ATTACHMENT 18

Description of Milan DH System.

Summary

Milan is a global city with points of excellence in different fields, from business to culture.

It is located in the middle of one of the most populated area in Europe and, thus, it represents one of the most important potential for DH expansion in EU. The total market potential for DH In Milan was estimated around 6 TWh/year.

District heating service in Milan started in the early 90s. During the years many small network were developed as stand-alone systems (so-called “episodi”) spreaded in the urban area of the city and of the nearby municipality of Sesto San Giovanni, without interconnections between different system.

Starting from 2008, with the constitution of A2A, currently the larger DH operator in Italy, a new approach was adopted. It foresee large investments in network expansion with the aim of interconnecting the existing small networks and to create three wide system in the West, East and North area of the city.

This plan was carried out by an investments of 200 M€ in the period from 2008 and 2013 and the three system have been implemented. Interconnection and network expansion makes possible the recovery of larger quantities of heat from existing production units (often owned by third parties) available in the area, the integration of the locally available renewable geothermal heat coming from groundwater. But the most important effect of the small system interconnections is by far represented by the growth of heat recovery from the WTE plants available on the area: WTE heat passed from 75,8 GWh in 2008 to 287,3 GWh in 2013 with an increase of 280% over the 5 years period. This was achieved only by increasing the overall efficiency of the WTE process (thanks to district heating) without increasing of the amount of treated waste.

The heat delivered to DH costumers doubled from 2008 to 2013, passing from 453 GWh in 2008 to 909 GWh in 2013.

Today the system connects 2.776 buildings for a total heated volume of 39,8 Mm3 delivers, corresponding to 165.800 flats (equivalent flat means an “average” flat, 80 m2 wide). The distribution network is more than 230 km long.

Despite this strong development in the recent years it is expected that the already performed investments, can consolidate their effects in the coming years resulting in a further important increase of the system dimension.

1. Description of the city

Milan has a population of more than 1.3 million inhabitants, the second city by population in Italy after Rome and the 13th in EU. Milan city is also the center of a much bigger conurbation, the 3rd metropolitan area by population density in EU, after London and Paris. Today Milan is the main city of Lombardia and the Italian economic capital, the main financial market and one of the most important university center of the nation. In particular Milan is one of the world capital of fashion and industrial design.

In the cultural field Milan is the most important Italian publishing center, both book publishing and information publishing; it is also at the top of the world music circuit thanks to the opera season of the Teatro alla Scala[1] and its long tradition.

Milan is reported to be the first Italian city by presence of visitors, thanks either to the cultural and artistic heritage of the city or to its business activities strongly related to Fiera di Milano[2], the main structure for industrial exposition in Europe.
In Milan will take place the 2015 edition of Universal Exposition: EXPO Milano 2015.

Milan occupies an area of about 182 km² in the western part of the basin of the Po Valley along the so-called "line of springs" where, in the subsurface, geological layers with different permeability meet, allowing deep water to appear on the surface and making in this way available renewable geothermal resources for DH applications too.

Milan, as much of the Po Valley, suffers from poor ventilation and this favors the stagnation of mists and pollutants. This is one of the major concerns of the Milan municipality which, in the framework of the Covenant of Major, has adopted a plan for sustainable energy[3] fostering 20% reduction of greenhouse gases and 50% reduction of the pollutants related to building heating. Municipality identified, fuel switching and district heating among the main instruments to reach these goals.

2. Milan: a great potential for DH development

This “Global City” laying in one of the most populated area in Europe, with its strong industrial and cultural tradition, its population open to innovation and sensible to environmental issues, can find in District Heating one of the key to successfully answer to the environmental problems it is facing and to make the best use of all the locally available energetic resources. We can affirm that today Milan represents one of the most important potential area in EU for DH to grow and develop.

[1] By the way Teatro alla Scala is a district heated building, together with other important public buildings of the city like the Courtyard, the Town Hall and Palazzo Reale (Royal Palace) in the very old city area, beside the Cathedral.
[2] The exposition facilities of Fiera di Milano are another important district heated structure of the city.
[3] The guidelines of this plan were submitted to a public consultation on June 2011 (in occasion of the election of the new Major): regarding DH more than 90% of the citizens approved the idea of increasing the diffusion of the system.

