17th „Building Services, Mechanical and Building Industry Days”
International Conference, 13-14 October 2011, Debrecen, Hungary

DISTRICT HEATING AND COOLING FROM RENEWABLE AND WASTE ENERGY IN BARCELONA

Christoph PETERS, Architect, Sabaté associates, cpeters@saas.cat

David SERRANO, Industrial Engineer, Districlima, david.serrano@districlima.es

Àngel ANDREU, Industrial Engineer, Ecoenergies Barcelona, angel.andreu@ecoenergies.cat

KEYWORDS*: district cooling, renewable energy, energy efficiency, urban planning.*

Abstract*:*
District heating and cooling networks supplying thermal energy to buildings have been developed as part of the revitalisation process that has transformed two huge post-industrial areas into innovation and residential districts in Barcelona. Both networks are technologically innovative. One project recovers waste heat from an urban waste fuelled electricity generation plant for heating and uses sea water cooled absorption machines for cold production. The other uses biomass for heat generation and exploits waste cold produced when depressurizing liquid gas shipped from overseas for natural gas distribution for cold production. On demand side, highly energy efficient buildings are required to achieve a reduction of the carbon footprint of urban areas. One of the first apartment blocks connected to the district energy network serves as a demonstration that this is possible. The experience of these projects is being used to train urban planners in a continuous education programme in order to introduce energy efficiency and renewable energies into urban planning.

1. Introduction

In recent times, Spain experienced cumulative annual growth resulting in energy demand almost doubling every decade. This pattern of growth is simply unsustainable. Although the progress of civilizations has so far been measured according to its energy consumption, in the near future it will be based on its ability to rationalize it.

Especially in countries highly dependent on external energy markets, energy efficiency, far from being something just in fashion, is an imperative need. This requires an integral and global approach to energy supply and demand management. In this context, planning for District Heating and/or Cooling (DHC) is a clear example of how to optimize energy resources in an urban area.

This smart solution, anticipating what will be the trend in the coming decades, was introduced in Barcelona in 2004. It should be noted that Spain has no tradition of such solutions. The interests of energy sector have been developed in other ways and the Mediterranean climate of much of the territory did not offer attractive returns on investment for traditional district heating networks. It is therefore especially significant that a District Heating and Cooling network already exists in Barcelona, that is by far the largest within the country and that a second one is under construction. The interest in the networks lies in the fact that both with exploit energy efficient technologies and integrate of renewable energy sources.

2. DHC – Barcelona Innovation District 22@: Revalorization of waste heat from power generation and sea water cooling

The first network is situated in the Innovation District, 22@, in the Eastern part of the city. This area was once known as the "Manchester of Catalonia" for being a huge manufacturing industrial area. It went into decline during the second half of the 20th Century and by the 1990s was characterised by thousands of square meters of abandoned factories. In this situation, Barcelona City Council developed a plan for long term urban and social transformation to revitalize the area and attract to it the new "factories" of the 21st Century. These “factories” are innovative companies, dedicated to medical research, new technologies, audiovisual production, etc. They are compatible with housing in the context of a social model designed to provide work and progress to new generations.

As part of the strategy to attract these kind of businesses, first class infrastructures such as district heating and cooling were needed. The initial district energy network development was given impetus by a unique event: the celebration of the Forum of Cultures 2004. The technical infrastructure is located just next to the Forum main installations. The network is run by GDF- Suez Group, which through its Spanish subsidiary COFELY España SAU. They have invested, operated and managed the project since 2004 through Districlima SA, the concession holding company for the 22 @ and the Besos areas, of which it is the major shareholder,

Districlima, SA, is owned by COFELY Spain SAU, Aguas de Barcelona (AGBAR), TERSA, ICAEN and IDEA. Each shareholder contributes to the project with an outstanding added value that makes it unique:

- COFELY Spain SAU, as part of the French energy group GDF-Suez has a broad experience in this kind of projects. It has developed, for example, the largest district cooling in Europe, located in the city of Paris and connected to hundreds of buildings, some of them as emblematic as the Louvre Museum.
- TERSA, public capital company that manages the urban waste-to-energy plant and various ecoparks. Besides being the shareholder representative of the Local Government, it is the reference supplier and supplies the steam that Districlima uses to produce heat and much part of the cold.
- Aguas de Barcelona, centennial company that distributes the water in the City of Barcelona, among other places, and that has an extensive experience in managing concessions and in the distribution and technical management of fluids.
- IDAE, public corporation under the Ministry of Industry, Tourism and Trade. It carries out broadcasting activities, technical advice, development and financing of technological innovation projects. It is an institutional reference that goes together with the development of the project and promotes, in a general way, the sector in many ways beyond those resulting from their responsibilities as a shareholder.
- ICAEN, institutional reference in Catalonia, under the Generalitat de Catalunya, which promotes energy efficiency projects, rational use of energy and development and innovation of energy technology and the area.

