CANAVESE DISTRICT HEATING SYSTEM
City of Milan, Italy

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SUMMARY

The 'fundamental idea' behind modern DH systems is to use local heat and fuel sources that under normal circumstances would be lost or remain unused.

In the Milan area it is widely available geothermal renewable energy from groundwater at a temperature of about 15 °C, not directly channelling to DH network. Using heat pumps, however, it is possible to increase the temperature up to 90 °C and to utilize the heat in a DH system.

The Canavese DH system, located in the east side of Milan, has been designed specifically to use this resource. It is composed by a high efficiency CHP plant integrated with a geothermal heat pump and by a distribution network. It was implemented in the framework of a general agreement between A2A Group and the Municipality of Milan for the enhancement of the DH service in the city, with the main aims of improving the air quality and enhancing energy saving and the use of renewable energy sources available in the area.

The system has been in operation since January 2008 and its development is still ongoing by the extension of the distribution network in the area.

At its maximum capacity (within year 2012), Canavese system will serve 50.000 inhabitants and will distribute more than 110 GWh/year of heat to costumers, saving the consumption of 7,200 TOE/year of primary energy and avoiding the emission of 30,000 t/year of CO_2, 36 t/year of NO_x, 70 t/year of SO_x and 3 t/year of particles.

Milano

Comune
di Milano

DESCRIPTION OF CANAVESE DH SYSTEM

DH IN MILAN: PRESENT SITUATION AND FUTURE DEVELOPMENT

DH service in Milan started in the early 90s, mainly based on heat production from WTE plants and from natural gas fuelled CHP plants (CCGT and CHP engines).

The heat produced is fed to the buildings by means of several large district heating networks (Annex 1) of which Canavese is the most recent one. At present these networks are separated but there is a program to interconnect them in the next few years to better optimize and develop the whole system.

The City of Milan has a population of about 1.300.000 inhabitants; the total primary energy demand for heating requirements of buildings is about 1.100.000 tep.

At present (December 31th, 2010) the district heating distribution network has an extension of about 100 km and serves about 265.000 inhabitants, corresponding to a peak power demand of 530 MW. In winter 2010/2011 (October 2010 – February 2011) the system distributed 38.5 GWh of heat to the costumers.

In the framework of general agreement between A2A Group and the Municipality of Milan it is under development a plan to strongly expand the district heating in Milan Municipality by mean of an increase in the thermal power and efficiency of existing production plants and a significant extension and integration of the heat distribution networks. Also, new production plants and district heating networks associated to them could be realized. The goal is to deliver the service, within year 2015, to more than 600.000 inhabitants equivalent and to increase at 1.200 MWt the thermal power installed at the condominium buildings (Annex 2).

This plan was presented in May 2009 at the Euro Heat & Power Congress in Venice.

CANAVESE DISTRICT HEATING SYSTEM

The Canavese district heating system consists of:

- a natural gas fuelled high efficiency CHP plant and an heat pump fed by groundwater for the production of hot water at maximum temperature of 90 °C. The plant also includes peak load boilers and thermal storage tanks (Annex 3);
- a large district heating network to supply thermal energy to the customers in the east area of municipality.

The Canavese DH system has been designed specifically with the main aim of enhance the use of locally available renewable energy to supply thermal energy requirements of buildings. The source of renewable energy has been identified in the geothermal energy from groundwater which is plentiful in the Milan area.

Behaviour of groundwater in the Milan area in the last 40 years

The behaviour of the water table in Milan during the last decades is illustrated in the Annex 4. Since Fifties, industrialization of the territory, especially in its Northern outskirts, caused a contemporaneous increasing use of groundwater by private concerns with the drilling of several thousand wells. Groundwater production in the province of Milan in the early 70s was estimated 2.5 billion m3/y, 1.1 of which by industry. The enormous quantity extracted caused a dramatic lowering of the water table which reached its minimum in 1975, indicative of an excessive withdrawal. Remedial measures including drastic limitations and controls over private users and the beginning of local industry relocation, which accelerated in the 80s and early 90s, resulted in groundwater production decline in the Milan Province to 1.1 billion m3/y in 1980 and around 1 billion in 2002 of which 756 million for human use. Milan municipality has delivered in the last few years 250 million m3/y of drinking water from some 400 wells. Wells in all the Province are estimated over 7,000. The water table rose abruptly in 1976-77 and then behaved differently depending on location (with significant lowering to the North and marginal variations elsewhere). Since 1992-1993 a new general upraise, culminating in 1998, caused the flooding of several underground works in Milan and its Southern outskirts. The urgent remedial actions undertaken included groundwater extraction from some 100 newly drilled wells and its discharge in existing canals. In the last few years the water table has remained generally stable, with small fluctuations, at a still relatively high level, generally correspondent to the 1993-1994 situation, which leaves many infrastructures in the wet.

The above elements have played an important role in the decision to use the available groundwater excluded from human use for large-scale space heating through geothermal heat pumps (recovering in this way a great quantity of renewable energy) with the relevant benefits of air pollution reduction and energy saving which will be discussed farther on.

The geothermal renewable energy from groundwater is widely available at a temperature of about 15 °C, not directly channelling to DH network. Using heat pumps, however, it is possible to increase the temperature up to 90 °C and to utilize the heat in a DH system.

Canavese plant

The first application of an heat pump fed by groundwater in a DH system has been realized in Canavese DH system. The Canavese plant has been realized on a property site which was a site for the storage of manufactured gas used in the city until early eighties (ANNEX 5, ANNEX 6).

The cogeneration plant is composed by three natural gas fuelled engines of 5,100 kW electric power each one for a total of 15,300 kW of electric power installed. The engines also produce heat which is recovered by exhaust gas and by intercooling. The total thermal power recovered is about 13,200 kW.

The heat pump is fed by groundwater. The groundwater is extract from the surface aquifer by a system of six wells forty meters deep. The groundwater is not for drinkable use and is abundant in the alluvial deposits of Po plain; its temperature is about 15 °C all over the year. Every well can operate at a maximum flow rate of 60 liters/second.

The heat pump operation flow rate is about 1,110 meters m3/hour. The heat pump absorbs about 5,000 kW of electric power to transfer the heat from groundwater to the district heating water return at 65-70 degrees of temperature. The thermal power generated by the heat pump is about 15,000 kW.

The groundwater discharge temperature is about 7-8 °C. An half of groundwater used in the heat pump is put back in the surface aquifer to save natural resource by means three wells. The rest of groundwater is discharged in natural watercourse.

The thermal energy produced by CHP engines or by heat pump can feed directly the district heating network or can be accumulated in the storage tanks.

Hot water can be also produced by auxiliary boilers which consist in three natural gas fuelled boilers of 15,000 kW of thermal power each one.

A thermal storage of 3,000 meters cube of capacity completes the Canavese plant for about 80,000 kWh of thermal energy.

