INTEGRATION OF RENEWABLE DISTRICT HEATING IN LAGUNA-VALLADOLID

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ABSTRACT

This paper presents an evaluation of the most suitable renewable sources of energy for Laguna-Valladolid considering the different alternatives of the location, and a detailed design of a demonstrator based on TRNSYS simulations developed in the framework of a European project, CITyFiED (repliCable and InnovaTive Future Efficient Districts and cities).

The overall objective of CITyFiED project is to develop a replicable, systemic and integrated strategy to convert European cities and urban ecosystems into smart cities of the future, focusing on reducing the energy demand and GHG emissions and increasing the use of renewable energy sources by developing and implementing innovative technologies and methodologies for building renovation, smart grid and district heating networks and their interfaces with ICTs and Mobility.

One of the main goals of this project is the development of a deep retrofitting of the buildings, and innovative district heating solutions in three large scale demonstrations, at Laguna-Valladolid (Spain), Soma (Turkey) and Lund (Sweden) in order to achieve powerful models suitable for replication across Europe.

Keywords: District heating, renewable energy, demonstrator, TRNSYS, CITyFIED.

INTRODUCTION

Energy efficiency in new buildings is important, but existing building stock is the main target. Existing buildings, however, are characterized by particular requirements and constraints that are not present in new buildings and that require new developments and adaptation of existing technologies. In order to fulfil the most recent EU directives, solutions for a drastic reduction in primary energy consumption are required. Space heating and domestic hot water preparation (DHW) represent the largest part of energy use in buildings nowadays [1].

Despite these existing initiatives and even though many of them focus on buildings retrofitting, the systemic renovation strategies at district or city level are still not generalized enough in Europe and even less in Spain, where the difficult current economic situation and social aspects do not help to spread the benefits of this approach. It is clear that some general barriers are holding back the massive deployment of such interventions, even if the technology is available and currently some business models such as ESCO are serving as catalysts. Thus, a strong effort is required to spread the benefits of the integrated refurbishment, to overcome the existing barriers and to provide innovative and effective solutions to address the current technical and financial challenges

This paper presents the main results obtained in CITyFIED project, in the evaluation of the most suitable renewable energy sources (such as solar energy, biomass, geothermal and wind energy) of Laguna de Duero (Valladolid, Spain) considering different alternatives of location, and a detailed design of the demonstrator based on TRNSYS simulations.

The intervention aims to drastically reduce the energy consumption by means of passive measures (façade retrofitting) and advanced control and distribution systems implementation, able to control temperature levels building by building. This will result in a good coverage of the energy demand and avoiding heat losses. Besides, an innovative district heating facility will be installed not only for heating but also for domestic hot water supply.

DISTRICT AND SYSTEM DESCRIPTION

Laguna de Duero is a little town located in the middle of Spain, fully integrated in the metropolitan area of Valladolid. Laguna's climate is Mediterranean-continental. Temperatures are very extreme, with big differences between day and night. Winters are cold, with frequent foggy days and frosts around 60 days per year. Summers are hot and dry but present low minimum temperatures during the night. According to this, heating is the principal energy demand of the buildings, as cooling devices are not usually present in dwellings.

Torrelago District:

The demo site, whose representative data are summarized in Table 1 involves 31 residential buildings, split into two phases (1488 dwellings and more of 4.000 residents) which are in use nowadays. Phase 1 has 12 buildings of 12 floors, with 4 apartments per floor of an average area of 100 m^2. These buildings were constructed in 1977. On the other hand, Phase 2 has 19 buildings (identical to buildings in Phase 1). 11 buildings were constructed in 1979 and 8 buildings were constructed in 1981.

Nº of buildings	31 buildings
Nº of dwellings	1488 dwellings
Nº of beneficiaries	> 4.000 residents
% of beneficiaries/municipality	> 18%
m^2 of constructed area subject of intervention	140.000 m^2

Table 1: Torrelago District general description.

Description of current energy systems:

The energy system of the district was composed of two independent gas-fired boiler rooms, one for each phase. These two District Heating (DH) systems provided thermal energy, covering both space heating (SH) and domestic hot water (DHW), for 19 and 12 buildings, respectively. In the case of Phase I, two gas-fired boilers with a total capacity of 5.938 kW were installed. Two gas-fired boilers with a total capacity of 9.386kW were installed in case of Phase II.