2.1 Estimation of the potential heat demand for DH

The total primary energy need of the city for heating purposes amounts to about 12,8 TWh, mainly provided by natural gas even it is still present a quite great amount of gasoil (about 20% of total primary energy supply for heating) expecially in the city center[4]. On this basis and with the aim of supporting the DH development plan A2A Calore & Servizi performed a more detailed study to estimate the potential heat demand suitable for DH. The study was performed with the help of Ramboll in the framework of the more general plan for DH development (*A2A/Ramboll, Strategic Plan for a Heat Transmission Network in Milan*). It was realized an heat mapping of the city outlining the potential buildings for DH supply with an estimation of their potential heat demand. The heat mapping is based on a database containing informations on:

- Classification of buildings on building level (residential, public etc.)
- Building volumes on building level (gross volume, heated volume and modified volume that is potential for DH)
- Modified building volume pr. km²
- Estimation of gas consumptions for heating purpose in m³ gas pr. km²
- Number of flats using other fuel (i.e. gasoil) than gas and DH in number pr. km²
- Location and heat consumption on the existing district heating costumers

Modified volume (i.e the volume assumed to be realistic for DH supply) has been obtained starting from gross volume taking into account two factors:

- Heated volume (to avoid the parts of the buildings which are not heated)
- Acquisition factor (to estimate, for each type of buildings, the expected fraction reasonably connectable)

It was clear at an early stage that the data had to be organised in such a way that the required heat mapping and analyses could be approached systematically. For that purpose, the city was divided into squares of 1 km^2, using a 15 km x 15 km grid (see Fig. 1).
In order to facilitate the analyses to determine the transmission network layout, the city was divided into four areas, each area holding a number of 1 km^2 squares. The potential for district heating, excluding the existing district heating supply, is indicated for each area.

	Heat demand MWh
Northwest	1,806,624
Southwest	1,110,526
North	804,391
East	2,393,213
Total	6,114,755

[4] AMAT (Municipal Agency for Environment and Territory) survey year 2010.

The total estimated potential heat demand for DH represents about 50% of the total heating needs of the city.

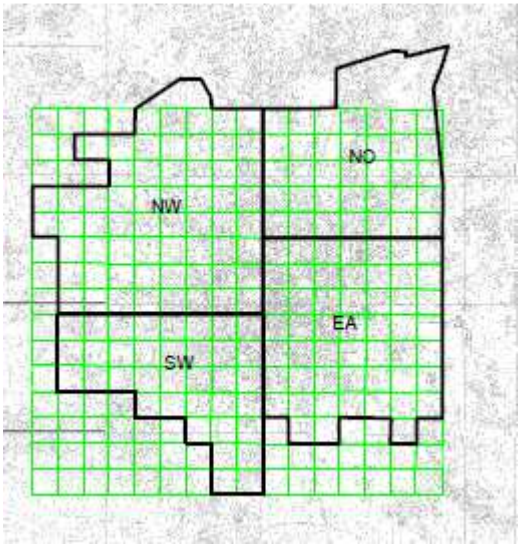

Fig. 1 - The four areas in Milan.

3. History of system development

District heating service in Milan started in the early 90s. During the years many small network were developed as stand-alone systems (so-called "episodi") spreaded in the urban area of the city and of the nearby municipality of Sesto San Giovanni, without interconnections between different system. The heat to these small systems was mainly provided by small natural gas fuelled CHP plants and integration boilers. One of these system, located in the north-west part of the city made use of the heat recovery from the Milan WTE plant (so-called Silla 2 plant) too but the small dimension of this system did not allow full heat recovery from the plant: as a result a considerable amount of heat produced by the waste to energy process was still wasted in the environment.

