Applied Energy 152 (2015) 94–108

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

The performance of small scale multi-generation technologies in achieving cost-optimal and zero-energy office building solutions

Ayman Mohamed [a,*], Mohamed Hamdy [a,b], Ala Hasan [c], Kai Sirén [a]

[a] Aalto University School of Engineering, Department of Energy Technology, P.O. Box 14400, FI-00076 Aalto, Finland
[b] Eindhoven University of Technology, Department of the Built Environment, Building Physics and Services, Den Dolech 2, 5612 AZ, Eindhoven, The Netherlands
[c] VTT Technical Research Centre of Finland, Espoo, P.O. Box 1000, FI-02044 VTT, Finland

HIGHLIGHTS

- The cost-optimal solutions for a new office building in Finland are obtained.
- The EBPD comparative framework methodology is followed.
- Biomass CHPs with high overall efficiency and low P/H ratio are economically viable.
- Biomass CCHPs do not have economic or environmental benefits over biomass CHPs.
- Extending the cost-optimal solutions by PV system yields NZEB with minimum LCC.

ARTICLE INFO

Article history:
Received 5 January 2015
Received in revised form 22 April 2015
Accepted 25 April 2015

Keywords:
EPBD recast
Life-cycle cost
Biomass
Combined heating and power (CHP)
Combined cooling heating and power (CCHP)
Zero-energy office building

ABSTRACT

This study investigates the economic viability of small-scale, multi-generation systems (combined heat and power (CHP), combined cooling, heating, and power (CCHP)), along with conventional heating and cooling systems combining sixteen heating/cooling energy generation systems (H/C-EGSs). The Energy Performance of Buildings Directive (EBPD) comparative framework methodology is followed. The local cost-optimal solution for an office building, in Helsinki, Finland is determined for each H/C-EGS as well as the global cost-optimum. The suggested energy efficiency measures get 144 building combinations, and alongside the H/C-EGSs, altogether 2304 cases. The results show that the global cost-optimum belongs to the ground source heat pump with free ground cooling. The investigated biomass-based CHPs are economically viable only with high overall efficiency and low power-to-heat ratio due to both low investment and operational costs. The biomass-based CCHPs do not have economic or environmental benefits over the biomass-based CHPs due to the significant increase entailed of both investment and operational costs. The fossil fuel-based CHPs with high operational costs are the worst solutions economically and environmentally. Extending the cost optimal solutions by a photovoltaic panels system yields the net zero-energy office building with minimum life-cycle costs as well.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

In order to reach the EU target of 20–20–20 (20% GHG emissions reduction, 20% increase of renewable energy and 20% increase in energy efficiency by 2020 from 1990 levels), the building sector has to be looked into, since the building energy needs in the European Union represent 40% of the overall energy consumption [1]. The Energy Performance of Building Directive 2010/31/EU, (EPBD) recast [2] specified that by the end of 2020, all new buildings shall be "nearly zero-energy buildings" (nZEB). As stipulated in this directive, all Member States (MS) shall ensure that minimum energy performance requirement achieving cost-optimal levels has to be set using a comparative methodology framework. The methodology framework was published as EU supplementary EBPD recast in 2012 as "Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU" [3]. In May 2012, Finland submitted the minimum energy performance requirements for calculating cost-optimal levels report to the EU [4]. This report shows the cost-optimal of the minimum energy performance of new residential and commercial buildings built in accordance with the current Finnish building regulations

* Corresponding author. Tel.: +358 50 431 5774; fax: +358 9470 23418.
E-mail addresses: ayman.mohamed@aalto.fi, aymansarwah@gmail.com (A. Mohamed).

http://dx.doi.org/10.1016/j.apenergy.2015.04.096
0306-2619/© 2015 Elsevier Ltd. All rights reserved.

Nomenclature

AC	absorption chiller
BSSP	building service system package
CAV	constant air volume
CCHP	combined cooling, heating and power
CHP	combined heat and power
CO_2-eq	CO_2 equivalent emissions
COP	coefficient of performance [–]
DC	district cooling
DH	district heating
dLCC	incremental life-cycle cost [€/m^2]
EEM	energy efficiency measure
EGS	energy generation system
EPBD	Energy Performance of Building Directive
GC	ground cooling
GHG	greenhouse gases
GSHP	ground source heat pump
H/C	heating/cooling
HVAC	heating ventilation and air conditioning
ICE	internal combustion engine
IFGT	indirect fire gas turbine
LCC	life-cycle cost [€/m^2]
MS	member states
mT	micro-turbine
NG	natural gas
nZEB	nearly zero-energy building
NZEB	net zero-energy building
O&M	operation and maintenance
ORC	organic Rankine cycle
P/H	power to heat ratio
PB	pellet boiler
PE	primary energy
PV	photovoltaic panels
Q_c	thermal cooling capacity [kW]
Q_h	thermal heating capacity [kW]
RET	renewable energy technology
SE	stirling engine
SFP	specific fan power [kW/(m^3/s)]
SHGC	solar heat gain coefficient [–]
SPC	space cooling demand [kW h/m^{2}a]
SPH	space heating demand [kW h/m^{2}a]
VAV	variable air volume
VCR	vapor compression refrigeration cooling system

