CHAPTER 9

The Use of Biomass in District Heating and Cooling Systems

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Abstract

Because of their environmental and economic advantages, district heating and cooling systems fed with biomass are of increasing interest worldwide. Their implementation not only reduces greenhouse gases due to use of a renewable energy resource but also reduces exploitation costs, benefitting from a centralized energy system. In addition, these systems entail significant advantages for the buildings connected to them in terms of safety, electricity demand, space availability and energy rating. Due to all of this, it is expected that one of the most relevant advancements in biomass use in the coming years will be its energy valorization by means of DHC systems.

Keywords: Biomass, district heating and cooling, efficiency, savings, profitability.

1 Introduction

The first district heating system was put into operation in Lockport, New York, in 1877. This system used a steam boiler and a distribution net of 4.8 km, which supplied heat to several industries and residential buildings. Nevertheless, the Romans were the real precursors of these systems: by means of wooden pipes, they distributed hot water among the rooms in buildings [1].

In 1983, the Hamburg council in Germany installed a centralized heating system that used the residual thermal energy of a central power station. Similar examples progressively occurred in the USA, Scandinavia and Denmark until the end of the Second World War, when the competitiveness with fossil fuels made the viability of the biomass systems disappear. This fact, together with the construction of large power stations in the outskirts of cities, notably increased the transport costs of thermal energy that in the majority of the cases was residual steam. This situation...
reverted again in 1970 because of the oil crisis; it was then that countries such as Sweden or Denmark started to wager on the incineration of municipal solid waste and the use of renewable energies, especially that from biomass.

District cooling systems are more recent. This technology was developed in the USA during the 1960s and its evolution has been provoked by the increment of the thermal energy demand in buildings from the tertiary sector (hospitals, faculties, etc.) and the increasing requirements of thermal comfort in the population.

These district heating and cooling (DHC) systems were also implemented in Asia beginning in the 1970s because of the high cooling demand in office buildings. Currently, 50% of cities in China have centralized systems, which are exponentially increasing because of high electricity prices and the existing energy deficiency.

An increasing and global evolution of these systems, which are instituted in almost every part of the world, is thus observed.

2 Legislative Framework

At the European level, the main norm in matters of centralized systems is the directive 2010/31/CE [2] on the energy performance of buildings. This directive defines the concept of centralized urban heating system; in article 6 it states that: ‘Member States shall take the necessary measures to ensure that new buildings meet the minimum energy performance requirements set in accordance with Article 4. For new buildings, Member States shall ensure that, before construction starts, the technical, environmental and economic feasibility of high-efficiency alternative systems such as those listed below, if available, is considered and taken into account: decentralised energy supply systems based on energy from renewable sources; cogeneration; district or block heating or cooling, particularly where it is based entirely or partially on energy from renewable sources; heat pumps.’

Moreover, in article 20, it is noted that: ‘Member States shall ensure that guidance and training are made available for those responsible for implementing this Directive. Such guidance and training shall address the importance of improving energy performance, and shall enable consideration of the optimal combination of improvements in energy efficiency, use of energy from renewable sources and use of district heating and cooling when planning, designing, building and renovating industrial or residential areas.’

Other legislative challenges from this directive that should be highlighted are summarized below:

- By the end of 2018, all new public buildings have to be ‘buildings with almost null energy consumption,’ and this requirement will be extended to all new private sector buildings by the end of 2020.
- Energy efficiency certificates are already mandatory for buildings that are going to be sold or rented.
- There is a positive influence of DHC systems on the energy performance of a building that has to be taken into account.
On the other hand, the new energy efficiency directive 2012/27/EU [3] cites that ‘district heating and cooling has significant potential for saving primary energy, which is largely untapped in the Union’ and introduces references to these systems such as their contributions to improving energy efficiency and the reduction of greenhouse gas emissions.

3 DHC Systems

3.1 Definition

According to the European directive 2010/31/CE [2], ‘district heating or district cooling means the distribution of thermal energy in the form of steam, hot water or chilled liquids, from a central source of production through a network to multiple buildings or sites, for the use of space or process heating or cooling.’