The pumping station which guarantees the circulation in the distribution network consists by 8 pumps with a flow rate of 550 m3/hour.

The total thermal power installed in the Canavese plant is about 75,000 kW, thermal storage excluded. With the thermal storage discharge the thermal power provided to the network can be over than 90,000 kW.

Unit production	Electrical power	Electrical efficiency	Thermal power	Thermal efficiency/Coefficient of Performance COP
Gas engines	15,100 kW	44%	13,200 kW	37%
Heat pump	-	-	15,000 kW	COP = 3
Boilers	-	-	45,000 kW	> 90%
TOTAL	**15,100 kW**		**73,200 kW**	

This system has been designed to provide thermal energy to the users increasing energy efficiency and reducing the fossil fuel consumption.

The base-load thermal energy demand is supplied by CHP engine. The electrical energy production can be sold to the electricity distribution network or, in case of increasing heat demand, fed the heat pump to produce more thermal energy. **In this case, when an engine supplies the electrical energy to the heat pump, the total Primary Resource Factor (PRF) of the gas engine coupled to the heat pump is 0.72**[1].

The peak of thermal energy request by customers is satisfied with the integration boilers production, with thermal efficiency more than 90%, or with discharge of thermal energy previously accumulated in the storage tanks.

The large district heating network consists of double (supply and return tubes) underground pre-insulated pipes of various diameter. The principal feeder is 600 mm inner diameter; the tee joint to final customers are 50 mm inner diameter.

The district heating network serves the east city area which is characterized for an high density population and an high heat buildings demand (Annex 7).

At 31th December, 2010 the district heating network consists of about 22 km of double pipes and about 210 heat exchange substation at the customers.

In detail, at 31th December, 2010 the district heating network consists of the classes of pipes showed in the next table.

INNER DIAMETER [mm]	LENGHT [m]
50	824
80	1.934
100	1.700
150	4.346
180	64
200	4.313
300	2.724
400	1.166
500	3.520
600	814

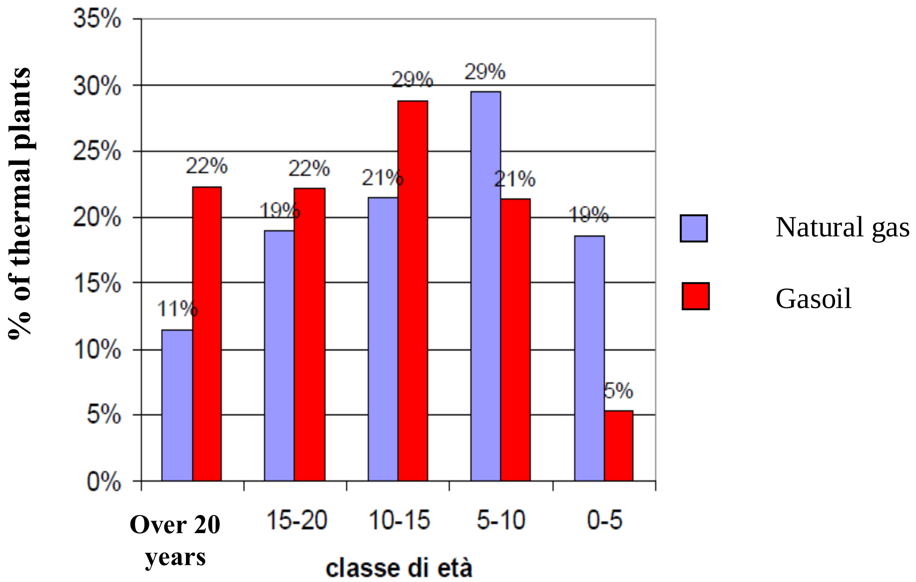
The detail of the heat exchange substation installed on the customers in showed in the next table.

1 Calculation performed according to the method proposed in EcoHeatCool project assuming 2,5 and 1,1 as values for energy factors of electricity and natural gas respectively.

HEAT EXCHANGE POWER [kW]	NUMBER OF SUSTATION [n°]	THERMAL POWER INSTALLED [kW]
0 - 100	34	3.180
100 - 200	87	15.140
200 - 300	63	16.750
300 - 400	19	7.100
400 - 500	5	2.500
500 - 600	5	3.000
major than 600	6	9.550

The major part of district heating customers are residential building. The average age of thermal plants installed on residential building is showed in the next figure. The most diffuse distribution facility in residential building is hot water heating plant by radiator circulation. The estimated seasonal energy efficiency of residential thermal plants is 80%.

Also some public building of municipality and of other institutions has been connected to district heating network. At present is in progress the connection of the principal courthouse building close to the city centre. At present the courthouse is heated by a 10 MW diesel oil boiler which will be totally substituted by DH. Diesel oil feeds other several building in the city, especially in the city centre, and produces pollutants like SOx and particle emission. By DH extension these pollutants could be avoided.



Estimated age of thermal plants on municipality of Milan – City of Milan Environmental and Mobility Agency, 2008

At the present, total thermal power fed by Canavese district heating is about 56,000 kW for about 1,800,000 meters cube. In 2010, the thermal energy supplied has been about 38,400 MWh. The program of connection of new customers is in progress: at maximum capacity the system will deliver 120 MW and over 110 GWht/year of thermal energy.

ENERGY SAVING AND ENVIRONMENTAL EFFECTS

Canavese CHP engines, boilers and heat pump use natural gas and electrical energy as fuels and produce electrical energy and thermal energy for the DH network. Electrical energy auto-consumption can be supply by self-production or buying electrical energy from distribution network.

Canavese plant operation data, October 2010 – February 2011		
Natural gas consumption	8,037,030	Sm^3
Electrical energy consumption	644.5	MWh
Net electrical energy sold to electricity distribution network	22,021	MWh
Thermal energy sold to customers	38,493	MWh

It is possible to calculate the Primary Resource Factor (PRF) for the system according to *ECOHEATCOOL GUIDELINES FOR ASSESSING THE EFFICIENCY OF DISTRICT HEATING AND DISTRICT COOLING SYSTEM - WORK PACKAGE 3 (*Ecoheatcool and Euroheat & Power 2005-2006). This methodology assumes 1.1 and 2.5 as Primary Resource Factor for natural gas and electrical energy respectively.

For winter season 2010/2011 (October 2010 – February 2011), the calculated PRF of Canavese DH system is 0.81.

At maximum capacity production, the expected PRF is 0.67.

The Canavese district heating system primary energy consumption can be compared with the primary energy consumption of the replaced energy systems, thermal and electrical. Also, the pollutants emission in atmosphere can be compared.

It's possible to compare:

- **SCENARIO 1**: consists of the energy consumption and emissions of pollutants into the atmosphere from the thermal plants replaced by district heating service. Primary energy consumption and emissions for the surplus electricity sold on the net as if it's produced by average national thermoelectric plant are also considered;
- **SCENARIO 2**: consists of the energy consumption and emissions of pollutants into the atmosphere from the natural gas CHP and heat pump Canavese plant.