In addition to shareholders' equity, the support received from local institutions should be remarked, through the companies 22 @ Barcelona (Company belonging to the City Council of Barcelona) and Besos Consortium (Barcelona City Council and Sant Adria de Besos Council) who, both as system regulators and promoters of urban and economic development of their areas, provide the definite boost for the successful implementation and development of the network from an innovative and environmentally committed city point of view.

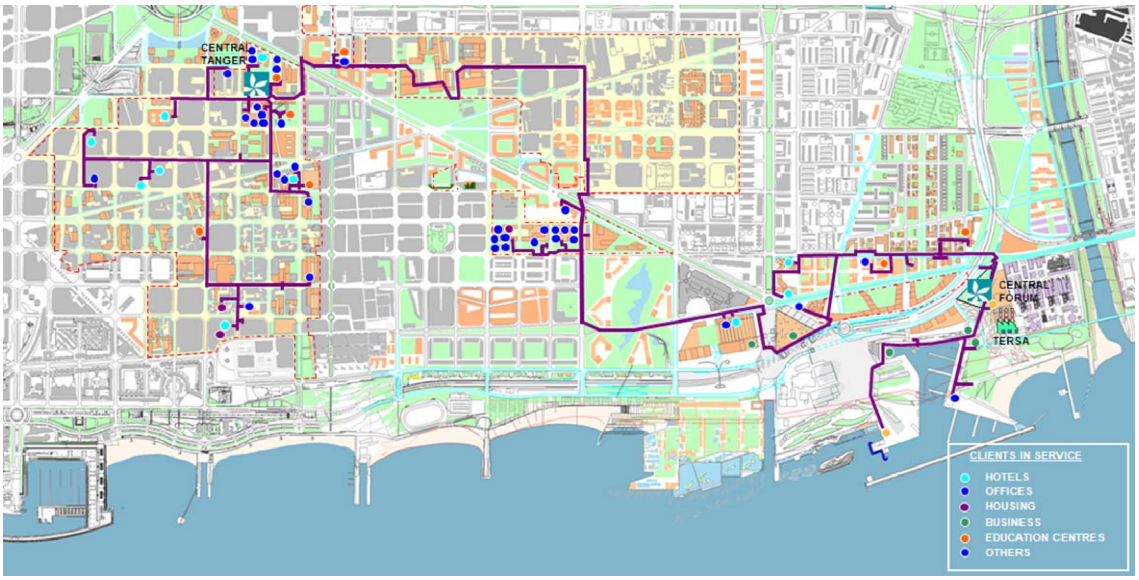


Figure 01. Network and main customers of Districlima, S.A.

The distribution network runs along Besos area and the 22@ innovation district, supplying currently over 60 large buildings of all types, from business parks, universities, social housing, health centres or hotels, to shopping malls, catering establishments or office buildings. The particularity is that the main energy supplied is cooling, with a contracted power of over 69 MW of cooling and 47 MW of heat along a network of over 13 km. The 4 parallel tubs network (2 for DH - forward 90ºC return 60ºC, and 2 for DC – forward 5ºC, return 14ºC) is under streets or in underground service galleries and works with variable flow (water is pumped from the plant according to demand) and constant volume (closed circuit). The network has a leakage detection system based on the variation detection of an electrical conductor inserted inside the polyurethane layer of the pipe, which prevents the moist at all times be transported head in or out of the pipes. The network water is treated drinkable water, with a permanent PH and conductivity control, and corrosion inhibitors in the heating network and biocide in the cooling network.

The hot water is driven over 90°C and returns at about 60°C, while cold water is driven at a temperature between 4 and 5°C and returns at about 14°C.The three efficiency factors in the Forum Plant are:

- Production of all the heat and most of the cooling from the steam generated in the combustion of urban solid waste coming from the nearby treatment plant,

- Use of a cooling system using sea water for the chillers, resulting in high yields without the use of cooling towers,
- Availability of a cold water storage tank of 5.000 m^3 of capacity.

