Towards zero-emissions in Torrelago District

Introduction

The European Union has among their objectives to reach before 2020 a 20% decrease of energy consumption, a 20% decrease of greenhouse gas emissions and a 20% increase of renewable energy usage [1]. According to the latest studies, around 6.2 billion people will live in urban areas by 2030, representing 70% of global population [2]. Moreover, thermal energy accounts for a great deal of the final energy consumption.

In this context, the European Commission developed 2010/31/EU and 2012/27/EU directives [3][4], aiming to foster the energy efficiency at building scale. District Heating Projects are a good solution to implement renewable energy use and not only improving energy efficiency, but also reducing greenhouse effect gases emissions

CITyFiED is a project that develops a systemic vision and a holistic strategy to adapt European cities and its urban ecosystem into smart, sustainable and inclusive cities of the future. The outcomes should deliver a highly replicable strategy to be firstly implemented in three real scale demonstrators and further expanded through a European Cities Cluster that will be created around the project.

The CITyFiED demonstration cities were: Laguna-Valladolid (Spain), SOMA (Turkey) and LUND (Sweden). This abstract will be focused on the Spanish project, which involves the retrofitting of a residential district, including a comprehensive district heating renewal and the improvement of the building envelope.

Torrelago is a residential district located in Laguna de Duero, near Valladolid, formed by 31 buildings that respond to three different typologies, containing a total 1,488

[1]. Presidency conclusions. European Council 2007, Brussels, Belgium, 8-9 March 2007, European Union:Belgium

[2]. Growth of cities endangers global environment – PhysOrg; URL: http://www.physorg.com/news/2011-08-growth-cities-endangers-global-environment.html; last access: 14th June 2017

[3]. Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings (recast). Official Journal of the European Union 2010, L. 153/13

[4]. Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. Official Journal of the European Union 2012, L. 315/1

dwelling where more than 4,000 residents live. Every building has ground plus twelve floor levels, occupied by an entrance hall and a total of 48 dwellings each with a surface of about 80 m^2 or 95 m^2, which means more than 140,000 m^2 in the aggregate.

The district was constructed around 1980 and is divided in two administrative phases: Community of Owners of Phase I is formed by 12 blocks (1 to 12) and Community of Owners of Phase II is formed by 19 blocks (13 to 31).

The group of buildings of Torrelago district represents the idea of district because of their spatial organization, with a common convergence to green and public space areas, and their strong similarities on design and construction elements. The central space of the area is occupied by a school, although this does not belong to the district and is not subject to the project.

The district is also characterized by its high construction density (198.4 dwellings/ha) and high population density (514.4 inh/ha) in relation to the other parts of the town.

Figure 1. Torrelago district in Laguna de Duero 3D view

Buildings and energy system description before retrofitting

Buildings

The buildings are made of medium constructive quality buildings built around 1980 with an old, insufficient and uncomfortable insulation. They were quite old and they had an excesive energy demand. During this period of more than 30 years, blocks have been remodeled inside, while keeping the original dimensions and composition of the façade.

The façade is made of brick cavity walls without insulation layer (25,5 cm), with an U-value of 1.36 W/m^2ºC, and presents numerous pathologies, such as thermal bridges in joint between façade and slab, fissures due to thermal expansion, fissures along the expansion joints, buckling of the façade, efflorescence on the bricks (due to condensation problems), lattice breakage or air infiltration through the façade. This way, most of the façade surface is made of brick cavity walls without insulation layer.

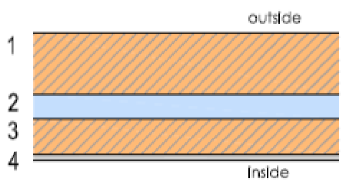
Figure 2. Some of the pathologies in the façades of the buildings (Top left: thermal bridges, top right: fissures, bottom left: efflorescence, bottom right: lattice breakage)

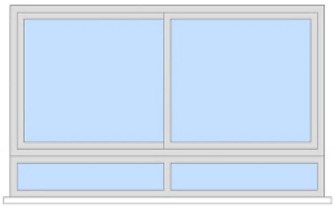
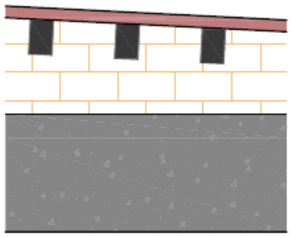
In some blocks, the surface of kitchens and clotheslines is covered by a 8 cm ceramic lattice that the majority of residents have broken to place a window, after adding to the kitchen the space of the balcony. These works have changed the appearance of the building and the uniformity of the façade.