For winter season 2010/2011 (October 2010 – February 2011), the difference (SCENARIO 1 – SCANARIO 2) gives the results that are showed in the table:

SCENARIO 2 (Canavese plant)			
Primary energy consumption	tep	6,857	
CO2 emission	t	16,504	
SCENARIO 1 (replaced energy system)			
Primary energy consumption	tep	8,871	
CO2 emission	t	23,279	
ENERGY SAVE	**tep**	**2,014**	**-22.7%**
AVOIDED CO2 EMISSION	**t**	**6,774**	**-29.1%**

The same scenarios could be compared to evaluate pollutants emissions such as NOx, SOx and particle.

SCENARIO 2 (Canavese plant)			
NOx emission	t	6.33	
SOx emission	t	0.14	
Particle emission	t	0.06	
SCENARIO 1 (replaced energy system)			
NOx emission	t	21.49	
SOx emission	t	28.36	
Particle emission	t	1.22	
AVOIDED NOx EMISSION	**t**	**15.16**	**-58%**
AVOIDED SOx EMISSION	**t**	**28.22**	**-100%**
AVOIDED PARTICLE EMISSION	**t**	**1.17**	**-95%**

For the same period, the locally avoided emission (i.e. avoided emission coming only by switch off the thermal plant replaced by DH system, without considering the avoided emissions from the CHP) are: about 2 t of NOx, about 7 t of SOx and about 0.3 t of particle.

At maximum capacity production, it is estimated that Canavese DH system can locally avoid emissions of about 5 t/year of NOx, 20 t/year of SOx and 1 t/year of particle.

Adding the contribution of CHP electricity the estimated avoided emissions (on a global basis) are about 36 t/year of NOx, 70 t/year of SOx and 3 t/year of particle. The avoided CO2 emissions will be 30,000 t/year.

Improving air quality in the Po plain: a key factor

The figures above show how DH can improve the air quality in the City of Milan. Milan is located in Po plain that is one of the area in the world most afflicted by air pollution caused by anthropic activities. The area is also affected in several period of the year by climatic conditions (atmospheric stability – see Annex 8) which do not help the improvement of the air quality.

NOx and particle are the most critical parameters. In autumn and winter seasons, the emissions from thermal plants installed on residential building contribute for about 35% to the total anthropic emissions (about 20% in the year).

DH systems could help in a substantial way in improving the air quality in the city. Their design has to fulfil the strict limitations stated by the local authority: the Regional Government enacted environmental laws to achieve the air quality objectives for the protection of public health. The criteria to authorize building and operation of combustion plant (including DH production plant) are very strict. First, BAT have to be adopted to maximize efficiency and contain pollutants emission in atmosphere. Second, the emission factors of pollutants for unit product must be lower than those of thermal plant installed on buildings.

INFORMATION, SOCIAL ACCEPTABILITY AND STAKEHOLDER ENGAGEMENT

The main difficulty to develop a district heating system in the City of Milan is to realized the network minimizing the impact on the inhabitants quality life (the population density is over than 7,000 inhabitants/km2; it's estimated that every day more than 400,000 vehicles enter in the city). These impacts are temporary but create great inconvenience on mobility system, particularly on traffic and on road parking.

To minimize it, A2A and Municipality have developed a method to authorize the occupation of public land and to manage road yard and to coordinate district heating extension with other public service (transport, electrical energy and natural gas distribution, drinkable water distribution and sewerage, telecommunication, etc…).

To inform inhabitants, A2A has adopted a specific information campaign which wants to achieve the objective to inform inhabitants about the nature of road yard, the state of work in progress and the benefits of district heating in terms of service, costs and environmental benefits (Annex 9).

The Research Center for the Environmental and Sustainable Development of Lombardia (Mathematical and Phisical Department of Università Cattolica of Brescia) has studied social acceptability of Canavese district heating and stakeholder engagement.

The introduction of the district heating means, by the inhabitants, the acceptance of the proposed change and a willingness to participate in terms of economic investment and behavior change. To reduce the resistance inhabitants must know the advantages due to the district heating system in terms of improved air quality and safety improvements. The objectives of the study are to know what are the inhabitants perceptions, expectations, needs and knowledge about district heating. Those informations can be used in specific information campaign to enhancement DH service, and in marketing actions also.

Results show that inhabitants know district heating system and that for inhabitants the first reason to connect to district heating is economic affordability and the second one is environmental positive effects and energy saving. People under 45 years old choose district heating driven by environmental reason more than the other. Safety benefits and economic benefits of district heating are appreciated but Canavese plant and it's characteristics aren't know by everyone. The major part of people interviewed have suffered a hardship by the road yard during district network realization and have stated to have not been previously informed. The information campaign must be enhanced.

One of the action suggested by inhabitants it's to have a public information point or a temporary shop in the district interested by the expansion of the network and by road yard: people want to know directly from A2A if is possible to connect to district heating and the duration of road work. Also, public periodic meetings to have information on energy services and environmental sustainability are appreciated.

PROGRAMME FINANCING AND PUBBLIC INCENTIVES

The project and the realization of Canavese DH System has been financed by A2A.

The Regional Government has made available a financial support for the realization of new DH systems or for the extension of existing DH systems. Canavese DH System has been admitted to this incentives.

Another form of public incentive are the "green certificates" connected to CHP. This is the same mechanism used to incentivate the electricity production from renewable energy (hydro, wind, solar, etc…) to which the CHP DH systems in operation before the end of 2008 have been assimilated by Italian laws.

