Energy 134 (2017) 438–448

Contents lists available at ScienceDirect

Energy

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

The effect of feed-in-tariff supporting schemes on the viability of a district heating and cooling production system

Juan Pablo Jiménez Navarro [a, *], José Manuel Cejudo López [b], David Connolly [c]

[a] European Commission, Joint Research Centre (JRC), Directorate for Energy, Transport and Climate, P.O. Box 2, 1755 ZG, Petten, The Netherlands
[b] Universidad de Málaga, Escuela Técnica Superior de Ingenieros Industriales, Grupo de Energética, Spain
[c] Department of Development and Planning, Aalborg University, A.C. Meyers Vænge 15, 2450, Copenhagen SV, Denmark

ARTICLE INFO

Article history:
Received 2 February 2017
Received in revised form
23 May 2017
Accepted 28 May 2017
Available online 29 May 2017

Keywords:
Combined cooling, heat and power
Combined heat and power
Energy policy
Optimisation
Feasibility
Feed-in-tariff

ABSTRACT

Combined cooling, heat and power systems represent an efficient alternative to supply heating and cooling demand compared to conventional boilers and air conditioner systems. However, considering the high level of upfront investment and the relatively long lifetimes, it is important to provide some form of long-term certainty to reduce the risk of deployment of these systems. To overcome this uncertainty, this paper describes a method to calculate an appropriate feed-in-tariff scheme to support investors and public authorities to foster the penetration of this technology in areas with high energy demands. It is subsequently tested in a scientific and technology park located in the south of Spain where different energy prices are studied. The results indicate that a feed-in-tariff is required to support the development of combined heating, cooling, and power systems, which not only improves the economic performance of the system, but also increases the utilisation of more efficient generation technologies such as combined cooling, heat and power systems.

1. Introduction

In the EU, half of the final energy consumed is used to satisfy heating and cooling demand [1]. In particular, cooling requirements are increasing rapidly in recent years [2]. As a result, distributed energy production for heating and cooling production purposes is one of the key elements of the energy strategy in the EU [3]. In this sense, energy solutions at a district level contribute to decentralised energy system and increase its efficiency.

District heating and cooling (DHC) systems are designed to satisfy heating and cooling demand combining local resources [4] and efficient energy generation technologies. In addition, the district approach allows i) a more efficient energy generation portfolio, primarily by utilising excess heat resources [5,6], and ii) higher penetrations of renewable energy technologies [7], a challenge for densely populated areas where little space is available. Therefore, they constitute a key enabling solution to achieve the decarbonisation of the European energy system [8].

However, DHC solutions require high level of investments and are subject to uncertainties concerning conditions of operation [9]. More specifically, their success is tied to changes in the energy demand to be satisfied, energy prices and the regulatory framework in the medium-to long-term [10].

Regulation plays a main role in the penetration of district heating and cooling solutions [11]. Adequate policy combined with financial support set by public bodies could finally enforce the investment decision. Across the EU, different schemes have been put in place based on financial support, market control or energy planning [12] that have been demonstrated effectively. On the contrary, there are examples where lack of policy commitment has led to the termination of district heating and cooling network projects.

Although different supporting mechanisms have already been tailored to promote the deployment of high—efficient energy solutions, this work investigates the optimal design of feed-in-tariffs schemes. They have been proved as the appropriate financial mechanism when technologies or solutions under study have not experiment a significant deployment [13].

Appropriate demand sizing is an additional key factor [14]. A simplified and accurate approach to determine energy demand to be supplied is essential for the final investment decision.

The objective of this paper is to offer a method to facilitate

* Corresponding author.
E-mail address: juan-pablo.jimenez-navarro@ec.europa.eu (J.P. Jiménez Navarro).

http://dx.doi.org/10.1016/j.energy.2017.05.174
0360-5442/

investors' decision making. Based on given energy price schemes, the proposed method calculates optimal combined cooling, heat and power (CCHP)/DHC solution providing information on economic indicators including marginal energy prices that ensure the system feasibility.

Thus, the method presented intends to be useful not only for energy investors but also for policymakers. Information on energy and economic performances will allow policy makers to understand DHC business models and then set appropriate supporting schemes to finally contribute to EU energy policies.

This paper is structured as follows: section 2 presents the method developed to get optimal solutions based on economic indicators, and section 3 sets out the case study quantifying the impact of different energy policies. Section 4 covers results derived from the optimal solution under different policy scenarios, and section 5 sets out sensitivity analysis to evaluate the impact of different assumptions concerning prices and performances. Lastly, section 6 presents the main outputs and the discussion about the role of energy policies in the promotion of these types of installations.