The original windows are single glazed metal-framed windows, nevertheless, many residents have installed a second window outside the original one, in order to reduce heat losses. The partition walls are made of a single layer of brick.

In the table 1 are shown the constructive elements previously mentioned in detail:

Table 1. Constructive elements features

Element	Detail	Picture
Brick cavity wall 1. Ceramic brick wall of 12 cm 2. Air chamber of 5 cm 3. Ceramic brick wall of 7 cm 4. Gypsum plaster of 1.5 cm		

Element	Detail	Picture
Ceramic lattice 1. Ceramic lattice of 10 cm		
Window 1. Single glazed aluminum window		
Roof 1. Asbestos cement (Uralita roofing) sheets 2. Wooden strips 5 x 7.5 cm. 3. Brick wall partition 4. Reinforced concrete slab of 25 cm		

Energy systems

The energy system of the district was composed by two independent gas-fired boiler rooms. These two District Heating (DH) systems provided thermal energy for each of the districts Phases: Phase I District Heating provided energy for 12 buildings in Phase I; and Phase II District Heating supplied energy for 19 buildings of Phase II.

District Heating 1 was composed by two gas-fired boilers with a total capacity of 5,938kW, with 2,672 kW and 3,266 kW respectively, two heat recovery systems, four pumps with fixed flow with five storage tanks of 5,000 liters installed in the return of the circuit, two tanks and two pumps with fixed flow for the Domestic Hot Water (DHW).

Regarding the DHW system, there were two heat exchangers and two storage tanks to produce DHW. Heat recovered in boilers was used to preheat water to produce DHW, with a previous storage in the buffer tanks. There were two circuits to distribute directly DHW from the boilers room to the dwellings, one circuit for buildings 1 to 7 and one circuit for buildings 8 to 12.

The boiler room of District Heating 2 had three boilers with a total power of 8,715kW, 2,905 kW each. The heat distribution system had five circuits that supplied heat to seven exchange substations. The DHW system was performed at each substation by heat exchangers and tanks accumulation.

The heating system was controlled by an analogical system that managed the flow temperature from the boiler and the temperature of storage DHW tank. The heating temperature set point was configured by maintenance personnel according to their experience, the weather conditions and the requirements of the neighbours. Heat flow temperature was usually between 70ºC and 80ºC. Nevertheless, the control system of DH2 was renovated before the start of the retrofitting.

Moreover, individual building thermal demand was not taken into account. Users did only control their dwellings' temperature by closing the radiator's cut-off valve.

Project justification

According to the request from the Communities of Owners of Torrelago and after the analysis performed, the needs to retrofit the façades following functional and energy efficiency criteria together with the actualization of the energy systems and energy management facilities were established.

To achieve these objectives, and taking into account the Horizon 2020 objetives, it is necessary to insulate the façades. The analysis of the thermal envelope of the buildings evidences the existence of significant heat losses. In fact, the actual U-values are not adapted to the Spanish Technical Building Code requirements for the specific climate area in which the buildings are sited.

Moreover, it was advisable to transform the previous DH systems in more efficient, sustainable and smart ones. The intervention in the framework of CITyFiED project works with the premises for reducing energy costs, introducing renewable energy sources and allowing a better control capacity with smart metering.

Renovation

The aims of the project are to reduce the energy demand and greenhouse gas emissions and to increase the use of renewable energy sources by implementing innovative technologies and methodologies for building renovation.

The district's retrofitting started on June 2014 and is still in progress.The district heating renovation is at the moment almost finished, except the installation of the cogeneration system and the façades' retrofitting of the of the Phase I is already finished, while the façades of the Phase II are expected to be finish by March 2018. T

Façades Insulation

To accomplish the objectives of the project, an intervention strategy has been defined, taking into accountthe façade retrofitting and the energy system renovation.Façades insulation guarantees around 40% of the energy demand reduction, making possible the objetives proposed in the project.