Table 2 shows the approximate current yearly energy consumption, demand and CO$_2$ emissions before district retrofitting works:

Summary of the interventions:

The principal actions being performed to improve thermal energy efficiency in the district are:

- Complete renovation of the façades to increase thermal insulation.

- Deployment of a new District Heating concept, to cover the demand by optimizing the production of thermal energy by means of a mix of energy sources. The use of renewables

must be maximized with the biomass-boiler system, which improves energy efficiency, stabilizes prices and reduces CO_2 emissions.

- A new pumping system based on variable flows is being installed, that will allow making an appropriate balance load to adjust production to demands.

- Implementation of a new control system in order to improve the management and efficiency of the installation. Individual thermal consumptions of each building will be considered on the District Heating control system, with the aim of making a better adjustment of production to consumption. Thermal consumptions of each individual dwelling from the building are being considered as well.

- A Combined Heat and Power facility will be installed, for self-consumption, with appropriate smart grid elements to make an adequate control.

OVERALL THERMAL ENERGY DEMAND BY USE		
Total Thermal Energy Demand	13.037 MWh	93,12 kWh·m^{-2}
- Space Heating	9.663 MWh	69,02 kWh·m^{-2}
- Domestic Heat Water	3.374 MWh	24,1 kWh·m^{-2}
OVERALL CO$_2$ EMISSIONS		
By gas		3,583 tCO$_2$
By electricity		58 tCO$_2$

Table 2: Overall demand and CO2 emissions for Torrelago-District.

DESCRIPTION OF DYNAMIC MODEL AND ANALYSIS OF CASE STUDIES

A dynamic simulation model of the district was developed in order to analyse the described system after considering façade retrofitting works as well as solar thermal energy generation implementation in the mentioned system. The results of the simulations performed by CITyFIED partners (ACCIONA and LKS) revealed that the energy demand for SH was in line of the initial conditions (deviation of 8.65%). After that energy simulations of the retrofitted buildings were carried out [1]. Simulations of the retrofitted case were performed using Design-Builder software [2], showing an energy demand reduction of almost 40%.

Biomass District Heating system:
Two district phases were connected to create a a unique district heating system. Installation of biomass boilers in order to substitute existing natural gas boilers was studied. Existing boilers, installed in the second phase's generation-station, were left as backup systems when biomass boiler's generation capacity would not be able to cover instantaneous demand of the district heating.

The described system's performance was studied by transient simulation software, TRNSYS [3]. Figure 1 shows a simplified hydraulic scheme of the modelled system, consisting of a main heating central with biomass boilers in combination with two buffer storages of 12 m^3 each. Close to Phase II a secondary heating plant is located with backup gas fired boilers.
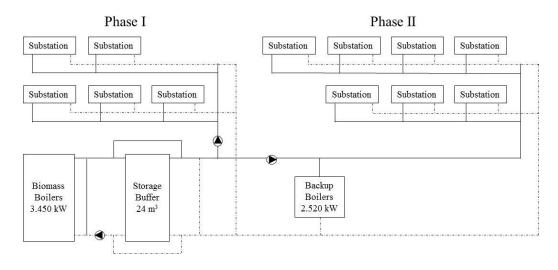
Figure 1: Schematic representation of the hydraulics of the system simulated.

System-performance strategy is divided into different operation modes depending on whole system load capacity and storage charging state. As long as the load stays lower than 3.450 kW, biomass boilers may cover it. When the load is higher than the biomass boilers' capacity they operate at full capacity but delivering in priority to Phase-I. Surplus heat is directed to Phase-II. Besides, in case heat is stored in DH net tanks, this additional capacity is discharged in parallel to biomass boilers.
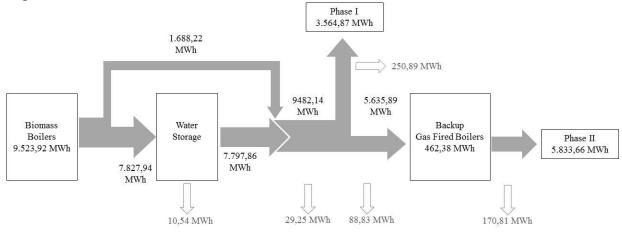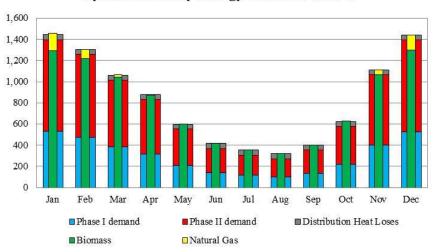