ANNEX LIST

Annex 1: DH system in Milan: present situation

Annex 2: Future development of DH system in Milan

Annex 3: Principle scheme of Canavese DH plant

Annex 4: Evolution of groundwater table in Milan in last decades

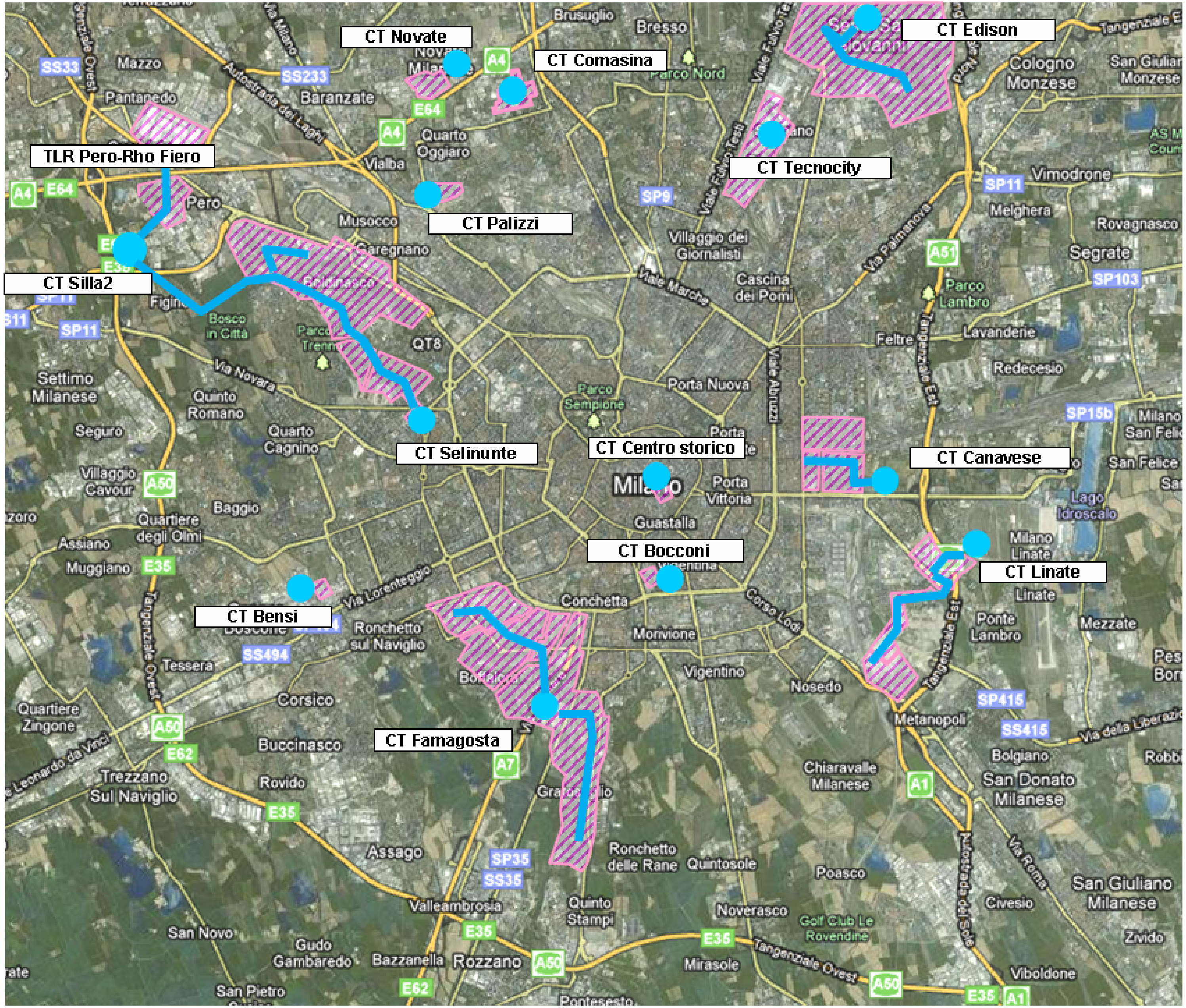
Annex 5: Canavese site for the storage of manufactured natural gas (photo of archive)

Annex 6: Canavese Plant

Annex 7: Canavese District Heating Network Development (2007 – 2010)

