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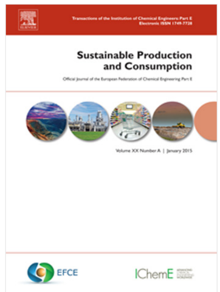

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A Novel Integrated Waste Energy Recovery System (IWERS) by Thermal Flows: A Supermarket Sector Case

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Abstract

The demand for resources and energy is increasing in the development of the economy. The increase in the price of energy that penalizes the benefits obtained, the growing competition in the commercial sector that motivates the adoption of improvements in the design of the establishments and the greater importance given by customers to the environmental sensitivity of commercial firms, encourages the adoption of measures aimed at achieving savings in energy consumption. In the commercial activity of a supermarket, steam originates as a residual fluid in the cooking processes of frozen doughs in bakery ovens. In the following a novel system is shown, designed to benefit from steam heat and improve energy efficiency in the production of hot water from supermarkets. The Integrated Waste Energy Recovery System (IWERS) developed, uses a storage cylinder equipped with a coil that benefits from steam heat generated in the bakery ovens. The system is evaluated according to operational and economic aspects, its implementation, in half of Spanish supermarkets and hypermarkets, would generate approximately 0.3% of the total annual reduction of greenhouse gas emissions that Spain is bound to get for diffuse sectors. The amortization period of the necessary investment is much lower than its cost, making the installation economically viable.

Highlights

- Supermarkets are in business expansion and presents a growth in energy expenditure.
- An innovative Waste Energy Recovery System (IWERS) for bakery ovens is described.
- Legal obligation to reduce GHG makes it necessary to apply new solutions.
- Energy recovery of thermal flows can reduce energy consumption to heat water.
- The use of waste heat of ovens increases the economic benefits of companies.

Keywords

Bakery oven; Energy saving; Greenhouse gas emissions reduction; Heat recovery; Residual fluid; Supermarkets.

Abbreviations

A: period of amortization of the installation of energy use of the residual fluids of bakery ovens (years).

B: cost of IWERS (€).

C: energy consumption to heat sanitary water with electric water heaters (kWh/year).

C_E: economic savings in electricity consumption (€/year).

CEEC: Clúster d´Eficiència Energètica de Catalunya. Catalonia Energy Efficiency Cluster.

C_T: annual economic savings (€/year).

C_W: economic savings in drinking water consumption (€/year).

D: operating hours of an electric water heater per year (h/year).

DHW: Domestic Hot Water.

E: energetic utilization of the residual heat of a bakery oven (kWh).

EU: European Union.

E_f: energy measured by the kJ/kWh meter during the first month (kWh).

E_i: energy of the residual fluids, measured at the condenser input (kWh).

E_l: energy measured by the kJ/kWh meter throughout the analysis period (kWh).

E_m: monthly energy use of the residual fluids of a bakery oven (kWh/month).

E_o: energy of the residual fluids, measured at the condenser outlet (kWh).

E_T: annual energy use of the residual fluids of bakery ovens (kWh/year).

E_y: annual energy use of the heat of a bakery oven (kWh/year).

f: factor of CO_2 emissions associated with electricity consumption ($kgCO_2$/kWh).

GDP: Gross domestic product.

GHG: Greenhouse Gases.

IWERS: Integrated Waste Energy Recovery System.

M: number of months a year has, divided by the number of months that the measurement of energy use was made (1/year).

mWC: meters of water column.

N: number of electric water heaters.

n: number of ovens.

P: power consumed by each electric water heater (kW).

R: price of electric power (€/kWh).

S: reduction in CO_2 emissions by adopting the energy saving measure, using the residual heat of the steam generated in bakery ovens ($kgCO_2$/year).

1. Introduction

Achieving sustainable development based on the use of renewable energies and the development of energy efficiency is a necessity within the economic model of the European Union (EU) by 2020. To begin this process, a series of objectives in terms of energy and climate change to be achieved by 2020 have been established by the EU member countries. The so-called 20-20-20 objective: to obtain at least 20% of energy consumption from renewable resources, 20% reduction in primary energy consumption achieved by improving energy efficiency and obtain a 20% reduction in greenhouse gas emissions (GHG) [1]. This situation involves the replacement of traditional energy systems for new systems developed in accordance with energy demand [2]. Hence, thermal energy recovery systems can play an important role in the field of energy efficiency. One of the sectors where it is more complicated to get this type of improvement are those known as diffuse sectors, which are not subject to the European emission trading scheme. Most of the emissions from the EU come from these sectors. The improvement of energy efficiency is a key aspect for policy makers, industrial managers, scientists and engineers [3]. The tertiary sector is made up of economic activities dedicated to offering goods and services to the consumer. The evolution of the Spanish economy in recent decades, is in line with the trend of the rest of the EU and has set the sector as the most important in the national economy with a steady increase in Spanish Gross Domestic Product (GDP) from 31% in 1965 to 67% in 2015 [4]. This is a heterogeneous sector that has in commerce the subsector with the greatest economic impact, an employment rate close to 33% in Spain and a continued forecast of growth in jobs [5]. The retail trade of the EU-27 presents a significant turnover with almost constant growth according to Table 1 [6].