Figure 2: Biomass system simulation yearly energy balance.

Figure 2 shows the analysed system performance. Approximately 95% of heat generation comes from biomass boilers in order to cover demands by Phase I and II, including distribution heat losses along the network, resulting in about 550 MWh. The rest of the heating needed is supplied by gas boilers, covering part of the demand in Phase II.

Substitution of gas fired boilers by biomass boilers in the generation system of Phase I supposes a 78% of primary energy savings and a yearly CO_2 emissions reduction of above 2 tones (see Table 3). Figure 4 shows the monthly distribution of heat generation, by either biomass or natural gas, in the analysed system. It may be shown that the auxiliary system is required during winter months, i.e. from November to March. During winter time both, SH

and DHW are required by DH residents and depending on the hour of the day, installed biomass boilers' capacity does not result enough to cover their necessities.

Figure 4: Monthly energy balance of the simulated biomass system.

Solar Generation in combination with biomass:

Solar thermal energy generation in combination with the previously studied biomass generation is proposed. This would be the first DH plant with solar energy contribution in Spain. Solar energy would be used in order to cover DHW demand [4]. Studied and implemented installation for each DH building substation is shown in Figure 5.
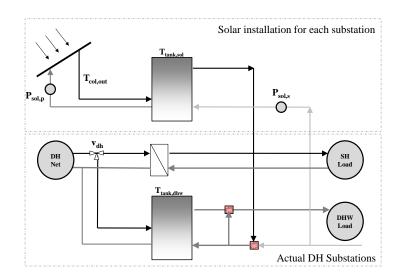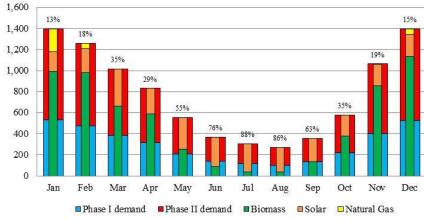

Figure 5: DHW implementation into DH-Substations.

Simulations were performed to estimate the required collector area for different solar fraction values [5]. A total surface of 4.400 m^2 would be needed to get a total solar fraction of 31% (including SH and DHW demand). Figure 6 shows the distribution for covering of the total heat demand, by solar (31,12%), biomass (65,45%) and gas (3,43%).

Solar-System monthly energy balance / MWh

Figure 6: Monthly energy balance of studied system with solar installation.

According to conversion factors summarized in Table 3, installation of solar thermal energy in combination with biomass installation would suppose a reduction of 30.20% in primary energy consumption and a reduction of 114.703 kg CO2 emissions to the atmosphere.

	Primary Energy Factor	CO2-eq emission factor / $g \cdot KWh_{TH}$
Biomass	0,2	7
Gas	1,1	222

Table 3: Primary energy factors and CO_2 equivalent emissions factors.

CONCLUSIONS

This paper presents the evaluation of the most suitable renewable source of energy of Torrelago's DH in Laguna de Duero (Valladolid) considering different alternatives within location and a detailed design of the demonstrator based on TRNSYS simulations developed in the framework of the European project CITyFiED. The results of the dynamic simulations show:

- Heat demand is reduced by approximately 40% after building retrofitting.
- Substitution of gas fired boilers by biomass boilers suppose a reduction of 95% in gas consumption, 78% of primary energy savings and a yearly reduction of CO_2 emissions of 2 tones.
- Solar generation in combination with biomass supposes a reduction of 30,20% in primary energy consumption and 114.703 kg CO_2 emissions. Only 3,43% of the demand is covered by the gas boiler.

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