In 2008 the A2A Group was created by the merger of the two former municipalized companies of the cities of Milan (AEM Milan) and Brescia (ASM Brescia) and after that a new approach was adopted in DH development in Milan, by transferring the long experience cumulated (lasting from the beginning of 70s) in the development and management of the DH system in Brescia and the related experience in the management of CHP plants and in the recovery of energy (electricity and heat) from waste and biomasses. The last, in particular, is a key activity for the A2A Group in its energy source diversification strategy. This WTE activity is mainly carried out in Lombardy, at the plants in Brescia, Milan, Bergamo (all connected to DH networks), but also in Campania, by managing the Acerra waste-to-energy plant near Naples (in this case only electricity recovery is possible). The A2A Group is today the leading Italian operator in both WTE and DHC markets.

The new approach for the Milan DHC development is implemented in the framework of a general agreement between A2A Group and the Municipality of Milan and foresees strong investments in network development (a little less than 200 M€ in the 2008-2013 period) with

the main goal of interconnecting the existing system and the creation of three wide system one in the West Milan area, one in the East Milan area and one in the North Milan/Sesto San Giovanni area (see Fig. 2). The interconnection of the systems allows to increase the utilisation of the most environmental sustainable and efficient sources and to reduce the operation of the smaller and less efficient plants.

Interconnection and network expansion makes possible the recovery of larger quantities of heat from existing production units (often owned by third parties) available in the area (examples are the Edison CCGT plant and the CORE WTE plant in North Milan/Sesto San Giovanni and the Linate airport CHP plant in the East Milan area) and the integration of the locally available renewable geothermal heat coming from groundwater (examples are the Famagosta plant in the South-West area and the Canavese plant in the East area which make use of heat pump combined with high efficient CHP units to recover the heat from the geothermal source at lower temperature and to feed it in the DH network at higher temperature). Integration of industrial waste heat sources in North Milan area are under development too.

The interconnections of the existing small systems in the West Milan area West Milan area makes possible a better utilization of the Silla 2 WTE plant: as a matter of fact heat recovery from the plant increased by 280% in the period 2008-2013: margins to further increase the heat recovery from the plant are still available and will be utilized in near future as the system will expand by the connections of new costumers along the network. Moreover the Silla 2 WTE plant sells heat to the network of the nearby Municipalities of Rho and Pero (managed by another DH operator) too: these networks provide the heating service to the industrial exposition facilities of Fiera di Milano.