Table 1. Evolution of turnover in retail trade in the EU-27 during the period 2000-2009.

EVOLUTION OF RETAIL BUSINESS FIGHT IN EU-27 DURING THE PERIOD 2000-2009 (MILLION EUROS)		
Year	Spain	EU-27
2000	75.95	1936.9[illegible]
2001	81.17	2059.25
2002	86.13	2164.67
2003	91.04	2267.90
2004	96.05	2422.45
2005	100.12	2602.18
2006	105.39	2818.40
2007	110.72	3062.25
2008	109.16	3292.01
2009	101.43	3065.04
Average of the period	106.35	2854.56

The growing importance of tertiary activities is one of the key elements in the dynamics of the Spanish economy [7]. This relevance also translates into high energy consumption and polluting emissions associated with this consumption. Climate change is one of the phenomena that has generated the most environmental, social and economic repercussions worldwide in recent years. The fight against this threat has become a priority objective for governments and the greatest environmental challenge in the history of mankind. To fight against climate change threats, it is necessary both to modernize production systems and make changes in the policies of business management aimed at reducing greenhouse gases (GHG) emissions. The European Union's commitment to this objective has led to the implementation of concrete measures in member states. As a consequence, Spain is obliged to reduce emissions in the diffuse sectors by 10% by 2020 compared to the emissions levels in 2005 [8]. Within the Spanish national inventory of GHG emissions, the commercial subsector belongs to the SNAP 02 category. In 2009, this group produced 7.7% of the total GHG emissions in Spain according to the Ministry of Environment and Environment Rural and Marine of the Kingdom of Spain. This trend of high energy consumption is common to all developed countries. Retail food consumption in the United Kingdom consumed 3% of total energy and was responsible for 1% of GHG emissions into the atmosphere [9]. The need to develop a suitable energy strategy in the commercial sector is reinforced by the increase in the costs of electricity, which meant a reduction in company benefits.

In recent years, new, more efficient technologies have emerged that have allowed the reduction of energy consumption in refrigeration, air conditioning, ventilation and lighting. However few of the latter have been carried out to reduce the consumption of bakery ovens in commercial establishments. In literature there are several references on the use of residual heat [10]. The captured heat recovered can be used for electricity generation, heating and cooling. Several authors highlight the potential of recovery of low-grade residual energy by technologies such as the use of heat exchange systems or energy storage [11]. Some studies have addressed the problem of CO_2 emissions and issues related to energy efficiency in various sectors, mainly studying their possible reduction and improvement options respectively [12]. To reduce energy consumption in supermarkets a practical guidance was needed to help designers, developers, and owners identify areas of opportunity and available resources [13]. However, many references regarding the recovery of heat lost in furnaces and the role of technological innovation in the performance of environmental and energy efficiency for European diffuse sectors have not been found. This article presents a novel Integrated Waste Energy Recovery System (IWERS), for the use of waste heat from the steam generated in bakery ovens of a supermarket, aimed at reducing GHG emissions of greenhouse gases to the atmosphere, as a consequence of the lower consumption of electrical energy. The cost of the IWERS, the period of recovery of the investment and its economic and environmental benefit are valued.

2. Material and methods

The study consisted of intensive field surveys, interviews and secondary data collection from 150 supermarkets. Consequently, it was concluded that the usual practice in a bakery of a large supermarket with an exhibition and sale area between 1000 and 2500 m^2, is to install two electric bakery ovens of 30 kW each. These ovens are used for baking bread and other bakery and pastry products which are sold daily at the establishment. During the baking of the bread dough, water is added to the oven chamber to maintain the moisture of the dough. Due to the high temperatures generated inside the oven, part of this water turns into steam. To collect the water left over from the baking process, there is a system which evacuates the steam in such a way that the steam passes through a steam condenser before being eliminated through the waste-water network of the supermarket.

The commercial distribution has suffered in the past decades important changes in the format of the establishments, particularly in the food retail trade, defining the following types of commercial establishments, depending both on the surface exhibition and the sale of the product:

- Self-service and traditional trade: these are types of small-scale retail stores, which do not exceed 100 m^2 and specialise in basic products such as fresh meat products, charcuterie, fishmongers or greengrocers. Such businesses are usually run by the owners unlike supermarkets and hypermarkets which have hired personnel.

- Supermarket: commercial establishment located within the cities with a sale surface of between 100 and 2500 m^2, selling consumer goods and basic needs such as food, cleaning products, hygiene, drugstore and among others.