D3-2012 [5] and D5 2012 [6] as well as existing buildings. The multi-generation systems including cogeneration heat and power (CHP) and tri-generation system (which is also defined as combined cooling, heating, and power (CCHP)) were not implemented in the Finnish report [4].

Several researches in Europe focused on the combination of building energy performance and cost analysis. Since the EPBD recast has been raised recently, a limited number of current studies refer directly to the objectives of the EPBD recast and related concepts. The implementation of the EPBD recast to determine the energy performance requirement under national perspectives is conducted and submitted by EU Member States as well as in some articles. Before publishing the EU supplementary EBPD recast [3], several studies tried to investigate the cost-optimal levels of minimum energy performance requirements such as [7]. Regarding the calculation method used to evaluate the minimum energy requirements achieving the cost-optimal levels within the comparative methodology framework, the developed optimization techniques were presented by [8] applied to new single family house and [9] applied to the retrofitting of existing office buildings. Regarding the national polices and perspectives comparing with the EPBD requirements, Turkey as an EU Member Candidate, the adaptation of cost-optimal calculations under national circumstances and Mediterranean climates of Turkey using an existing office building is presented in [10]. Most of the aforementioned and similar studies investigated the building elements without changing the supply systems or with limited conventional systems.

The CHP as a proven and reliable form of technology provides various energetic, economic, and environmental advantages compared to the separate production of heat and power at the large and district levels. Various fuels can be supplied to the CHP systems such as natural gas (NG), diesel, peats, biogas, and biomass (wood). The biomass and biogas are considered renewable energy sources. Implementing small scale (in the 30–2000 kWe range [11]) biomass-based CHP as a supply system in the residential and commercial buildings was carried out from different perspectives. Techno-economic investigation of implementing biomass-based CHPs was carried out by [12,13]. Some studies investigated the biomass-based CCHP where the biomass-based CHP was coupled with thermally-activated cooling technology [14,15]. Meanwhile the net zero energy building (NZEB) definition is raised, the biomass-based CHP systems were investigated as a main energy supply system in [16,17]. Moreover, the energy matching capability of the micro-scale bio-syngas-and natural gas (NG)-based CHP systems operated under thermal and electrical tracking strategies, fulfilling NZEB balance are investigated in [18,19]. None of these studies looked at the cost-optimal levels for the minimum energy performance as a primary objective of the EBPD recast for multi-generation systems.

The main objective of this study is to find the local cost-optimal level for each heating/cooling energy generation system package (H/C-EGS) implemented on a representative new office building in Finland using the comparative methodology framework as well as the global cost-optimal level which is the minimum cost-optimal level among all H/C-EGSs. The H/C-EGSs are illustrated in Section 3.2, consisting of five conventional systems, four different biomass-based CHPs with a vapor compression refrigeration (VCR) system, four biomass-based CCHP with same technologies of the biomass-based CHP but coupled with absorption chiller (AC), and three fossil fuel-based CHPs with a VCR. The new office building is the same reference office building used in the Finnish report [4], selected as a representative office building built in accordance with the current Finnish building regulations D3 and D5-2012 [5,6]. Moreover, the other objective is to find the economical solution along with the economic viability of achieving the nZEB and NZEB when a photovoltaic panels system (PV) as a renewable energy technology (RET) is implemented either to the obtained local cost-optimal or the minimum energy performance solutions. The minimum energy performance solution refers to the solution that has minimum energy consumption.

2. Methodology

In this study, to find the local cost-optimal levels, as well as the global cost-optimal level for the implemented heating/cooling energy generation system packages (H/C-EGSs) serving all considered building energy efficiency measure (EEM) combinations, the steps of cost-optimal framework methodology explained in the EU supplementary EPBD recast [3] are followed. Fig. 1 shows in detail the layout of the methodology used to achieve the objectives

Download English Version:

https://daneshyari.com/en/article/6687082

Download Persian Version:

https://daneshyari.com/article/6687082

Daneshyari.com