The Central has the following equipment to produce energy:

Cold production:

- 2 Broad absorption machines with 4.5 MW each
- 1 cold water storage tank of 5,000 m^3
- 2 Mc Quay electric chillers of 4 MW each
- 2 Johnson Controls electric chillers of 7 MW each
- 3 seawater / cooling water exchangers of 12.5 MW each
- 1 sea water collection system of 5,000 m^3/h

Heat production:

- 4 steam / water exchangers of 5 MWh each
- 1 gas boiler of 20 MW (backup, in service only if steam is not available)

Figures 02/03, Exterior view of the central production in the Forum area and absorption machines

Currently, energy is produced at a single plant located in the Forum area, next to the site that held the Forum of Cultures 2004 that gave birth to this project. A second pick up and pumping plant, Tanger Plant, currently under construction, is located in the heart of the Media cluster of the innovation district 22 @. This second plant is intended to ensure supply in periods of higher demand and operate if needed in case of any eventuality.

One of the peculiarities of this plant is that it will have an advanced system of ice storage, which will allow the production of cooling energy during periods of low demand - and lower electric cost - in order to be distributed later on during periods of high demand. At a first stage, it will have 2 large ice tanks of 40.000 kWh each - through which glycol will circulate at an average temperature of 4°C. At a further stage, the installation of a third tank of similar characteristics is foreseen.

Evolution of the project:

2002- Project start
2003- Building of Forum Plant and first 3.3km of network
2004- Exploitation use with 4.4km of network and 10 connected buildings in the Forum area
2006- Prolongation of network in the 22@ area with a total of 21 connected buildings
2008- 10.8 km of network and 37 connected buildings
2010- 13.1km of network and 59 connected buildings.

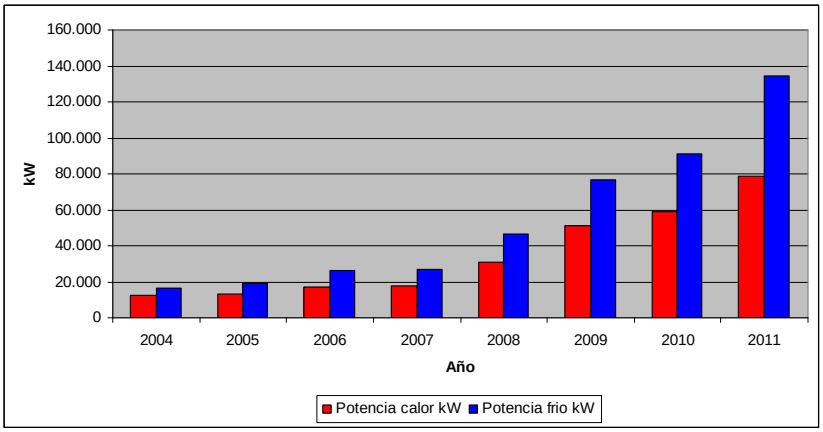


Figure 04. Evolution of installed power

The Districlima project implies a reduction of over 53% in use of fossil fuel and an annual saving of more than 10,100 tons of $C0_2$ emitted into the atmosphere, compared to decentralized thermal energy production. This numbers are based on the high Cooling Energy Efficiency Ratio of 5.2 achieved by the system in production and distribution, and an outstanding Heating Energy Coefficient of Performance of 11.7 due to the revalorization of waste heat.