- Hypermarket: a commercial establishment located in the periphery of the cities where customers usually need to move in some type of transports. This type of supermarket has a sales surface area of over 2500 m^2. In addition to consumer goods and other basic needs, other products such as textiles, electronics, electrical appliances and so are sold. Moreover, services with other types of activities such as the catering business are combined.

Supermarket-type establishments have been consolidated in all countries and are experiencing rapid growth in developing countries [14], mainly due to the proximity of the service provided to consumers along with a successful policy of prices. Although in a rapidly growing economy, energy efficiency is more likely to slow the rate of demand growth rather than reduce consumption below current levels [15]. Within the commercial sector, the entire supermarket type establishments have one of the highest energy consumption per square meter in all commercial and industrial sectors. Currently, the format of hypermarkets and supermarkets in Spain presents the following trend, according to Table 2 [16].

Table 2. Number of hypermarkets and types of supermarkets in Spain.

	Number of establishments
Hypermarkets	418

Large supermarkets	3172
Medium supermarkets	4876
Small supermarkets	8481

The energy of supermarkets depend on business practices, store format, product mix, shopping activity, the equipment used for in-store food preparation, preservation and display. The electrical energy can vary from around 700 kWh/m^2 sales area per year in hypermarkets to over 2000 kWh/m^2 sales area per year in convenience stores [9]. The electricity bill for Spanish supermarkets exceeds one thousand three hundred million euros [17], distributed mainly between refrigeration with approximately 50%, lighting with approximately 30%, air conditioning and ventilation with approximately 8% and bakery ovens with approximately 10% [18]. This consumption is the most significant expense for supermarkets and the reduction has become a primary objective by companies. Thus, the reduction of polluting emissions in commerce is also a requirement, an opportunity both to modernise the sector by incorporating more efficient equipment in order to improve the competitiveness of companies, hence increasing the level of profit for the saving in energy consumption (Fig. 1). The bakery oven reduction of the energy consumption and improvement in energy efficiency is especially interesting although it is very little considered and developed.

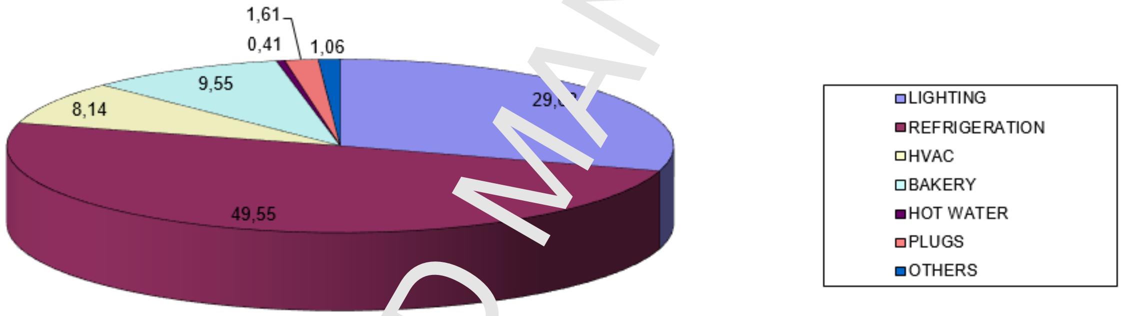

Fig. 1. Percentage distribution of electricity consumption in a supermarket.

2.1. Description of the steam condenser of an electric bakery oven.

The steam condenser is a stainless steel tank filled with water up to a certain level, which is located on the electric furnace. To condense the steam that is generated inside the oven by the baking of the bread, the steam is passed through this deposit in a forced way by the use of a fan. The tank has a cold water connection (1) from the general water network of the supermarket, governed by a cut-off solenoid valve (2) and an overflow (3) connected to the drainage network of the room (4). The solenoid valve is controlled by a thermostat (5), so that the steam generated in the furnace when crossing the raft heats the water there until it reaches the temperature at which the thermostat (5) is set. Then, when the solenoid valve (2) is opened and cold water is let out of the water supply of the supermarket (1), the water level in the steam condenser increases and the hot water is evacuated to the drain (4) through the overflow (3). In this way, the water in the steam condenser is cooled, sending the thermostat (5) to close the filling solenoid valve (2) and so. This is a simple system to condense the steam generated in the furnace from which it is possible to achieve a significant important improvement in energy efficiency and savings in water consumption through the use of the steam heat.

