration, desalination;
- Commercial applications: hotels, hospitals, malls, universities, data centres;
- Agricultural applications: greenhouses, drying.

Limited manuscripts were submitted, and only four were accepted and published.

2. A Short Review of the Contributions

Two papers addressed cogeneration using internal combustion engines in buildings based on real data. The first [1] analysed the long-term economic performance of some projects in the Mediterranean climate of Athens, Greece, while the second [2] focused on the short-term, detailed economic performance of a cogeneration system in a hospital. A third paper [3] modelled the performance of a cogeneration system in a greenhouse and evaluates its economic efficiency versus the European country and the kind of cultivation.

The last paper [4] examined the economics of heat engines and heat pumps in recovering waste heat in oil refineries.

A more detailed description of each contribution is provided in what follows.

1. Economic Assessment of Cogeneration Systems in Operation [1]

In this presented paper, a systematic method to evaluate the economic operating performance of existing combined heat and power (CHP) or combined cooling heat and power (CCHP) generation systems was applied. Two key performance indicators were selected to evaluate both the technical and the economic performance, based on operating recording data: capacity factor and capital recovery. The case study for eight projects in Athens was presented to reveal the current situation of CHP in Greece and identify reasons that hinder its penetration. Interesting conclusions were reached from the analysis. Only two out of the eight projects managed to achieve the break-even point in less than four years since the beginning of their operation, while oversizing phenomena were noted in many cases, leading to extremely low capacity factors. The results referred to three hotels, two office buildings, a mall, a hotel, and a school. All cases used internal combustion engines and some among them included additionally absorption chillers.

2. Techno-Economic Performance Assessment of a Trigeneration System Operating in a Hospital [2]

In this contribution, the techno-economic performance evaluation of a combined cooling heating and power (CCHP) system installed in a hospital building in Greece was presented. The aim was to verify performance standards and evaluate real behaviour while highlighting economic gains. In this research, system performance was evaluated using actual and year-round field measurements. The data were used to calculate the recovered heat and the generated electric energy. Furthermore, the performance was modelled and compared with the manufacturer's specifications. A financial assessment was conducted through energy cost analysis to verify the operating viability of the system, for both its heating and cooling functions. The results showed that, overall, after eight years of operation, energy efficiency was still within design standards. Electrical efficiency was constantly above 30%, while thermal efficiency was around 40–45%. Total efficiency was usually above the 75% threshold, characterising the system as fully CHP operating. The analysis also pointed out the economic efficacy of the system in the Greek energy market. The results verified the potential of a CCHP system for improving the energy and economic performance of a building.

3. Cogeneration Economics for Greenhouses in Europe [3]

Cogeneration is a cost-effective technology, and modern greenhouses are considered one of the best applications for it due to their energy intensity. Considering that in such cases the production cost is significantly affected by the cost of energy, the potential of combined heat and power (CHP) has already been examined and proved in practice in some European countries, with the Netherlands being the most representative example. In this study, a comparative investigation of the greenhouse energy cost in all European countries was presented using a combined cooling, heat, and power (CCHP) system. Using actual historical data spanning a decade, a total overview of the European level was given regarding greenhouse thermal requirements and CCHP energy costs for the cultivation of products with an accepted temperature cultivation range of 20 +/− 5 °C. By consulting (1) the available daily historical meteorological data for the 2008–2018 period, (2) the recorded actual electricity and natural gas prices for the 2008–2018 period, and (3) the technical characteristics of the CCHP system, the annual heating and cooling requirements of greenhouses were determined for all EU countries. Assuming a cogeneration unit with an internal combustion engine (ICE) as a prime mover, as well as a single-effect absorption chiller for the production of useful cooling, the unitary cost of energy was estimated, along with the annual cost for heating and cooling per unit cultivation area. Using this methodology, the economic efficiency of cogeneration in greenhouses was assessed for the selected 10-year period, allowing the identification of the countries that benefit the most from this technology. The results revealed that the spark ratio (i.e., the electricity-to-natural-gas price ratio) is the most crucial parameter for greenhouse costs. For countries where the ratio is larger than 3, greenhouses can even result in extra cash flow instead of energy expenditures. The most favourable conditions for cogeneration use were found in Italy and the United Kingdom, with average spark ratios of more than 4, resulting in an annual total cost of heating energy close to -7 EUR/m^2 per year. On the other hand, cogeneration proved not to be a cost-efficient system in Sweden and Finland because of significantly high greenhouse energy requirements.

4. Recovery and Utilisation of Low-Grade Waste Heat in the Oil-Refining Industry Using Heat Engines and Heat Pumps: An International Techno-economic Comparison [4]

In this contribution, the techno-economic feasibility of onsite electricity and steam generation from recovered low-grade thermal energy in oil refineries using organic Rankine cycle (ORC) engines and mechanical vapour compression (MVC) heat pumps in various countries was assessed. The efficiencies of 34 ORC and 20 MVC current commercial systems were regressed against modified theoretical models. The resulting theoretical relations predict the thermal efficiency of commercial ORC engines within 4–5% and the coefficient of performance (COP) of commercial MVC heat pumps within 10–15%, on average. Using these models, the economic viability of ORC engines and MVC heat pumps were then assessed for 19 refinery streams as a function of heat source and sink temperatures and the available stream thermal energy for gas and electricity prices in selected countries. Results showed that (1) conversion to electrical power with ORC engines is, in general, economically feasible for heat-source temperatures >70 °C, although with high sensitivity to energy prices; and (2) steam generation in MVC heat pumps, which is even more sensitive to energy prices, is not economical under all conditions—it is only viable with high gas/low electricity prices, for large heat sources (>2 MW), and higher temperatures (>140 °C). In countries and conditions with positive economics, payback periods down to two years were found for both technologies.

3. Conclusions

The submitted papers are compared in the following Table 1 concerning the engine (mover), sector (industry), and method applied.

Table 1. Paper classification.

References	Engine	Industry	Method
[1]	Internal Combustion Engine	Buildings	Key Performance Indices, Real Data
[2]	Internal Combustion Engine	Buildings	Key Performance Indices, Real Data
[3]	Internal Combustion Engine	Greenhouses	Modelling, Statistical Data
[4]	Heat Engines, Heat Pumps	Oil Refineries	Modelling, Literature Data

Since a few papers were submitted, limited topics were covered. However, the economics of cogeneration was revealed for some sectors such as buildings, greenhouses, and oil refineries. These results were obtained during the years before the energy crisis of 2022, but they can also be easily projected to the present years of higher energy prices. Obviously, economic efficiency is an even more interesting subject.

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