To sum up, the DHC systems are pipe systems that connect the energy sources to the energy consumption points. Their main advantage is the efficient use of thermal energy for the acclimatization of buildings and/or facilities. In addition, they are capable of taking advantage of the residual heat from thermal and/or cogeneration plants, industrial processes and renewable energies. Driven by the ability to provide synergies between local resources and thermal sinks, DHC systems have interfaces not only with a huge variety of other energy and non-energy sectors (Fig. 1), and function therefore with close collaboration from other stakeholders, such as the renewable industry (solar, geothermal and biomass, including waste), building owners, operators and users, industrial facilities and the service sector, but also with urban planners and local authorities [4].

3.2 DHC systems fed with biomass

To achieve a competitive district system from an economic and sustainable point of view, it is necessary not only to use efficient technologies but also to use residual and/or renewable sources of energy such as biomass.

The only difference between a conventional system and a DHC system fed with biomass is the power plant, which is the main element of the system because its objective is to satisfy the thermal demand. This plant has to be dimensioned and designed according to the fuel and technology to be used and its location.

Regarding biomass fuels, the most commonly used is lignocellulosic biomass with moisture content lower than 20%. For economic reasons, biomass is generally used in chips (100–150 €/tonne), although pellets (300 €/tonne) are an option to consider when the heterogeneity of the biomass supply can alter the behaviour of the plant (Fig. 2) and, in consequence, the energy supply [5].

The technical requirements necessary to use biomass in the DHC systems are generally established by the manufacturers of the boilers and are focussed on the particle size and on the moisture and ash contents. Table 1 shows the characteristics of a biomass sample suitable for use in these centralized systems.
3.3 Advantages and disadvantages

DHC systems have several advantages in comparison with the individualized systems. Among them, the most relevant are listed below:

- Economic savings for the consumer due to the reduction of the necessary power and the final price of the energy consumed.
- Sustainability because of using renewable sources of energy.
Table 1: Characteristics of a biomass sample suitable for use in DHC systems according to the manufacturer [6].

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Suitability range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (mm)</td>
<td>0–5</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>6–15</td>
</tr>
<tr>
<td>Lower heating value (kcal/kg)</td>
<td>3,800–4,250</td>
</tr>
<tr>
<td>Ash content (%)</td>
<td>0.5–2.5</td>
</tr>
<tr>
<td>Volatile content (%)</td>
<td>70–80</td>
</tr>
<tr>
<td>Sulphur content (%)</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td>Chlorine content (%)</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Fixed carbon (%)</td>
<td>&lt;30</td>
</tr>
</tbody>
</table>

- Flexibility to be adapted to the energy demand.
- Efficiency related to the higher yield and the better insulation of the pipes.
- Higher value of the building because of its better energy rating.
- Easy management caused by the better relationship between promoters and clients.

These systems have some disadvantages such as:

- The necessity of an agreement between all the agents: administrations, promoters, users, enterprises, etc.
- The infrastructure necessary to connect the power plant to the final consumers.

4 The Model of Energy Service Companies

One of the drivers of the DHC systems is the so-called Energy Service Company (ESCO) model [7]. This model is based on the definition of ‘a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user’s facility or premises, and accepts some degree of financial risk in so doing’ established by the directive 2006/32/CE on energy end-use efficiency and energy services [8].

The payment for the services delivered is based (either wholly or in part) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria established in the energy performance contract (Fig. 3).

The key characteristics of this type of enterprise or ESCO are as follows [9]:

- The ESCO guarantees the energy savings and/or the provision of the same level of energy service at a lower cost by implementing energy efficiency measures.
- The remuneration of the ESCO is directly tied to the energy savings achieved.
- The ESCO can either finance or assist in arranging financing for the installation of an energy project they implement by providing a savings guarantee.
The ESCO retains an on-going operational role in measuring and verifying the savings over the financing term.

ESCOs offer a large range of energy services including: energy analysis and audits; energy management; project design and implementation; maintenance and operation; power generation and energy supply; monitoring and evaluation; facility and risk management.

ESCOs can be grouped into different ownership groups [9]:

- ESCOs that originate from equipment manufacturers and suppliers.
- ESCOs that stem from energy utilities or supply companies, public sector agencies or public–private joint ventures.
- Independent ESCOs.
5. The Case of Geolit, a DHC Central System Using Biomass

Geolit Acclimatization is a company created with the objectives of design, procurement and construction of an efficient and innovative DHC system, with benefits for its users and for the environment. This DHC system was the first one constructed in Spain. It is located in the province of Jaen, where there is a high energy potential from residual biomass from the olive oil sector. In accordance with this, the facility was designed for the use of this biomass as a fuel.