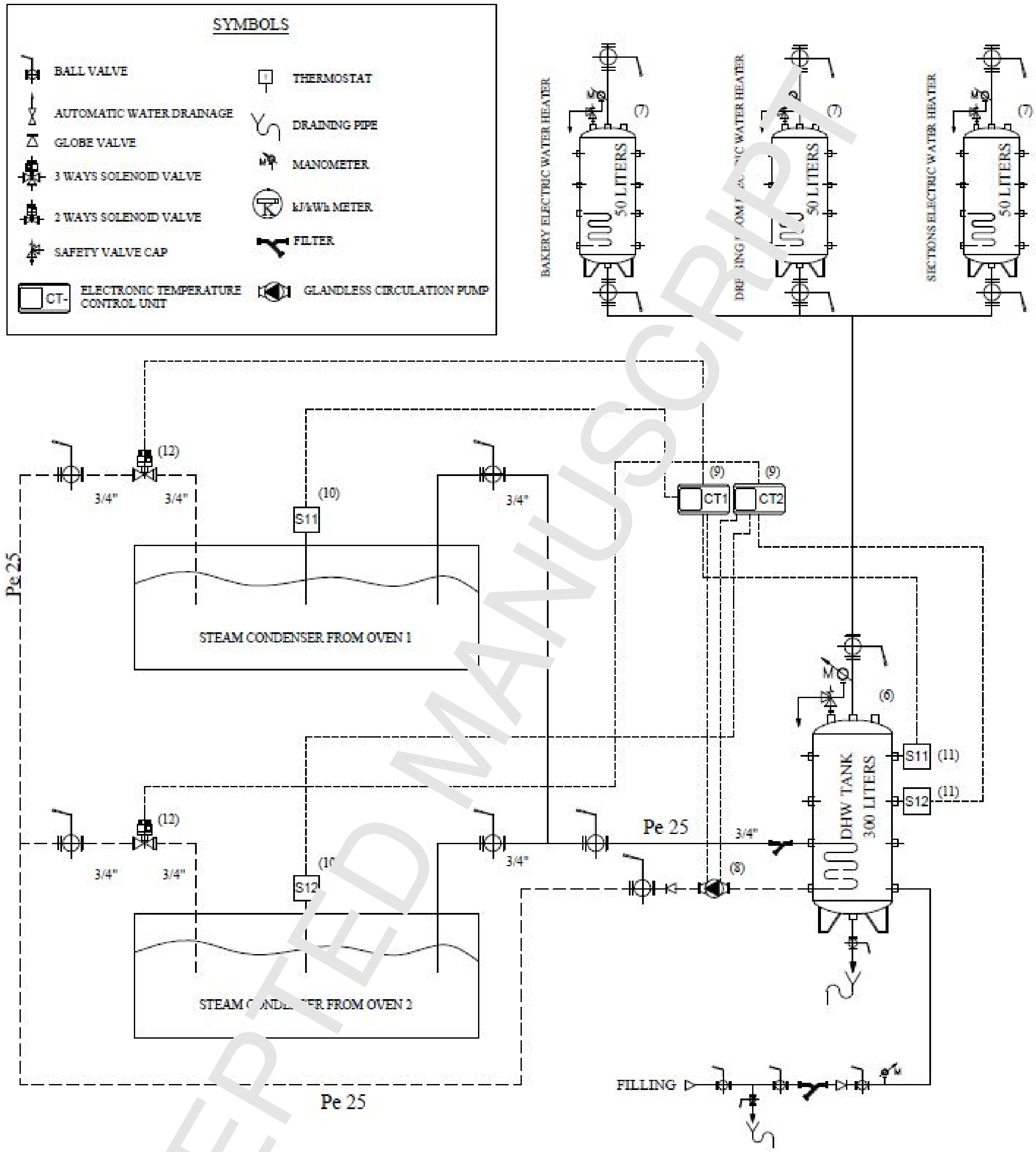

Fig. 2. Schematic diagram of IWERS for energy use of the residual heat of the steam produced in the bakery ovens of a supermarket.

2.2. IWERS for waste heat recovery.

This work shows a technological development of a new system for utilising the residual heat of the steam to preheat water destined for the supermarket consumption, achieving improvements in two different facets: heating water more economically and reducing the amount of clean water consumed in the supermarket [19].

A large supermarket has three fifty litre electric water heaters to heat the water used in the following areas of the establishment: staff changing rooms, butchery, charcuterie, fishmonger, bakery and the cleaning room. Since supermarkets are usually located in the commercial premises of the basement of residential buildings, the generation of hot water is not supported by any renewable energy source, such as thermal solar panels as the roofs are not properties of the commercial establishments and the installation would require the authorization of the owners of the building, which in most cases is difficult to obtain. Therefore, this system constitutes one of the few clean sources of thermal energy which can be used in supermarkets and is also a generator of energy savings and reduction of polluting emissions into the atmosphere. IWERS is designed to improve energy efficiency in the production of hot water, consisting of the installation of a storage tank (6) prior to the electric water heaters (7). This tank has a capacity of three hundred litres and takes advantage of the heat released from the bakery ovens to preheat the water that then goes through the electric water heaters, where it is heated in a second stage until reaching the consumption temperature. To achieve this, as indicated in Fig. 2, the tank-cylinder, equipped with a heat exchange coil in stainless steel is installed. Thus, in the tank the hot water from the steam condensers of the furnaces is used to heat the water used in the supermarket. To guarantee the correct circulation of water between the ponds and the coil, a glandless circulation pump (8) is used. On the other hand, if the water in the steam condensers is colder than in the storage tank, it will not be interesting for the pump to work as rather than heating the water in the tank it would cool it down. To avoid this, centralized circuits of differential temperature regulation (9) are placed between each steam condenser and the tank. Control units have two thermal sensors, one for measuring the temperature of the steam condenser (10) and one for measuring the temperature of the storage tank (11), so that if they detect that the temperature of the steam condenser is greater only by 2 ºC than the tank (this temperature differential is adjustable) the solenoid valve (12) of the corresponding steam condenser is closed, stopping the flow of water through the steam condenser. Hence, if only one oven is working at any time of the commercial activity of the supermarket, the water circulates towards the corresponding steam condenser, not penalizing the cold water of the other stationary oven. In addition, if the two solenoid valves are closed, the glandless circulation pump (8) will also stop, to ensure the safety of the pump and the reduction of the electrical consumption. IWERS is made up of the following elements:

1. Electronic temperature control unit (9) for comparing the temperatures between the storage tank and the steam condensers of the bakery ovens, the proportional part of electrical connection of the temperature sensors, the activation of the solenoid valves and the circulation pump. 2.- Domestic hot water (DHW) tank of three hundred litres capacity (6) for a working pressure of up to 8 bar in the DHW circuit and 6 bar in the coil with a maximum working temperature of 90 ºC. Internally protected against corrosion by coating of epoxy resins of three hundred microns, food quality and thermally insulated by heat-insulating with 50 mm thick flexible polyurethane foam and polyethylene sheath. Including permanent cathodic protection equipment by electronic titanium anodes. 3.- Supply and assembly of two motorized two way valves (12), one-half inch with brass body, including actuator and accessories. 4.- High efficiency glandless circulation pump (8) with 0.20 kW motor and in-line construction, selected with the following characteristics: Pump flow = 0.24 m^3/h and Pressure = 5.32 mWC. And proportional part of electrical control panel and protection, wiring and connection, elastic anti-vibration hoses, connecting elements, proportional part of collectors, valves, cut-off valves, retention and filter. 5.- Rigid copper pipe of one millimetre of thickness, diameter 20/22 mm, for assembly inside the supermarket, with a proportional part of valves, supports and small precise materials for its correct assembly. Even insulation for copper pipes, with proportional part of valve insulation. 6.- In addition to all the electrical, electronic and mechanical connections necessary for the commissioning of the installation. Table 3 shows the cost of the equipment which form the system's part.

Table 3. Cost of IWERS elements.

	Cost €
Electronic control unit and sensors	550

Storage tank	740
Motorized two-way valves	85
High efficiency motor pump unit	250
Rigid copper pipe	300
Electrical, electronic and mechanical connections	100
Total	2025

2.3. Usable energy.

Taking into account that the electric water heaters work an average of four hours a day, heating water for three hundred and ten days a year, which are the opening days of the supermarket. The energy consumption to heat the sanitary water in a traditional way, with three electric water heaters of 1.5 kW each, is as follows:

$C = N \cdot P \cdot D$

C is the energy consumption (kWh/year), N is the number of electric water heaters, P is the power consumed by each electric water heaters (kW) and D is the electric water heaters operation time in one year (h/year).

The energy use of the residual fluids of an oven (kWh), is:

$E = E_i - E_o$

Ei is the energy of the residual fluids, measured at the entrance of the steam condenser (kWh) and Eo is the energy of the residual fluids, measured at the outlet of the steam condenser (kWh).

The monthly energy use of the residual fluids of a bakery oven is:

$E_m = E_l - E_f$

E_l is E measured during the entire analysis period (kWh) and E_f is E measured during the first month (kWh). Obtaining annual usable energy for each oven (kWh/year), applying:

$E_y = E_m \cdot M$

M is the number of months in a year, divided by the number of months that the measurement of energy use was carried out (m/year).

The energy of the residual fluids of the bakery ovens that can be used annually (kWh/year) is obtained as:

$E_T = n \cdot E_y$

n is the number of ovens, in the case of a large-sized supermarket n = 2.

2.4. Decrease in CO_2 emissions

The reduction in CO_2 emissions ($kgCO_2$/year), associated with the consumption of electricity in the supermarket, by adopting IWERS is:

$S = E_T \cdot f$

f is the factor of CO_2 emissions associated with electricity consumption ($kgCO_2/kWh$). In Spain this factor is set by the Ministry of Industry, Energy and Tourism of the Spanish Government. These emissions amounted to 0.331 $kgCO_2/kWh$ in 2017 [20].

2.5. Economic savings.

The economic savings due to the reduction in electricity consumption (€/year) for each bakery oven is:

$C_E = E_T \cdot R$

R is the price of the kWh of electric power (€/kWh). In Spain, P is obtained from the estimated average between the three Spanish periods for charging electricity P1, P2 and P3, with a value of 13 cents for each kWh consumed in 2017.