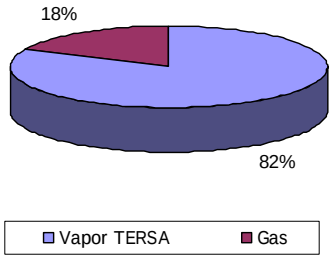


Figure 05. Energy use for heat production 2010

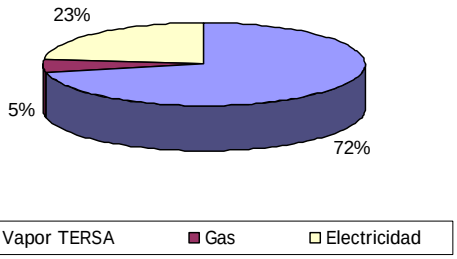


Figure 06. Energy use for cold production

3. Demand side energy reduction – 95 “A” Classified Apartments

On demand side, it is the task of architects and engineers to conceive highly energy efficient buildings in order to improve the carbon footprint of our cities. One example is the social housing apartment block promoted by the Barcelona Municipal Housing Board and designed by Sabaté associates Arquitectura i Sostenibilitat (SaAS), Barcelona, with 95 flats (12,600 m2 gross floor area). This building achieved an ”A” rating according to the Energy Performance in Buildings Directive (3.8 $kgCO_2/m^2 \cdot a$). Its main features are continuous thermal insulation of the building envelope with U-values inferior to 0.3 $W/m^2 \cdot K$ (more than 50% below legal requirements), wooden windows with reduced thermal transmittance, exterior movable wooden blinds that allow take advantage of solar gains in winter but allow individual shadowing in summer, as well as a ventilated façade avoiding overheating in summer. The main part of the apartments counts on two exterior façades, oriented to street or court yard, favouring natural cross ventilation.

The project is one of the first, privately developed and sold residences that have been connected to the Districlima energy network. The main advantages for the developer are the savings due to the absence of a gas installation, the reduction in space required for installations (both in the basement and on the roof), the reduction of noise due to the (lack of) installations and particularly the reduction of maintenance compared to individual heating systems.

An energy service company provides the end users with an integral service including contracting, metering, invoicing, maintaining and running of a 24 hours service, and provides Districlima with a single customer and point of contact in the building. This is important for effective management as the residential clients are very numerous and small compared to Districlima’s other clients (mainly. commercial and office buildings) At first, only heat is being supplied as first phase, as this is social housing and demand for cooling is minimal. The cold supply pipes are installed up to the building ready to give service once the ground floor commercial area starts its activity and requires cooling.


Figures 07/08. 95 apartments connected to district energy in Barcelona Innovation District 22@

4. DHC – Barcelona and L’Hospitalet de Llobregat: Valorization of waste cold from depressurizing liquid gas

A second District Heating and Cooling network is under construction at the other end of the municipality of Barcelona, (in particular the area of La Marina district south of Montjuic Mountain, close to the port of Barcelona) and in the municipality of L’Hospitalet de Llobregat, (in particular the harbour area of Zona Franca). The development follows a similar pattern with the aim of converting a former industrial area into a new industrial and tertiary sector estate as well as a residential neighbourhood served by a heating and cooling network. The DHC solution is phased in time and adapted to current requirements and to the 2 municipalities’ future urban development.

Here, the energy operator is Ecoenergies Barcelona, part of Dalkia (Veolia Energía Group) that subscribed a contract for 30 years concession for the construction, operation and maintenance of the DHC of Barcelona and L’Hospitalet. Ecoenergies shareholders are Dalkia (62.5%), Barcelona City Council (17.5%), Agefred (Grupo Dalkia – 10%), Copisa (10%). Ecoenergies collaborates with the Cities of Barcelona and L’Hospitalet as well as with the Catalan Energy Institute (ICAEN) and the Spanish Institute for Diversification and Energy Savings (IDAE) as well as TERSA, EMSHTR and other local entities.

This project will allow the buildings of the 2 municipalities to be provided with heating, cooling and domestic hot water respectful of the environment. The DHC will also offer industrial cooling (-10ºC) to industrial customers. The solution is adapted to different types of customers: residential, industrial and tertiary sector. It includes the operation of 3 energy production plants integrated to the urban landscape, linked by a pipes network, in an area foreseen to up to 12.600.000m^2 ground floor area.

Figure 09. DHC Network in Barcelona and L’Hospitalet de Llobregat

The production central system is designed under the principle of modularity and security of supply, equipment consists of:

Heating:

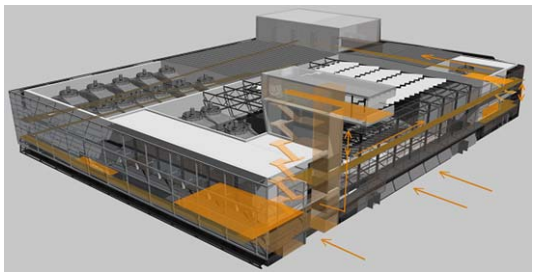
- Conventional: 120 MW
- Generated from biomass: 10 MW

Cooling:

- Conventional: 68.5MW
- Industrial cooling : 12 MW
- Recovered from the Enagas plant: 30 MW

Electricity:

- Generated from biomass: 2MWe



With high its efficiency equipments, the Zona Franca energy plant is the heart of the DHC. It is where all the information from the 3 energy plants and the network is gathered and continually monitored. With an architecturally innovative design, the plant is integrated in the urban environment and representative of the energy types utilized (each side of the plant presents a building fabric representative of the energy mix).