The thermal installations of Geolit work to supply hot and cold water for 35,000 m² of acclimatized buildings [11,12].

5.1 Specifications of the facility

5.1.1 Thermal production building

The thermal production building (Fig. 4) is an independent building where one can find boilers, chillers, pumps and cooling towers for the production and distribution of hot and cold water.

The installation includes two biomass boilers specifically designed for olive stone and olive chip combustion as well as forest and agricultural residues or energy crops.

5.1.2 Hot water production: biomass boilers

Hot water is produced through the operation of two biomass boilers (Fig. 5). The total installed thermal power is 6,000 kW, well above the initial thermal demands (2,500 kW estimated). Both boilers are located in the central heating room.

The biomass building was created and installed with a modular design and automatic operation, in which each of the modules has the characteristics described in Table 2.

The biomass boiler complex is associated with a huge biomass storage silo (450 m³). The installations are controlled by an electronic control system located in a separated room.

Figure 4: Thermal production building at Geolit.
5.1.3 Cold water production: single-effect absorption chillers

The hot water boiler outlet, at 90°C, is used like an energy inlet in the single-effect absorption chiller. These equipments use a LiBr-like absorbent and can provide 4,000 kW in the form of cold water at 5.5°C. Therefore, this equipment produces cold water from hot water without a significant use of electricity.

In addition to the 4,000 kW single-effect absorption chiller another absorption chiller (backup system) is available, which can provide 2,000 kW in the form of cold water at 5.5°C (Fig. 6).

The absorption chiller works using a proven design principle. It consists of four chambers: the evaporator, the condenser and two absorption chambers.

An adsorption chiller is a highly reliable, efficient solution that takes heat to produce chilled water, which in turn can be used for cooling and linked into refrigeration applications. Absorption technology produces chilled water down to as low as 3°C, as required, making it ideal for any application with a high cooling demand.

The two absorption chambers contain heat exchangers packed with silica, with a valve between them to allow vapour pressure equalization. Between each absorption chamber and the ‘evaporator’ and ‘condenser’ chambers, valves allow the transfer of vapour when there is sufficient pressure differential.

5.1.4 Distribution network

The distribution network operates in a four-pipe configuration (independent circuits for hot and cold water).
The ‘pre-insulated’ pipeline was selected for this installation due to the advantages of such pipes in front of in situ insulated pipes: minimal heat loss; quick installation; long life and minimum maintenance; and minor civil works (pipe buried directly).

This is a factory-made pre-insulated pipe, designed specifically for transporting hot or cold fluids in long distance systems, minimizing heat losses. These pipes are fitted with a rigid polyethylene outer shell that provides the mechanical protection needed for it to be directly buried in the ground.

5.2 Fuel and heat demand

The annual biomass consumption is approximately 1,800 tonnes, or 1,500 tonnes dry basis. In total, 7,674 MWh is the yearly energy demand for Geolit. The installation operates approximately 4,000 h per year in total. The boiler efficiency is 85%. Calculations show that the nominal heating capacity of Geolit is 3.26 MW.

5.3 Main advantages

The main advantages of this DHC system are as follows:

- It provides users with significant financial savings.
- The energy is directly delivered to the residents, as energy-producing elements in each building are not necessary. Consequently, it avoids risks and dirt, improves the use of spaces and eliminates maintenance or repair operations.
- It improves the energy efficiency and causes less environmental impact because the CO₂ emissions are avoided, unlike when generated with other systems: 0.63 kg CO₂/kWe for cold water production systems based on electricity; 0.21 kg CO₂/kWe for hot water production from natural gas.
6 Conclusions

The development of biomass as an energy resource makes its use for thermal energy production necessary. Among thermal applications, DHC systems are destined to play a crucial role because of their advantages for the environment but also for promoters, consumers and public administrations.

Nevertheless, the proper implementation of these systems requires:

- An improvement of the quality of biofuels.
- Development of the supply and logistic infrastructures.
- Higher stability of the biofuel price.
- Social concern.
- Technical developments focussed on the improvement of the boilers, which should increase their efficiency and make them capable of working with different types of biomass to ensure the energy supply.

References