The savings in drinking water consumption (€/year) by the steam condensers system for each bakery oven is:

$C_W = (W_i - W_o) \cdot M \cdot k$

This is both an economic saving and an environmental improvement.

W_o is the flow rate of water consumed for the condensation of the steam measured the first month (l), W_i is the flow rate of water consumed for steam condensation during the entire measurement period (l) and k is the cost of water (€/l). In northern Spain k = 1.5 €/1000 l.

The total annual economic savings (€/year) is obtained from:

$C_T = n \cdot (C_E + C_W)$

2.6. Amortization period

The amortization period (years) of the installation of the energy recovery system of the residual fluids of the bakery ovens of a supermarket is:

$A = B / C_T$

Where B is the cost of IWERS installation for two bakery ovens (€), (Table 3).

3. Results

The data obtained for each of the two existing bakery ovens in the supermarket, the amount of clean water consumed in the condensation process of the steam, as well as the energy produced and the temperature of the water at the outlet of the steam condenser, measured during a six-month period by type testing are shown in Table 4.

Table 4. Data obtained by the counters placed in a bakery oven of a supermarket.

	Data taken on Type Testing 1 02/11/2017	Data taken on Type Testing 2 04/11/2017	Data taken on Type Testing 3 06/11/2017	Data taken on Type Testing 4 08/11/2017
Average energy produced	123.8 kWh	364.4 kWh	575.7 kWh	798.8 kWh
Average litres consumed	1777 litres	6673 litres	11129 litres	15755 litres

Average water temperature at the outlet of the steam condenser	45.3 ºC	44.1 ºC	45.2 ºC	44.3 ºC

To carry out a study of the water and energy savings which can be obtained by using IWERS, the thermal power dissipated in the steam and the volume of clean water used in the condensation was measured. To do this, a meter was installed to measure the ratio kJ/kWh between the water input from the supply network to the steam condenser and the water outlet of the condenser to be evacuated. Thus, the amount of water that fed the steam condenser and the energy lost when the hot water was discharged through the waste-water network was recorded, as shown in Fig. 3.

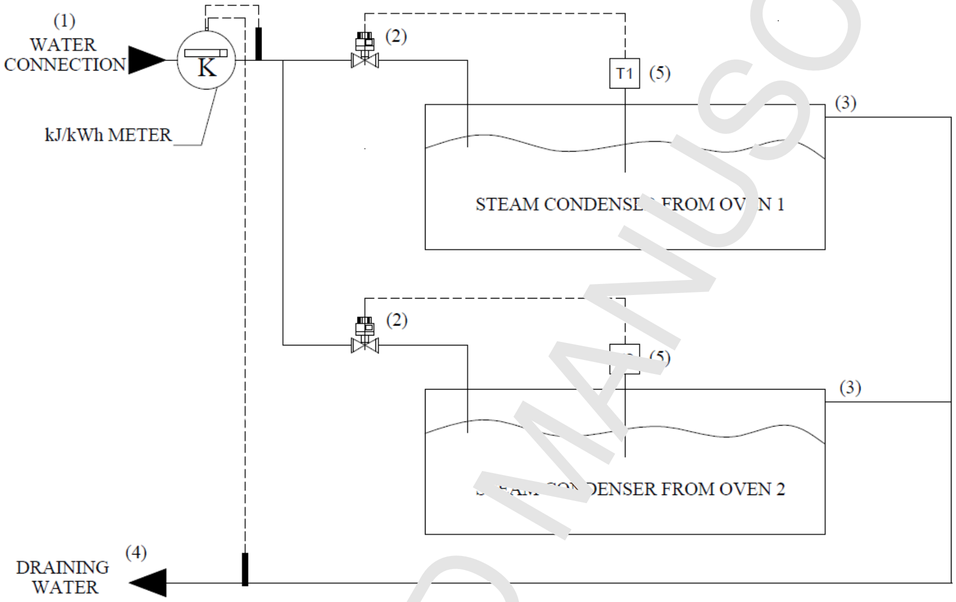

Fig. 3. Detail of assembly of the kJ/kWh meter placed in the bakery ovens of a supermarket

With the proposed energy use system, the following results have been obtained in terms of decreasing electricity consumption, water consumption and reducing CO_2 emissions associated with energy consumption. The results have been evaluated for the cases of an installation of 1 oven (Case A) and 2 ovens (Case B) in Table 5.

Table 5. Decrease in electricity and water consumption, energy use and decrease in CO_2 emissions for the cases studied.

	Decrease in electricity consumption (kWh/year)	Decrease in water consumption (m^3/year)	Energy use (E_T) (kWh/year)	Decrease in CO_2 emissions (S) (kgCO_2/year)
Case A	1350	28	1350	447
Case B	2700	56	2700	894

Table 6 shows the economic results in terms of the savings obtained with IWERS and the amortization period.