One of the engagements of Ecoenergies is oriented towards environmental education: for this reason, the plant was designed to ensure comfortable & safe visits of the energy center while under operation by means of external walkways, glass viewing points and auto guided tours.

Figures 10-12. Representation of the Zona Franca energy plant

The particularity of this innovative DHC system lies in the energy sources used.

Heating production: Biomass originated from the maintenance of the city’s parks and gardens of Barcelona is recovered via a biomass plant (approximately 8,000 tons per year) with a complement of biomass originating from the forests of Catalonia (total of 28,000 tons per year). District heating will be produced by a biomass central. The hot water will circulate at 90º and return at 60º to the central.

Figure 13: Actual picture of the Biomass plant

Cooling production: Recovery of the residual cooling originated from the industrial depressurisation process of the Enagas plant (30MW)

The company Enagas has installations situated in the harbour of Barcelona which depressurise liquid gas (LNG) arriving by boat at a temperature of -165º C into standard distribution gas through a heating vaporization process. This process uses seawater to as a heating fluid (the heat transfers from the seawater to the gas, leaving the seawater very cool).

Figure 14: Representation of the Cooling Recovery plant

Incorporating improved technological elements, the DHC solution proposes the construction of an energy plant at the harbour with the objective of recovering this residual cooling energy.

The cooling will be transferred to a secondary circuit of glucolated water at a temperature of -10ºC to the Zona Franca energy plant, stored in ice accumulation tanks and then sent to the cooling network. This recuperated cooling energy will be used for air conditioning purposes by the DHC customers.

Finally the Marina energy plant will provide the neighbourhood of La Marina in a first phase and interconnect with the Zona Franca plant via the network in a second phase acting as a peaks energy generation plant.

The solution’s prime objective is, while delivering thermal energy services, to contribute to the reduction of the energy consumption & the emissions and reduce the local environmental impacts using systems with high efficiency and renewable energies. It is anticipated that the project will save 1% on energy consumption for the city of Barcelona, that 13.400 t of CO_2 emissions will be avoided as well as substantial emissions of NO_x y $PM_{10.}$ The project was recognized by the European Union as one of the best energy projects in southern Europe.

5. DHC and the European project UP-RES

The experience of both projects will contribute to the training offered by the Catalan Chamber of Architect’s Continuous Development Institution “Escola Sert” in the framework of the European Commission co-financed project UP-RES – Urban Planners with Renewable Energy Skills.

The project aims to design and implement five pilot courses for 150 urban planners and architects, one in each partner country such as Finland, Germany, Hungary, Spain and United Kingdom. It aims at overcoming and eliminating non-technological barriers currently impeding the market penetration of renewable energy systems offering heating and cooling services (RES H/C). The particular focus is regional and urban planning, where energy has not traditionally been a key factor. For some countries planning guidance is already driven by energy efficiency and renewable energy. However, there is nevertheless a lack of awareness among planners in local authorities of how to put this into practice. In other countries, like Spain, energy efficiency and urban energy networks were not a major issue in urban planning until now, and specific emphasis has to be put on their introduction into the planning process.

The training is organized in the different partner countries according to the specific needs of the target groups. The main target group consists of European urban and regional planners working in national, regional and municipal authorities. The secondary target group are building inspectors, whose job is to review and approve the basic designs and detailed plans for new build and building refurbishment projects. This wide range of target groups leads to very specific and detailed training programs as in Hungary, where the training is to be developed in 60 ECTS (European Credits Transfer System) during a two years postgraduate University course, while for example in Finland or Spain the training is very practitioner oriented and delivered in different modules on specific issues during one year.

A comprehensive dissemination and communication UP-RES program uses pan-European institutions, such as the Association of European Schools of Planning (AESOP), European associations of heating and cooling utilities and research institutes (Euroheat & Power and AGFW) and the International Federation of Housing and Planning (IFHP) as information communication gateways. The best practices, training concepts and created tools are disseminated and communicated through the gateways in 10 languages as a means to promote RES H/C adoption in regional and urban planning institutions. In such a way, the regional and urban planning can start creating favorable conditions for RES H/C expansion in Europe.