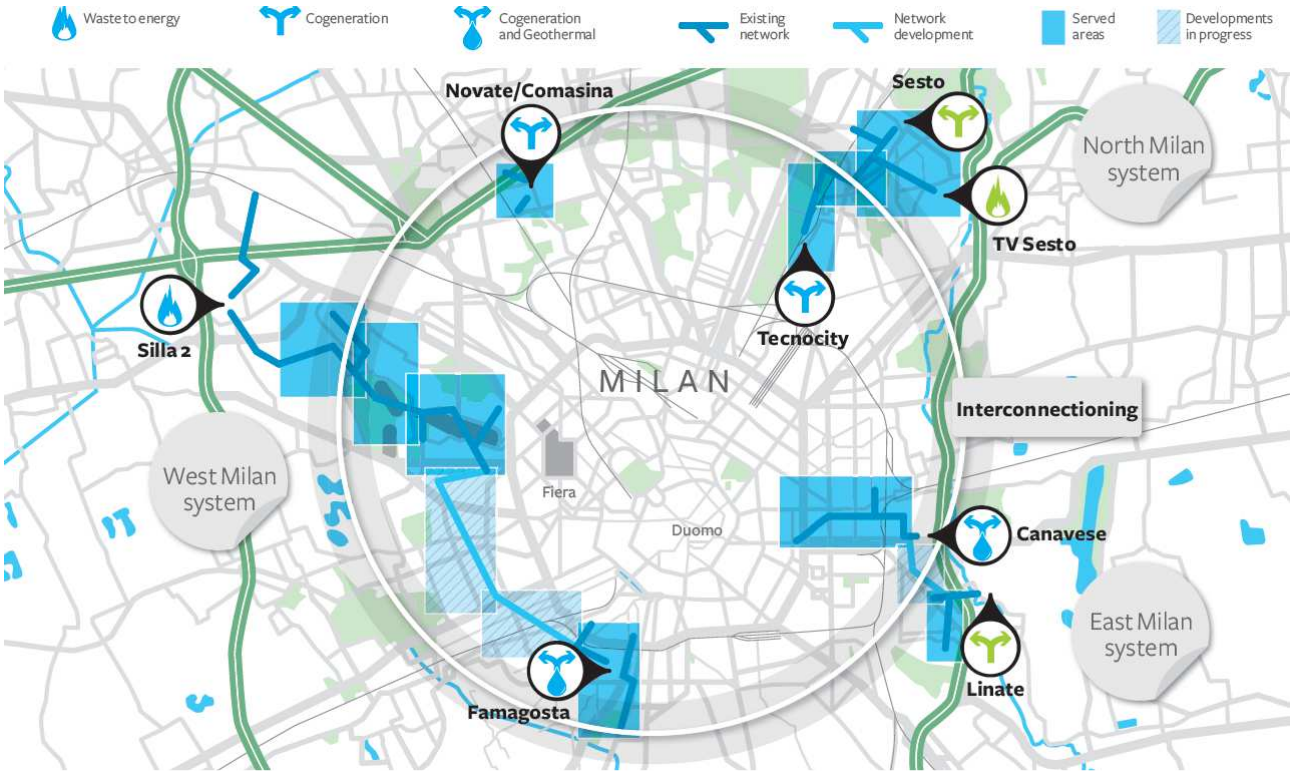

Fig. 2 – Development of three wide DH systems in Milan/Sesto San Giovanni area

It is also to point out that for most of third parties plants connected to the system, DH represents, an indispensable source of additional income that makes possible the economical sustainability of these plants in a framework of the current strong decrease of the prices in the electric market.

Today the three main DH system have been created by laying large diameters pipelines (DN500) interconnecting (see Fig. 2):

- In the West Milan area the Silla 2 WTE plant in the north-west area to the Famagosta CHP and geothermal plant in the south-west area: the heat transport pipe between the two plants is more than 10 km long and interconnects along the way the existing DH systems around the San Siro stadium and of the Giambellino district.
- In the East Milan area a 2,5 km transport pipe interconnects the Linate airport CHP plant and the Canavese CHP and geothermal plant. The East system is currently expanding to the deep city center (till the Cathedral square) where there is still an high concentration of single building gasoil boilers. In this way it should be possible to provide CHP and renewable heat to this part of the city, shutting down these old and pollutant heating systems.
- In the North area a 2 km transport pipe interconnects the DH system of Milan North and Sesto San Giovanni: in this way the Sesto San Giovanni CCGT plant by Edison, the Sesto WTE plant by CORE and the Tecnocity CHP plant by A2A can provide together efficient and renewable heat to the costumers of the northern part of the city.

4. Key physical, energy and Environmental Data of Milan DHC system

The Milan DH System improved it performances in term of Efficiency, greenhouse gas reduction and reduction of pollutants emissions of NOx, SO2 and Particulate Matter over the years as the expansion of the system developed in the urban area.

Production data

During the 5 years considered (from 2008 until 2013) the heat produced by the system doubled passed from 486 GWh in 2008 to 1004 GWh in 2013. The related electricity production from CHP and WTE plants passed from 212 to 257 GWh. The heat delivered to customers (i.e taking into account the distribution losses) also doubled passing from 453 GWh in 2008 to 909 GWh in 2013.

As said this result was achieved mainly by increasing the utilization of locally available renewable sources and heat recovery from WTE plants.

In particular a peculiar characteristic of the Milan system is the utilization of ground water energy (which can be found in large amounts in Milan urban area) to produce hot water by means of great heat pumps. Two heat pumps, 15 MWt each (among the biggest installed in Europe) are operated in Canavese and Famagosta plants in combination with high efficiency CHP units, which provide either heat to the DH network or the electricity needed for heat pumps operation. Two-thirds of thermal energy produced by heat pumps is extracted by

ground water and it is therefore renewable and locally “zero emissions”. In 2013 the total amount of thermal energy produced by heat pumps was 61,6 GWh. But the most important contribution to heat production increase comes by far from the growth of recovery of heat from WTE plants: WTE heat passed from 75,8 GWh in 2008 to 287,3 GWh in 2013 with an increase of 280% over the 5 years period.