Annex 8: Pollution on Po plain

Annex 9: Information campaign in road yard

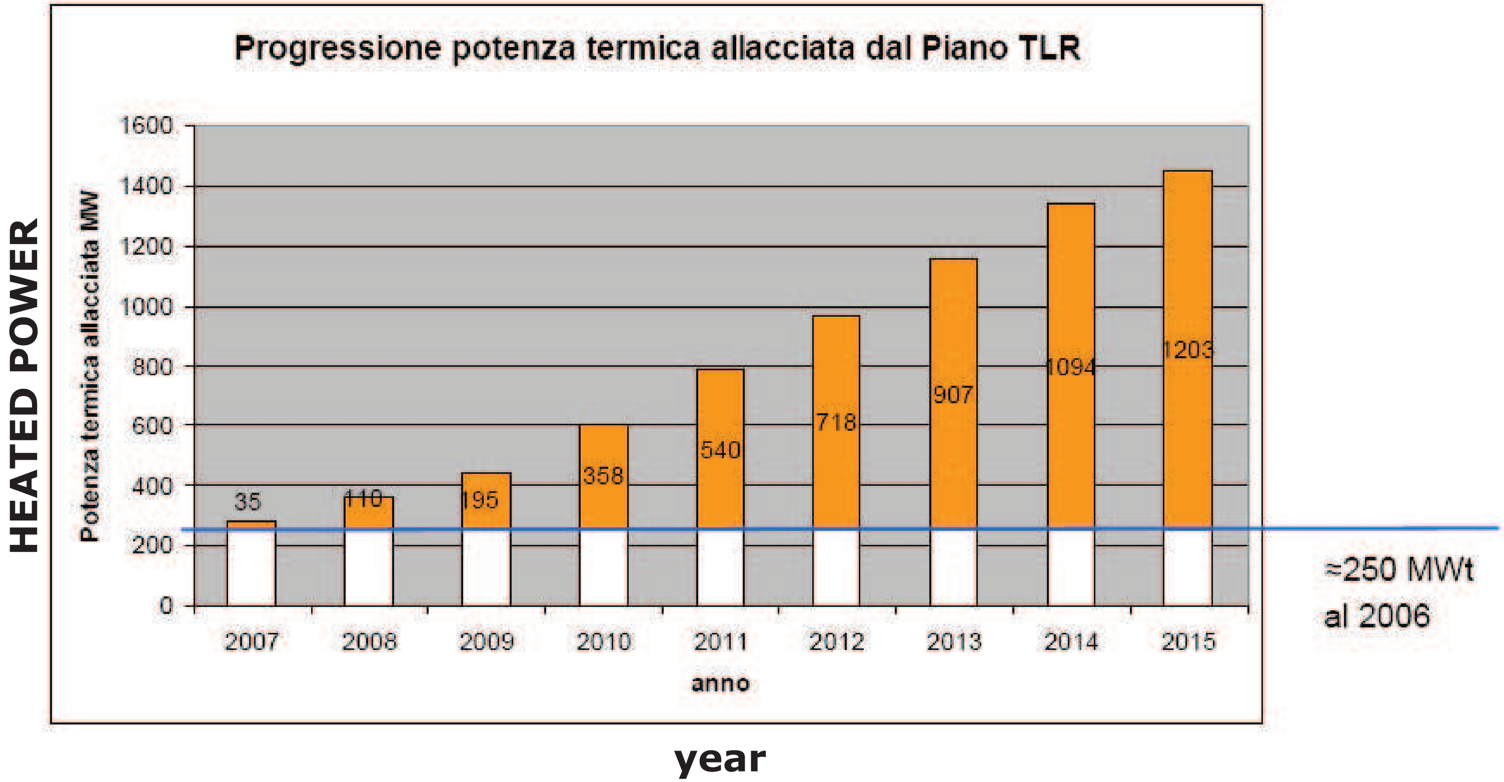


Canavese District Heating System

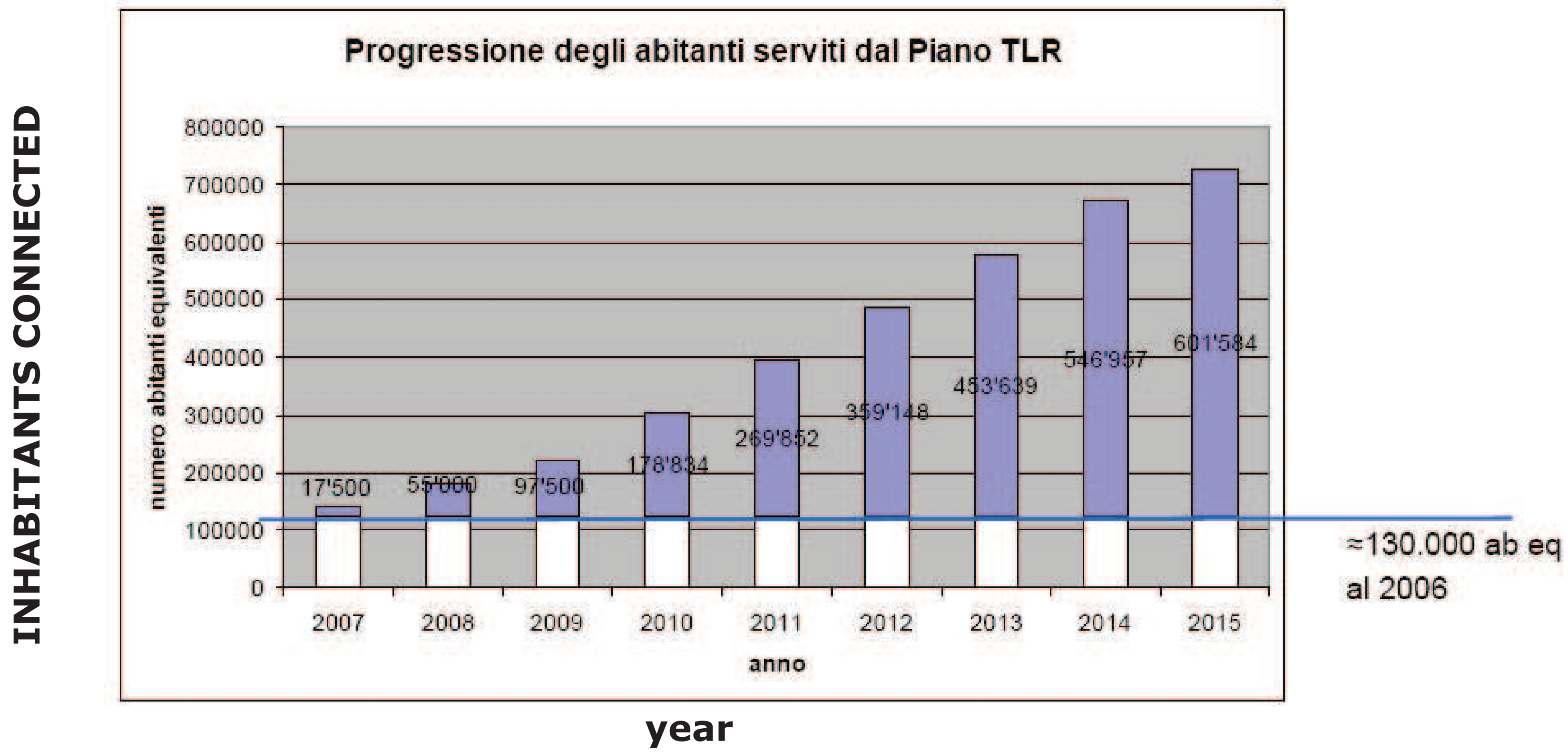
ANNEX 1

