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Geothermal source heat pumps under energy services companies finance scheme to increase energy efficiency and production in stockbreeding facilities

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ABSTRACT

In Europe energy services are underutilized in terms of their potential to improve energy efficiency and reduce external energy dependence. Agricultural and stockbreeding sectors have high potential to improve their energy efficiency. This paper presents an energy model for geothermal source heat pumps in stockbreeding facilities and an analysis of an energy services business case. The proposed solution combines both energy cost reduction and productivity increases and improves energy services company financing scheme. CO_2 emissions drop by 89%, reducing carbon footprint and improving added value for the product. For the two different evaluated scenarios, one including winter heating and one including heating and cooling, high IRR (internal return rate) values are obtained. A sensitivity analysis reveals that the IRR ranges from 10.25% to 22.02%, making the investment attractive. To make the research highly extensible, a sensitivity analysis for different locations and climatic conditions is presented, showing a direct relationship between financial parameters and climatic conditions. A Monte Carlo simulation is performed showing that initial fuel cost and initial investment are the most decisive in the financial results. This work proves that energy services based on geothermal energy can be profitable in these sectors and can increase sustainability, reduce CO_2 emissions and improve carbon footprint.

1. Introduction

ESCOs (energy service companies) share the aim of developing, installing and financing comprehensive, performance-based projects, typically between 5 and 10 years in duration, with the goal of improving the energy efficiency or reducing the load of facilities operated by their customers. ESCOs are becoming universally more important for their promotion of energy efficiency, renewable energy systems and demand-side load demand, which is known as ES (energy services) [1]. Countries that have experienced privatization of their electricity utilities are particularly interesting in terms of ESCO utilization. Other American and European sectors, such as street lighting or hospital facilities management, are currently undergoing liberalization and privatization, increasing business possibilities for ESCOs. Energy services can provide an effective solution for increasing both energy efficiency and the utilization of renewable energy sources. ESCOs are one of the key factors for controlling and reducing the increasing energy demand in Europe and control CO_2 emissions [2]. Despite the financial conditions in Europe and the increasing energy demand, which favor the use of ESCOs, the energy service market in the EU (European Union) is far from utilizing their potential to improve energy efficiency and reduce external countries' energy dependence [1–9].

Many studies have addressed the factors influencing decision-making for energy efficiency investments, but few focus on the EU. In particular, Spain has an extremely high potential for energy efficiency improvement; however, the ESCO industry is not achieving the desired results. Financial barriers are key players, but other factors also limit the effectiveness of ESCOs. International markets, including the US, developing countries such as China and Brazil, and the EU, demand small-scale energy services. These small-scale solutions can provide effective energy consumption reduction in buildings, small industries and commercial facilities. MES (micro-energy services) provide a new development scenario for small ESCOs that can easily access financial markets and promote technologies in which they specialize. In Europe, typical ESCO fields are public building, supply side projects, cogeneration, lighting refurbishments and district heating. In Spain, the sector is

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Nomenclature

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CDD	cooling degree days
CLT	critical lower temperature
COP	coefficient of performance
CT	comfort temperature
CUT	critical upper temperature
ECT	evaporation critical temperature
EER	energy efficiency ratio
EPC	energy performance contract
ES	energy service
ESCOs	energy service companies
EU	European Union
GCHP	ground-coupled heat pumps
GFHP	ground frost heat pump
GSC	guaranteed savings contract
GSHP	geothermal source heat pumps
GWHP	groundwater heat pumps
HDD	heating degree days
HHV	higher heating value (kWh/m^3)
HVAC	heating ventilation and air conditioning
IGA	investment grade audit
IPMVP	international performance measurement and verification protocol
IRR	internal rate of return
M&V	measurement and verification
MES	micro energy services
NPV	net present value
PI	price index
ROI	return of investment
SPF	seasonal performance factor
SSC	shared savings contract
SWHP	surface water heat pumps
VGHX	vertical ground heat exchangers