Table 6. Economic savings and amortization period in cases A and B.

	Economic savings in electricity consumption (C_E) (€/year)	Economical savings in water consumption (C_W) (€/year)	Total economic savings (C_T) (€/year)	Amortization period (A) (years)
Case A	176	42	176	4.6
Case B	352	84	436	

Once the potential of IWERS was identified, an analysis of the positive effects of the implementation on the total of Spanish supermarkets and hypermarkets was carried out. Table 7 shows a summary of the results obtained.

Table 7. Annual economic and energy savings, annual reduction of CO_2 emissions and annual percentage of GHG emission reduction in the diffuse sectors according to the 20-20-20 objective for Spain, obtained with the use of IWERS in Spanish supermarkets and hypermarkets.

	Small and medium supermarkets	Large supermarkets	Hypermarkets	Supermarkets and Hypermarkets
Annual economic savings	1,452,248 €/year	689,704 €/year	181,776 €/year	2,323,728 €/year
Annual energy savings	9.0 GWh/year	4.3 GWh/year	1.1 GWh/year	14.4 GWh/year
Annual reduction of CO_2 emissions	3.0 $ktCO_2$/year	1.4 $ktCO_2$/year	0.4 $ktCO_2$/year	4.8 $ktCO_2$/year
Annual percentage of GHG emission reduction in the diffuse sectors according to the 20-20-20 objective for Spain	0.17 %	0.10 %	0.02 %	0.29 %

4. Discussion

For the implementation of IWERS, 4 possible scenarios penetration of this technology were developed. The basis for the four cases considered is the summary of the Results in Table 7. Penetration levels have been determined based on four posible implementation levels of the IWERS System in different percentages of the total amount of supermarkets and hypermarkets in Spain. The use of scenario planning has tangible benefits for strategic planning in two ways: some of the key decisions can be taken to an operational field and the risk is reduced by ignoring the small changes within the development context. To do that, a growing level of penetration between supermarkets and hypermarkets was estimated. In relation to the total of existing supermarkets and hypermarkets in Spain, the defined cases were:

Case 1: 75% hypermarkets and 25% supermarkets. Case 2: 50% hypermarkets and 50% supermarkets. Case 3: 25% hypermarkets and 75% supermarkets. Case 4: 100% hypermarkets and 100% supermarkets.

IWERS has been designed to reduce the consumption of electricity needed to heat the water used in supermarkets. This system is applied in other types of commercial establishments where bread and other bakery products are produced. Additionally, there is an increasing proliferation in our cities, such as fuel stations with small shops, bakery cafes, restaurants and small food establishments.

Identifying four possible scenarios of implementation of the IWERS System in Spanish supermarkets and hypermarkets, the following results were obtained, represented in figures 4 and 5.

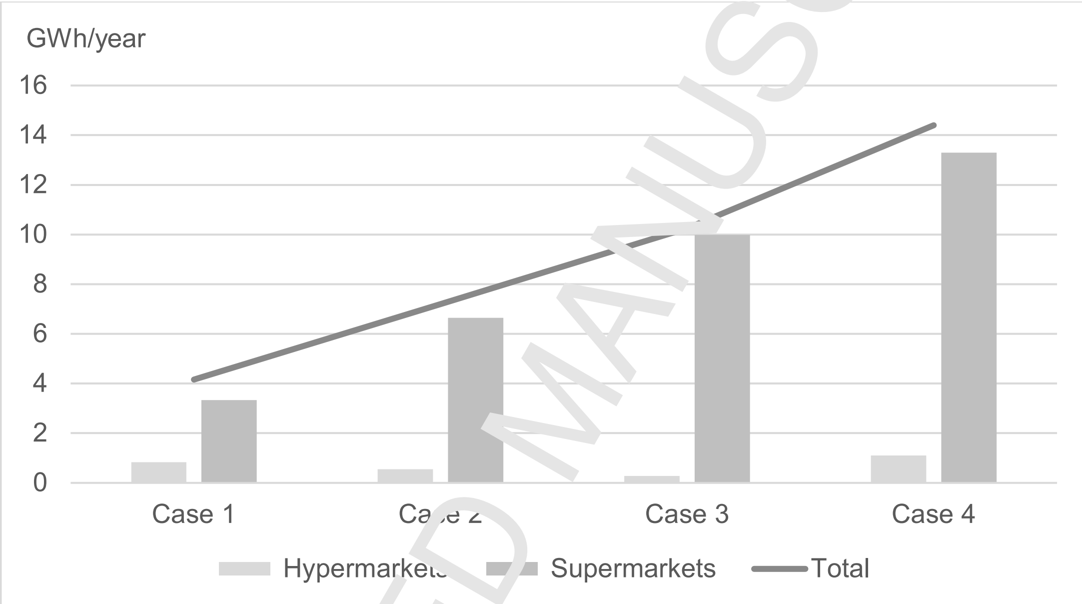

Fig. 4. Results of energy saving in four possible IWERS implementation scenarios.