City of Milan - A2A district heating systems, 2010

MILANO DISTRICT HEATING – FUTURE DEVELOPMENT



MILANO DISTRICT HEATING – FUTURE DEVELOPMENT



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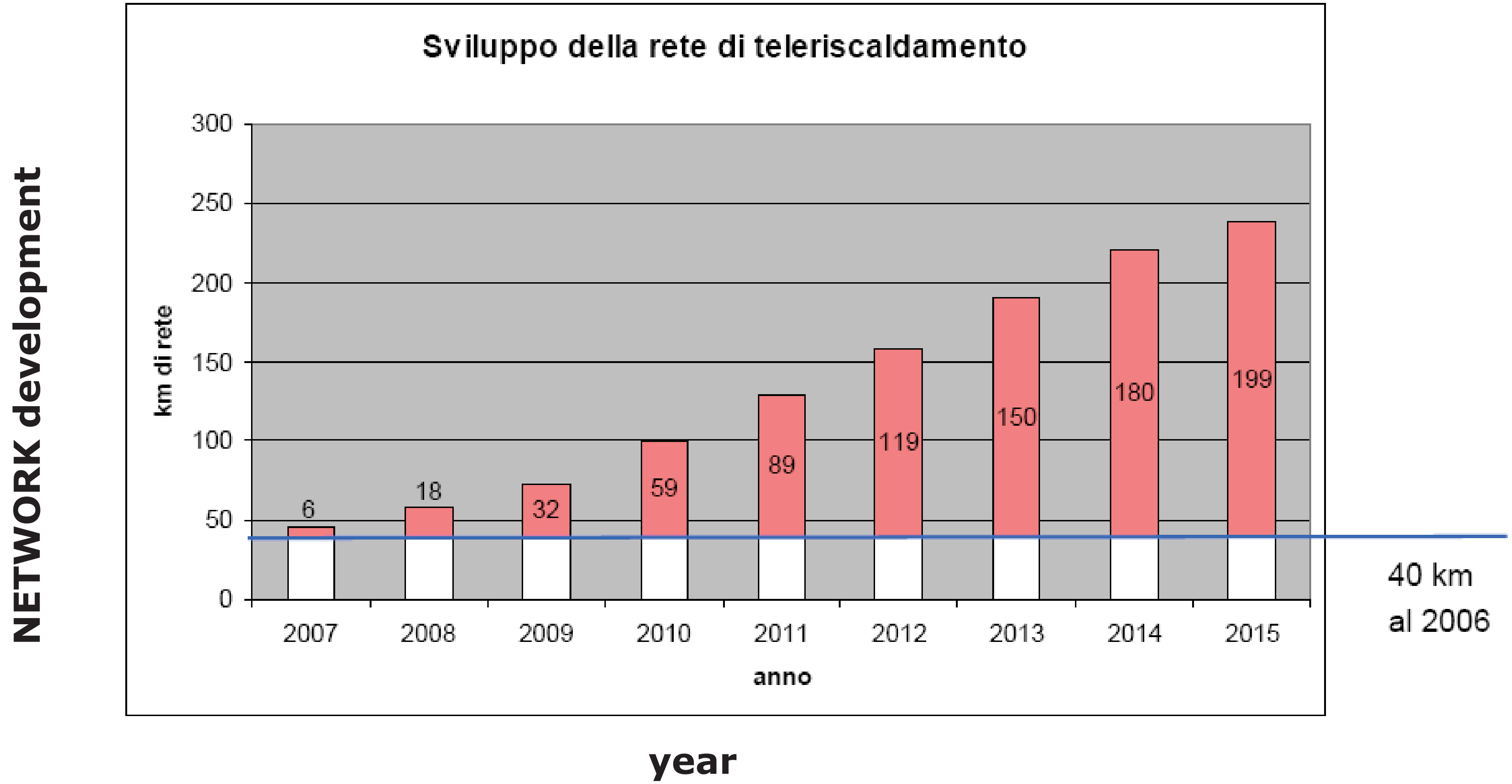