This goal has been achieved, as said, by means of the extension of the DH system connected to the large WTE plant Silla 2 in West Milan area and by means of the transformation of Sesto CORE incinerator in a cogeneration plant in the North Milan/Sesto San Giovanni area. It's important to point out that this goal has been achieved only by increasing the overall efficiency of the WTE process (thanks to district heating) without increase of the treated waste.

Another key figure over the period considered from 2008 to 2013 is the reduction, in relative terms, of the thermal energy supplied by natural gas integration boilers. If in 2008 42% of heat came from integration boilers, while in 2013 this percentage reduced to 31%, despite the doubling of the overall dimension of the system.

In tables 1 and 2 are summarized the key data of DH Milan System in 2008 and 2013 in terms of installed thermal and power capacity, heat and electricity output and primary energy inputs.

Table1: DH Milan System in 2008

Production facilities	Thermal Power	Electric Power	Heat Output		Electricity Output	Fuel energy input (natural gas)	Electricity use
	MWth	MWe	MWh/a		MWh/a	MWh/a	MWh/a
Heat from waste-to-energy plant	105	59	75.800	16%	-	2.253	-
Natural Gas Cogeneration units	114	153	207.550	43%	278.658	672.031	-
Natural Gas Heat boilers	278	-	202.600	42%	-	217.433	-
Auxliary electricity use							17.369
TOTALE	497	212	485.950	100%	278.658	891.717	17.369

Table2: DH Milan System in 2013

Production facilities	Thermal Power	Electric Power	Heat Output		Electricity Output	Fuel energy input (natural gas)	Electricity use
	MWth	MWe	MWh/a		MWh/a	MWh/a	MWh/a
Heat from waste-to-energy plant	131	65	287.310	29%	-	5.904	-
Natural Gas Cogeneration units	151	192	340.442	34%	437.692	1.025.289	-
Geothermal Heat Pumps	30	-	61.538	6%	-	-	23.229
Natural Gas Heat boilers	522	-	315.226	31%	-	342.779	-
Auxliary electricity use							25.114
Total	834	257	1.004.516	100%	437.692	1.373.972	48.343

Fig. 3 reports the breakdown by different type of heat source of the total installed thermal capacity (834 MWt) and heat production (1004 GWh) of year 2013. It can be seen that 69% of the heat comes from a mix of CHP, WTE and renewables, thus classifying the Milan DH system as an efficient one even according to the recent definition of 2012/27/EU Directive on Energy Efficiency.

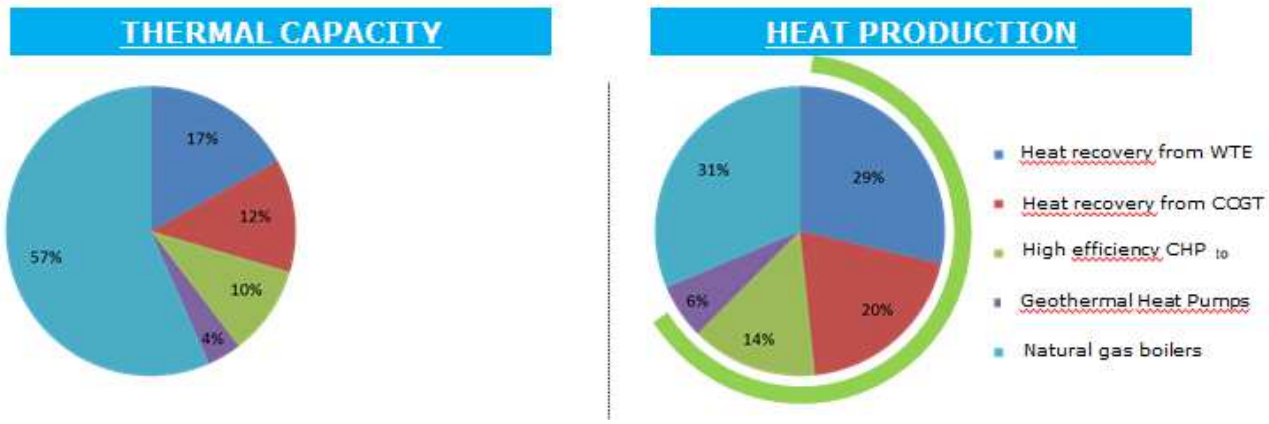

Fig. 3 - Year 2013. Breakdown by heat source of the total installed thermal capacity (834 MWt) and heat production (1004 GWh)