2. Method

The proposed method was built around a comprehensive CCHP system (Fig. 1). In real applications, these systems are equipped with back-up energy generation equipment to guarantee a minimum level of energy supply at any time. Therefore, they can potentially operate as a conventional or as a CCHP energy production system.

This dual operation fits the purpose of this work by providing enough flexibility to assess different scenarios. So, for a given set of equipment and energy prices some of the equipment will be selected as part of the optimal solution. Thus, if the optimal solution is conventional generation, then a back-up boiler and mechanical chiller will be part of the solution and sized according to the demand. In this particular case, electricity demand is satisfied by purchased electricity from the grid. On the other hand, if the CCHP is the optimal solution, all the elements included in Fig. 1 will be part of the optimal solution. In this case, electricity supply is managed depending on prices.

Three different types of elements were included in the system: demand, energy generators and storage.

2.1. Energy demand and selection of typical days

Energy demand is the main input when sizing CCHP/DHC installations. As the final objective for any energy system, demand sets the comparison framework to evaluate different energy scenarios. Energy demand influences not only the size of the generation components but also the benefits derived from the system operation. Therefore, an accurate calculation of the energy demand determines the success of any further feasibility study.

According to energy flows that could be potentially delivered by CHP systems, heating, cooling and electricity demand have to be modelled. Thermal energy supply includes heating and cooling demand. In the case of electricity, demand includes not only energy for electric appliances, but also the energy required to operate electric chillers.

To calculate energy demand patterns, a detailed energy simulation program was used [15]. In particular, the selected software allowed the modelling of dynamic effects that may significantly change energy demand compared to other simplified methods [16]. According to the dynamic of thermal behaviour in buildings and considering the level of aggregated demand at district level, a time step of 1 hour was chosen to simulate energy requirements [17].

Hence, the chosen time step led to an 8760-dimension problem on an annual basis. To facilitate the resolution of the optimisation problem, clustering techniques were applied leading to a reduced dimension by selecting a reduced number of typical days [18,19]. In the clustering process, some considerations were taken to ensure that the original demand was estimated accurately. Firstly, those days where demand peak occurred were included in the clustering. Additionally, the selection had to incorporate a number of days that complied with two requirements: i) the error in the load duration curve (ELDC), defined as the relative difference between the original and the estimated load duration curve, is lower than 10% and,

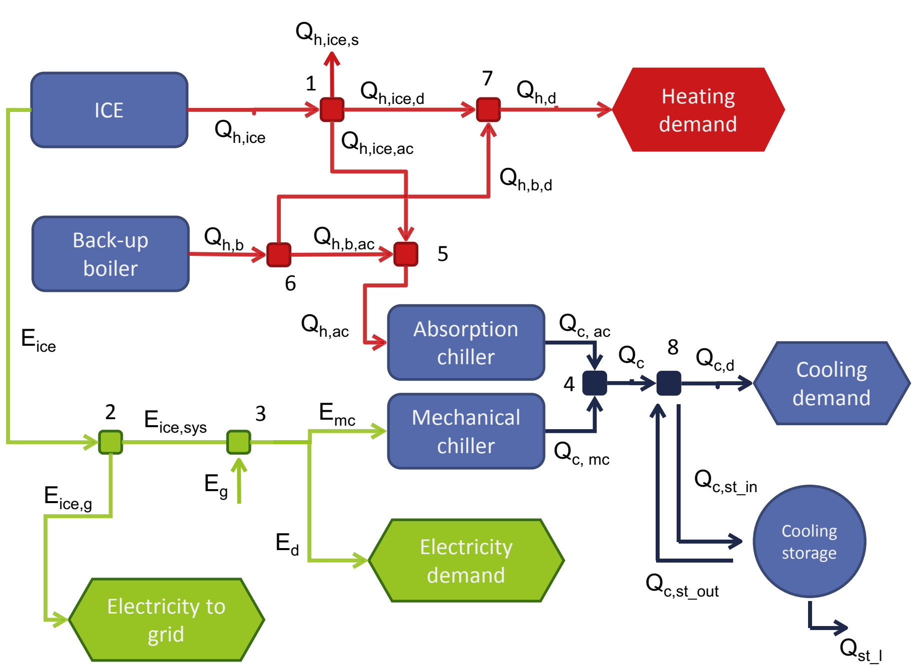

Fig. 1. Scheme for a combined heating, cooling and power facility.