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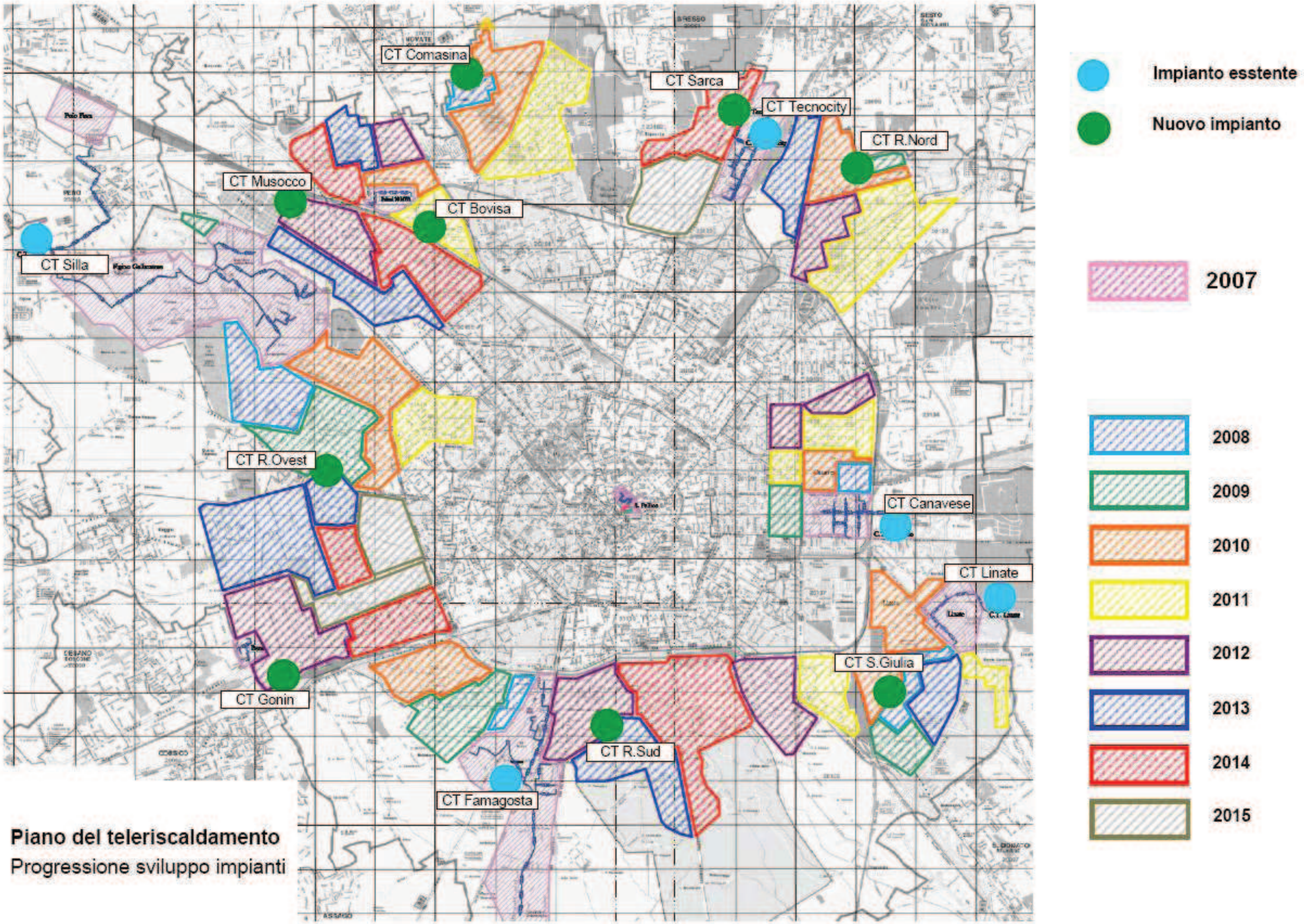
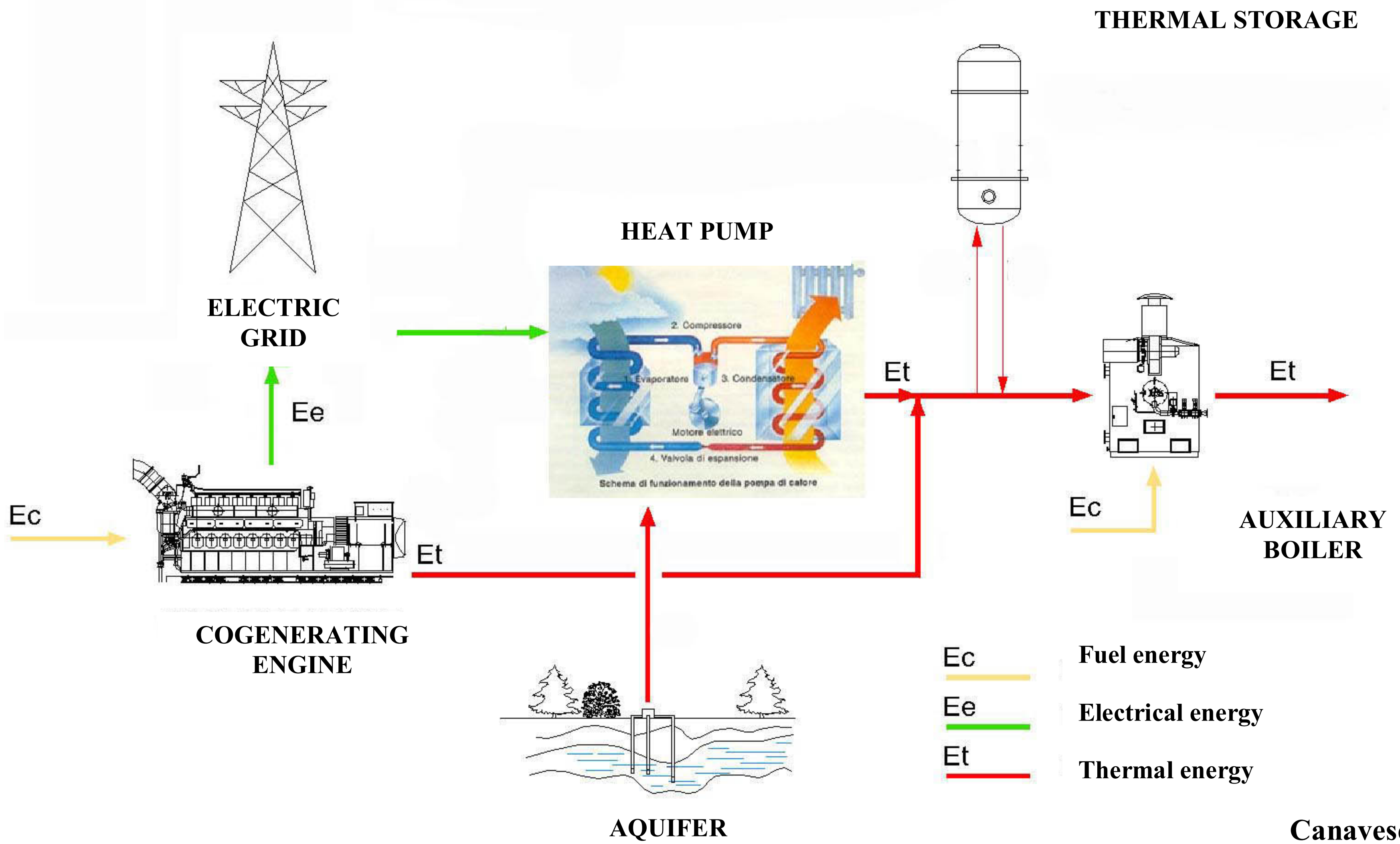
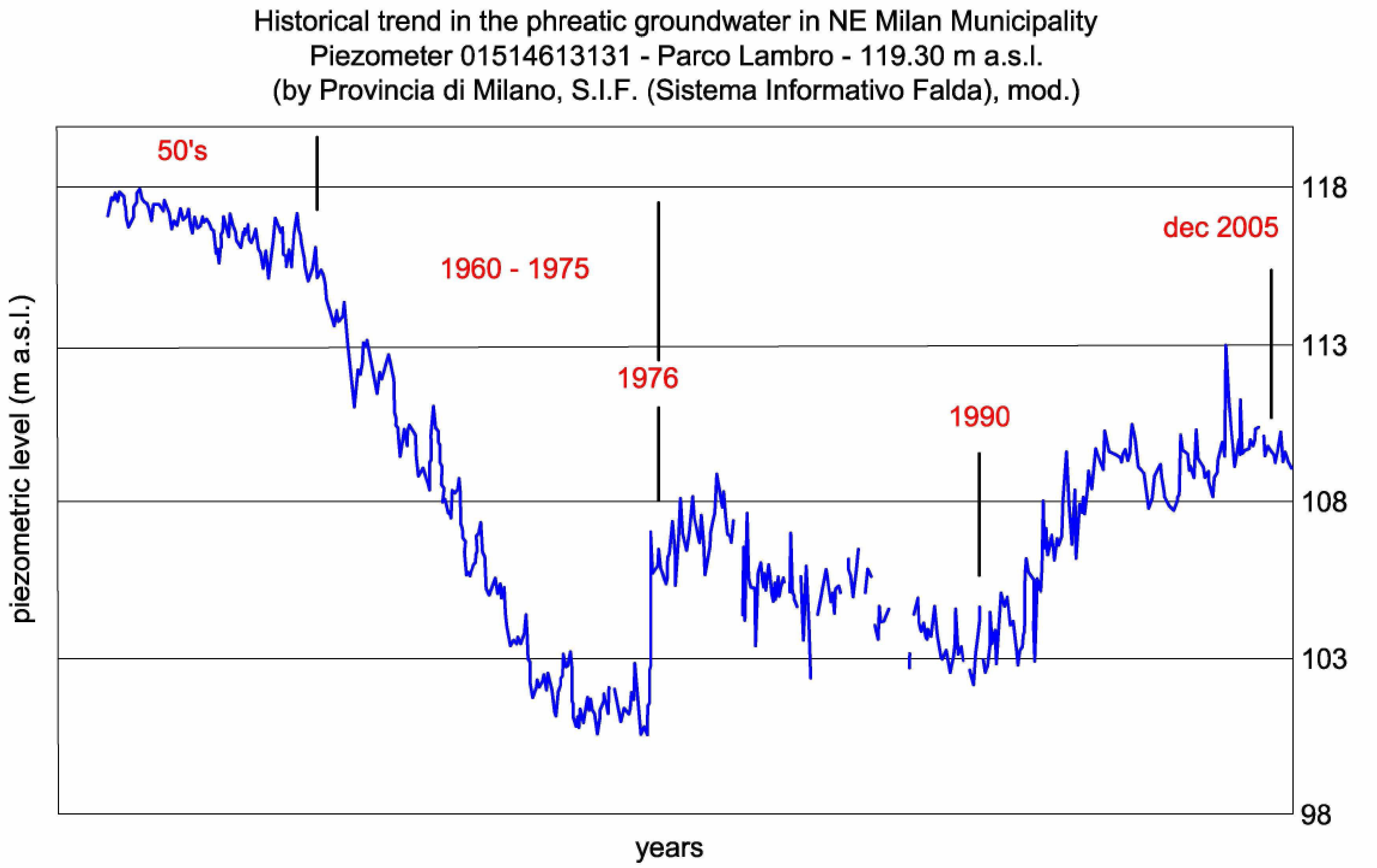