Brick cavity walls

The façade solution consists of an ETICS (Exterior Thermal Insulation System) that are attached to the exterior wall of the buildings. This system is composed by:

- 8 cm expanded polystyrene (EPS) sheet for insulation (density 15-20 kg/m^3) fixed by adhesive mortar and mechanical anchors.
- 1.5 cm mortar layer (cement mortar + fiberglass mesh + cement mortar + white finishing mortar).

Some of the issues considered for the selection of this solution were its resistance, stability, security, durability, cost-effectiveness, ease of assembly and modulation possibilities.

After de retrofitting, the resulting wall () will have a width of 35 cm and an U-value = 0.34 W/m^{2o}C. The Technical Building Code (Spanish buildings regulation) requires a U-value ≤ 0.66 in Laguna de Duero climatic zone.

The ETICS solution defined takes into account thermal and comfort issues (temperature and humidity) as well as aesthetic design. Block final appearance will be mainly white, with some colored areas on each block as seen in Figure 3.

Figure 3: Infographics of the appearance of buildings after the intervention.

Ceramic lattice

In the kitchens and clotheslines, where the majority of the lattice was broken to place a window, a cilindric tubular aluminium lattice has been placed, fixed thanks to an auxiliary structure, covering the original ceramic lattice and giving a uniform and aesthetic solution to the service areas of the façade.

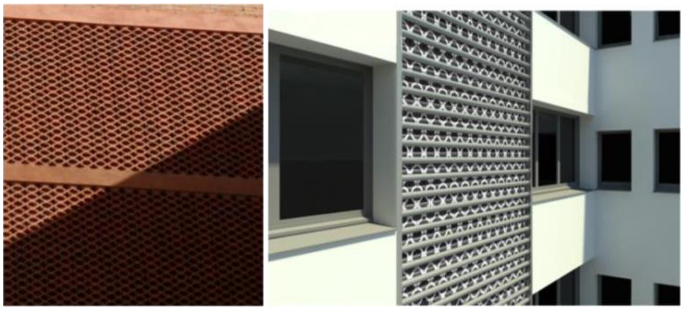


Figure 4: Original ceramic lattice (left) work & future solution (right)

District heating system

Both District Heating systems have been joined in only one, in order to reduce peak periods, make the curve of consumption more homogeneous, and biomass boilers have been installed. For those purposes, it was necessary to define the characteristics of the new centralized biomass plant, the distribution network, pumping systems and control equipment, in order to cover heating and DHW needs of the 31 buildings of the Spanish demo site.

Thanks to the refurbishment in the district heating system, the share of energy savings is increased from 40% to 50%.

Boiler rooms

A new building has been built to place the biomass boiler room and biomass silo. The area occupied by the biomass silo is 72.4 m^2 and height 5.9 m, so the useful volume of the silo is approximately 400 m^3. Due to this reason it was decided to build this room underground, to avoid the occupation of useful areas.

Figure 5: Biomass boilers

Thermal energy generation is implemented by three renewable energy biomass boilers, two of them of 1,250 kW and one of 950 kW. The boilers have a triple heat exchanger, to achieve maximum heat transfer and efficiency. Using digital control system and modulating regulation, boilers reaches a performance of 90%. Additionally, all three Phase II District Heating boilers are kept to use them in case of peaks, biomass boilers breakdowns or lack of supply of biomass. This boilers allow decreasing 3,392 tCO2/year over 3,583 tCO_2/year (94% CO_2 avoided).

In the primary circuit of the boiler a motorized three-way valve and constant flow pump will be installed to prevent the decline in the return temperature below 65°C, since they are non condensation boilers. Moreover they were also installed all connection, expansion, security and control elements needed for connection to the buffer stores. To know precisely the energy generated, a thermal energy meter will be installed in the primary circuit of each boiler.

Two inertia tanks of 12,500 liters capacity are installed, as seen in Figure 6. This tanks system has a double function: Buffer effect, increasing the return temperature to the boilers, since the substations return temperature is too low, and stratifies the water mixture for supplying the heating water at the higher possible temperature.