Network and costumers data

According to the annual report of AIRU, the Italian association of district heating operator, the total length of the DH network of the Milan system in 2013 amounts to238,3 km. The network is designed to be operated at a maximum temperature of 130 °C and at a maximum pressure of 16 bar.

The number of buildings connected to the network amounts to 2.776, corresponding to a total heated volume of 39,8 Mm3. It has been estimated that the DH system reaches 110.000 equivalent flats[5].

Energy efficiency and environmental performances

Table 3 summarizes the improvement of the performances of the Milan DH system in terms of: Primary Energy Factor (fP,dh), CO_2 emission coefficient (Kdh) and renewable and recycled fraction (Rdh) from year 2008 to year 2013 (the calculation has been performed indicated in the report "Calculation of energy indicators for district energy systems in the course of the 2015 Global District Energy Climate Awards"):

The results of calculation, here forward, are representative of the positive improvement obtained by DH Milan System in this years.

Table 3 – energy efficiency and environmental performances of Milan DH system

	Year 2008	Year 2013
$f_{P,dh,nren}$	**0,67**	**0,55**
$K_{P,dh,nren}$	**199**	**159**
R_{dh}	**15**	**33**

[5] Equivalent flat means an “average” flat, 80 m^2 wide

As said in section 1 of this document Milan, as much of the Po Valley, suffers from poor ventilation and this favors the stagnation of mists and pollutants. Quality of the air in the city is thus one of the major concerns of the Milan municipality in particular for what concerns PM10 and NOx concentrations. The DH system provides help to the city also in this field. Table 4 summarize the reduction in the urban area of the main pollutants related to the DH operation in year 2013:

Table 4 – Improvements of pollutant reduction between 2008 and 2013 (ton/year)

Emission reductions (tons/year)	Year 2008	Year 2013
NOx	-62,2	-129,2
SO_2	-23,0	-46,2
PM10	-2,5	-5,0

5. Near future developments : the Consolidated Scenario

As said in section 4 thanks to the huge investments performed, the Milan DH system doubled its dimension over the 5 years period from 2008 to 2013. It is important to notice that these already performed investments, summed to the other ones planned for further expansion of the distribution network, are expected to consolidate their effects in the coming years.

Thus a further important increase of the system dimension is expected within year 2020. This scenario (called "consolidated scenario") will be taken into account by Milan Municipality in the SEAP currently under development in the framework of the Covenant of Majors.

The consolidated scenario foresees a further increase of the heat delivered by the system up to 1.400 GWh, while the energetic and environmental benefit in this scenario are summarized in table 5.

Table 5 – DH performance in the consolidated scenario – year 2020

	Consolidated scenario - 2020
Energy saving	68.000 Tep
Avoided CO2	180.000 t
NOx reduction	-152,8 t
SO2 reduction	- 71,7 t
PM10 reduction	-7,9 t

6. Considerations for further developments

Even in the consolidated scenario the DH dimension will be far from saturate the potential DH market of the city estimated in section 1 (6 TWh/year). There is further potential for DH to grow if new sustainable heat sources will be identified. A possibility is the exploitation of the large amount of heat currently wasted in the environment by three large power plants located at less than 30 km away from the center of the city.

It has been estimated that recovering the heat from one of these plant, by mean of the construction of a long distance heat transmission infrastructure, could allow to increase the dimension of the DH system up to 3 TWh/year, 50% of the market potential estimated in section 1.

This possibility is currently under evaluation in relation to the huge investments required to the construction of the long distance heat transmission network and to the future expected scenario for the electricity market.