The economic savings achieved increased by 73% from the first scenario to the second, 42% from the second to the third and 41% from the third to the fourth (Fig. 4). The percentage of savings per year is 12 times lower in hypermarkets than in supermarkets. The potential of economic saving, through the implementation of IWERS, allows for greater improvements in energy efficiency as the proportion of supermarkets increases (Fig. 5). Altogether, an energy saving of 14.4 GWh/year could be achieved, which means savings of 2.3 million Euros per year, equivalent to a reduction of 4.8 kt/year of CO_2.

Figure 5 shows the results of GHG emissions reduction in the diffuse sectors, according to the 20-20-20 objective for Spain, an increase of 63% from the first case to the second, 43% from the second to the third and 39% from the third to the fourth.

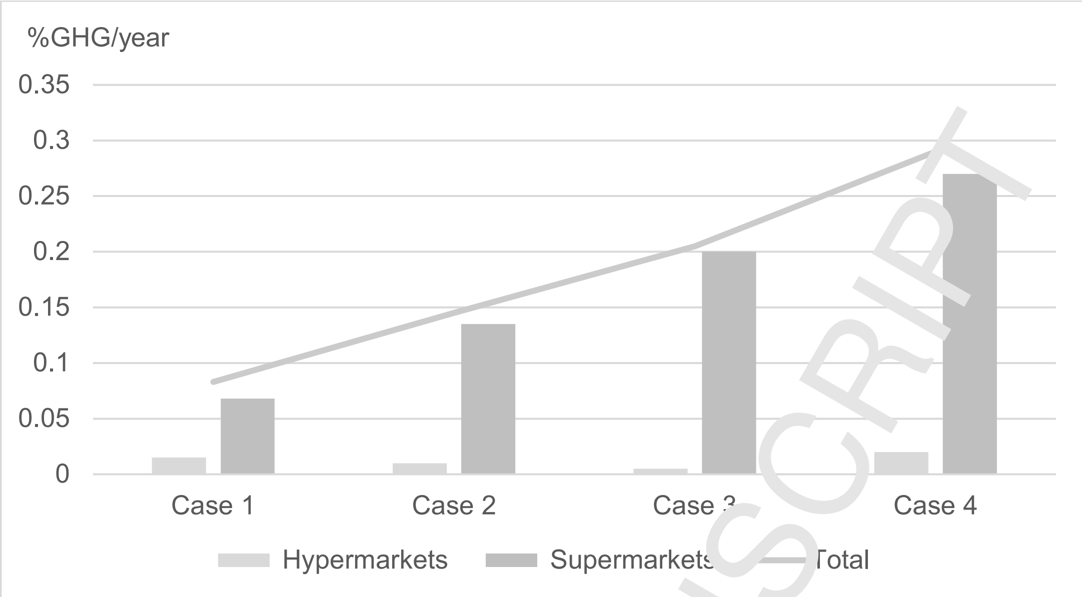

Fig. 5. Percentage of GHG emission reduction in the Spanish diffuse sectors, according to the 20-20-20 objective for Spain, in four possible IWERS implementation scenarios.

5. Conclusions

IWERS implementation has allowed to obtain the following conclusions:

The residual heat contained in the steam is a surplus of unused energy which generates an added cost for the consumption of water and the necessary installation for its removal. The proposed system will capture the waste heat generated in the baking of the products that are made in bakeries to take advantage of another process such as the generation of hot water converting it into a source of free thermal energy production.

Case 4 is shown as the best, since it enables to achieve an energy saving of 14.4 GWh/year, which represents an annual saving of 2.3 million Euros and an annual emission reduction of 4.8 $ktCO_2$. However, the need for a high degree of implementation of the system is not the most likely. A potentially viable outcome as could be in case 2, in which at least 50% of these results are achieved.

The amortization period of the investment to implement the system is short, not reaching five years. This is a shorter period of time than the useful life of the system which is estimated to be twenty years. This makes IWERS economically interesting.

It is an innovative system to reduce polluting emissions to the atmosphere associated with the consumption of electricity in commercial establishments, a sector which has not been willing to apply novelties aimed at reducing these emissions. However, according to result of environmental commitments signed by the States, emissions reduction efforts are required.

The application of the system to half of the supermarkets and hypermarkets in Spain would generate 0.15% of the total annual reduction of GHG emissions in the diffuse sectors, which Spain, according to the Objective 20-20-20 signed by the member states of the European Union, is obliged to carry out.

The predictable increase in the price of electricity and the importance given by food retail customers to the environmental awareness of companies could facilitate the IWERS implementation.

In addition to supermarkets, the system could be implemented in other commercial and industrial establishments where ovens, which generate steam associated with baking, are used.

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