Figure 6: Inertial tanks

There was installed a general manifold where distribution pumps are implemented. There are two pumping systems, one for Phase I District Heating and another for Phase II District Heating. The previous pumping system has been renovated, changing it for a variable flow pumping system which allows reducing the electric energy consumption when the system works at medium load.

Substations

A new substation system has been installed in each Phase I building, and is located for this purpose on the ground floor of each portal. Each substation consists of a 350 kW heat exchanger for heating system, a 1,000 liters inter-accumulator for DHW and 2 smart energy meters allowing an intensive monitoring plan of the whole substation. In addition, every pipeline in the substations have been insulated in order to minimize heat loses.

In phase II buildings the 2/3-buildings substations have been renovated in order to adapt it to the new demand and control system of the new district system. Therefore, new heat exchangers have been implemented and heating building pumping system has also been renovated.

Control system

A completely new system has been installed, which controls both phases of the district heating. On the one side, inertia tanks temperatures control the phase II pumping load, reducing it when the temperature decreases from 73ºC. This strategy avoids decreasing the boilers return temperature below the minimum in order to protect them. Then, gas-fired boilers are turned on and supply heating energy to the phase II.

On the other hand, heating supply temperatures are controlled by a motorized 2-way valve through the ambient temperature outside of the buildings, reducing the heat looses when ambient conditions are not very demanding.

In addition, each dwelling has a thermostat provided with a cut-off valve, avoiding consuming heating energy when the set temperature has been reached. Moreover, radiators in each dwelling have been provided with thermostatic valves.

Finally, and individual smart energy meter has been installed in each dwelling in order to allow the community of owners to implement individual billing to each tenant.

CHP system

It is intended to install a renewable energy system that will contribute to the installation of thermal and electric energy for self-consumption. The proposed system is a team of micro cogeneration. This is the only part of the DH which has been not installed yet. CHP is an efficient and clean approach to generate electric power and useful thermal energy from a single fuel source. The smartblock is shown in the

Figure 7: Smartblock Cogeneration system

next figure and it has 73.4 kW of thermal power and 33 kW of electric power.

The main goal of the CHP engine is to compensate electricity overcosts of the biomass boilers and to supply a part of DHW demand. Figure 7 shows the cogeneration system.

Summary

The retrofitting of Torrelago district in Laguna de Duero, Valladolid (Spain) is part of the European FP7 project CITyFiED. Torrelago district is divided in two phases: Phase I which includes 12 buildings and its retrofitting is already finished since January 2016, and Phase II which consists of 19 buildings and whose retrofitting is not finished yet. In the following table is shown the main characteristics of the district:

Table 2. Main features of the district

Buildings	31
Dwellings	1488
Residents	4000
Surface	144,000 m^2
Total investment	16.5 M€
Total EC contribution	8 M€
Total energy savings expected	50 %
Total CO_2 emissions avoided	94 %

The project includes the retrofitting of the façades, in order to improve the insulation of the buildings, and the renovation of the energy system, with the objective of including renewable energy sources and improving energy efficiency and thermal comfort. In the following tables are shown the main differences in the buildings and energy system before and after retrofitting.

Table 3. Main changes in the district

Before Retrofitting	After Retrofitting
12 cm ceramic brick + 5 cm air chamber + 7 cm ceramic brick + 1.5 cm gypsum plaster (without insulation). Width = 25.5cm U-value = 1.36 W/m²ºC	Added: 1.5 cm mortar finish + 8 cm EPS **Width=35 cm and U-value = 0.34 W/m²ºC.** Expected **reduction in the energy demand of 40%** due to insulation.
2 separate District Networks	1 District heating
Energy generation facilities: Two gas-fired boiler rooms **(one for each phase):** • **Boiler room 1: 5.9 MW** • **Boiler room 2: 8.7 MW**	**Energy generation facilities:** Both District Heating systems have been joined. • **3 biomass boilers, 3.5 MW** • 3 gas boilers (8.7 MW) are kept • **Cogeneration system** 33kWe, 73.4kWt
Analogical and simple control system	**Digital and adaptative** control system
Old substations in phase II and inexistent substations in phase I	**New substations** in phase I and **renovated** substations in phase II
Fixed flow distribution	**Variable flow** distribution
Users did only control the temperature by closing the radiator's valve.	**Thermostat** with cut-off valve **Dwelling smart metering**