Canavese District Heating System

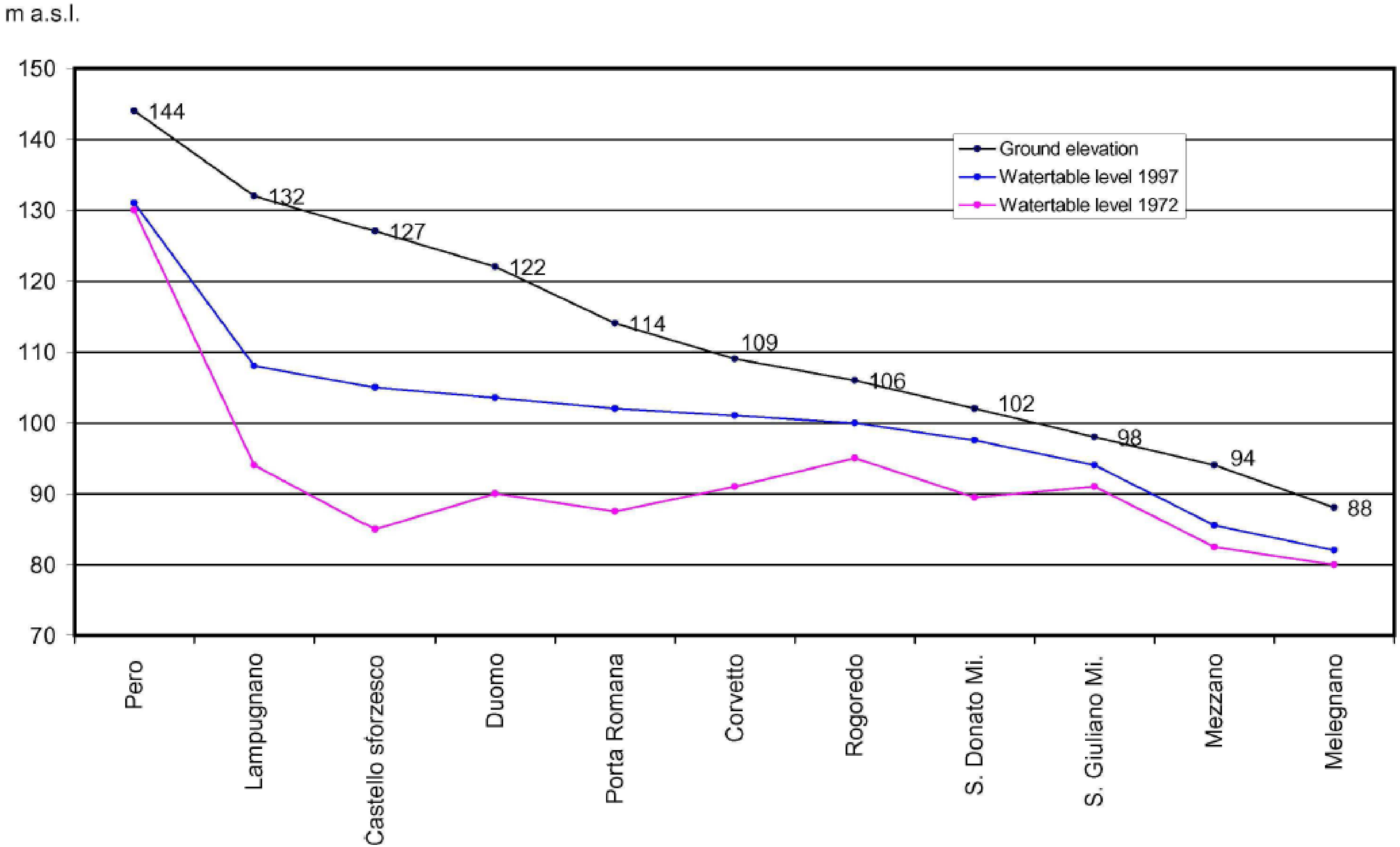
ANNEX 3

Principle scheme of Canavese plant



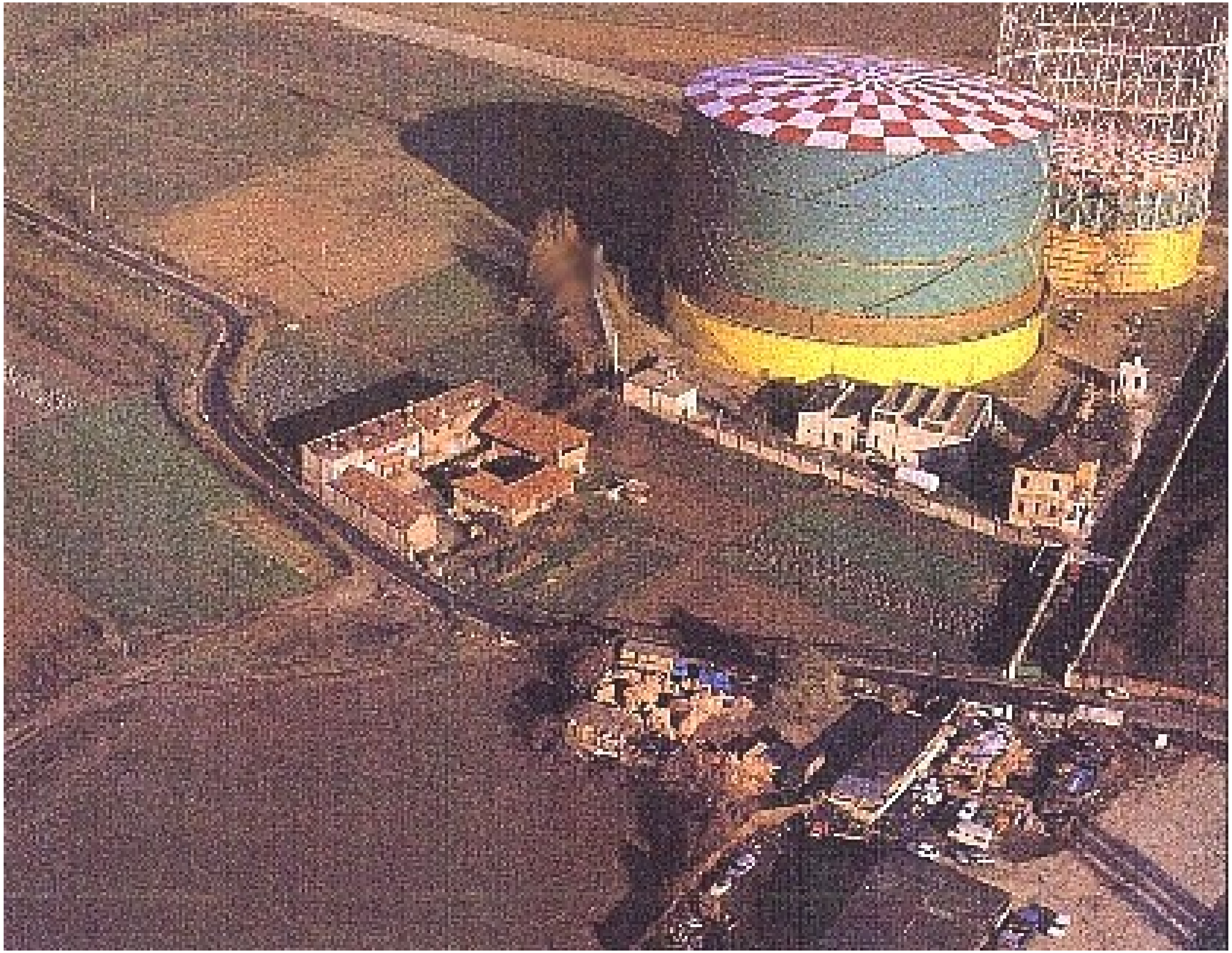
Canavese District Heating System

ANNEX 4 - Evolution of groundwater table in a tipical NE Milan well between 1952 and 2006 (by Provincia di Milano, S.I.F. (Sistema Informativo Falda), 2006)



Canavese District Heating System

ANNEX 4 - Greater Milan NW-SE cross-section of groundwater table levels 1972 and 1997 (Barnaba P.F., 1998 mod.)



Canavese District Heating System

ANNEX 5

Canavese site for the storage of manufactured natural gas (photo of archive)

Canavese District Heating System

ANNEX 6 – Canavese Plant