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Combined cold, heat and power system, based on an organic Rankine cycle, using biomass as renewable heat source for energy saving and emissions reduction in a supermarket

Joaquín Navarro-Esbrí[a]*, Francisco Molés[a], Bernardo Peris[a], Adrián Mota-Babiloni[a], José Pascual Martí[b], Roberto Collado[b], Manuel González[b]

[a]*ISTENER research group, Universitat Jaume I, Spain.*
[b]*EXPANDER TECH S.L., Universitat Jaume I, Spain.*

Abstract

Supermarkets are recognized worldwide as great energy consumers, especially in developed countries. Typically, energy consumptions are due to cold, heat and electricity requirements. So a Combined Cold, Heat and Power (CCHP) system (also called trigeneration system) can be used to reduce energy demands and, hence, greenhouse gas emissions to the atmosphere. In this way, this work proposes a small-scale Organic Rankine Cycle (ORC) CCHP application in a supermarket. The ORC has been designed to be used with a biomass boiler, and to produce electricity and useful heat at two different temperature levels related to an absorption chiller and supermarket heating demand.

With this in mind, this work conducts the experimental characterization of the CCHP system in a test bench. Thereby, the experimental results obtained are used to predict the expected performance of the system under the supermarket conditions, as well as to quantify the energy, environmental and economic benefits of the application.

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*Keywords:*organic Rankine cycle; combined cold, heat and power; biomass; supermarket.

* Corresponding author. Tel.: +34 964728137; fax: +34 964728106
*E-mail address:*navarroj@uji.es

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1. Introduction

Supermarkets and retail food stores are recognized worldwide as great energy consumers, especially in developed countries. According to Tassou *et al.* [1], retail food outlets in the UK are responsible for around 3% of total electrical energy consumption, and 1% of total greenhouse gas emissions. In particular, cooling and heating demands are the most representative energy consumptions in supermarkets, accounting for 64% over the total (46% refrigeration and 18% heating, ventilation and air conditioning systems) [2].

Trigeneration systems are proven as a solution to reduce energy demands and to save greenhouse gas emissions [3]. Therefore, the use of Combined Cold, Heat and Power (CCHP) systems in supermarkets is receiving an increasing attention. In this way, Marimón *et al.* [4] proposed different configurations of CCHP systems, and Suamir and Tassou [5] modeled conventional supermarket integrating refrigeration and CCHP systems. Both studies have demonstrated the benefits of CCHP systems through payback periods lower than 5 years.

The CCHP proposed in this study is based on the Organic Rankine Cycle (ORC), which is proven as a suitable technology to take advantage of low grade heat sources to produce electricity and useful heat. Thus, Peris *et al.* [6] proved that electrical efficiencies around 11% and thermal efficiencies of 89% could be reached by using a small-scale system from a low temperature heat source [6]. Moreover, the thermal energy required by the ORC can be supplied by means of a renewable heat source, such as a biomass boiler or solar thermal, contributing to the energy and environmental issue [7].

In the following, section 2 presents the CCHP system to be installed in the supermarket. In section 3 the test bench used to characterize the CCHP ORC performance is briefly exposed. Section 4 shows the experimental results, which are used to predict the expected behavior under the supermarket conditions, as well as to quantify the energy, environmental and economic benefits of the application. Finally, the main conclusions are summarized in section 5.

Nomenclature

$\dot{Q}$	thermal power (kW)
T	temperature (ºC)
$\dot{V}$	volumetric flow rate (m3/h)
$\dot{W}$	electrical power (W)

Greek symbols

η	efficiency (-)
ρ	density (kg/m3)

Subscripts

exp	expander
i	in
n	net
o	out
oil	thermal oil
pp	pump
w	water

Acronyms

CCHP	Combined Cold Heat and Power
ORC	organic Rankine cycle