Math formulae

T_g	undisturbed ground temperature (°C)
Xs	soil depth (m)
As	annual surface temperature amplitude (°C)
$T_{s,max}$	maximum surface temperature (°C)
$T_{s,min}$	minimum surface temperature (°C)
L_h	heating length (m)
L_c	cooling length (m)
$T_{g,min}$	minimum ground temperature, calculated for a depth (°C)
$T_{g,max}$	maximum ground temperature, calculated for a depth (°C)
α	soil thermal diffusivity (m^2/s)
t_o	time constant (days)
COP_h	coefficient of performance – heating mode (non dimensional)
COP_c	coefficient of performance – cooling mode (non dimensional)
R_p	pipe thermal resistance (°Cm/W)
R_s	soil thermal resistance (°Cm/W)
$\overline{q}$	average monthly load (kW)
q_{max}	peak monthly load (kW)
F_h	load factor in heating mode (non dimensional)
F_c	load factor in cooling mode (non dimensional)
$q_{d,\ heat}$	heating mode power (kW)
$q_{d,\ cool}$	cooling mode power (kW)
$T_{ewt,max}$	maximum design water temperature (°C)
$T_{ewt,min}$	minimum design water temperature (°C)
P'	revised energy cost in the current year (€)
P^0	energy cost in the previous year (€)
f	price revision factor (non dimensional)
a	fuel percentage (%)
b	electricity percentage (%)
$PI_1^{Electricity}$	unitary electricity price for the current year (€/kWh)
$PI_0^{Electricity}$	unitary electricity price for the previous year (€/kWh)
PI_1^{Fuel}	unitary electricity price for the current year (€/kWh)
PI_0^{Fuel}	unitary electricity price for the previous year (€/kWh)
q_{sen}	specific sensible heat (kW/pig)
q_{lat}	specific latent heat (kW/pig)
q_{total}	specific total heat (kW/pig)
Q_{sen}	sensible heat (kW)
Q_{lat}	latent heat (kW)
Q_{total}	total heat (kW)
T_{min}	minimum temperature in the location (°C)
T_{max}	maximum temperature in the location (°C)
$T_{base-heating}$	base temperature for heating degree days calculation (°C)
$T_{base-cooling}$	base temperature for cooling degree days calculation (°C)

experiencing slow growth, and the energy service providers are large utilities, construction and multi-service companies (Goldman et al., 2002) [3]. Last survey and research study about the sector in Spain shows that sector turnover accounted 800 M€ in 2013, with an annual increase of 6.3% in comparison with 2012. Office buildings and residential buildings accounts 34% of the turnover and street lighting 20%. Hospitals accounts 13% of the global turnover and industrial facilities 15% [4,5].

The most common projects are public buildings, private non-residential buildings and industries involving cogeneration, audits, HVAC (heating, ventilation and air conditioning) control systems and lighting. European Union has an important agricultural and stockbreeding sector in which important energy efficiency improvements can be achieved [1–9]. Reductions in energy consumption make the sectors more competitive and provide added value to products via sustainable production certificates and footprint reduction [6]. Renewable energy can provide an effective solution for climatizing stockbreeding facilities by ESCOs. GSHPs (geothermal source heat pumps) are typically used in buildings, but they can also be used with good results in industrial facilities. To evaluate geothermal energy usage for both direct use and geothermal heat pump many references are related in the bibliography [7,8] but no references for ESCOs using low enthalpy geothermal energy are found.

In this paper, a GSHP-based solution is proposed and evaluated as a way to reduce energy consumption in stockbreeding facilities. The technical and financial model for the ESCO is developed and analyzed, and a particular case is proposed for pig farming in Spain. The proposed energy service achieves extremely good results; in addition to reducing energy consumption, the more adequate thermal conditions increases the pork production, reduces the simple ROI (return of investment) and makes the investment more attractive for both the ESCO and the industrial producer. To make the study more robust, a sensitivity analysis and a Monte Carlo