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Status and perspectives of the district heating and cooling infrastructures in Italy

Ilaria Bottio[1,2], Fausto Ferraresi[3,1], Bruno Della Vedova[4,2]

[1] Associazione Italiana Riscaldamento Urbano - AIRU, P.za Luigi di Savoia 22, 20124 Milano

[2] Unione Geotermica Italiana – UGI, Via Quintino Sella 84, 50136 Firenze

[3] HERA Group, V.le C. Berti Pichat 2/4 - 40127 Bologna

[4]Department of Engineering and Architecture, Trieste University, Via Alfonso Valerio 10, 34127 Trieste

dellavedova@units.it

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ABSTRACT

The space heating by district heating infrastructures in Italy has steadily increased on average by about 16 Mm^3/y over the last 7 years, with respect to about 8 Mm^3/y in the previous 14 years, reaching more than 260 Mm^3 by the end of 2011. The main energy source used to feed the systems is the natural gas, though the renewable energy sources (mainly heat recovery from Waste-to-Energy and biomasses) are significantly growing. The geothermal resources are still marginal, but positive news is expected from a few new projects in Grado, Ferrara and Pomarance. Though there is a large potential for DHC in several northern Italy cities and towns, the main reason why it did not take off yet is mainly related to the high investment required to realize the distribution networks and to the lack of appropriate regulatory schemes and energy policies. The new Italian National Energy Strategy has identified priorities, actions and specific measures to save primary energy by energy efficiency and sustainable use of energy resources. DHC infrastructures have a significant role in this respect, but it will be crucial to identify and remove the regulatory and non–regulatory barriers.

1. INTRODUCTION

Italy is facing a persistent structural weakness resulting from insufficient energy resources and an increased dependence on energy imports; on the other hand it needs to reduce the greenhouse gas emissions and to increase the use of renewable energy sources (RES). Energy efficiency and sustainable use of energy resources are headline targets to address these challenges, as they are clearly recommended by the new directive 2012/27/UE that calls for a series of national initiatives and measures covering the entire energy chain, including the District Heating and Cooling (DHC) systems.

This Directive recognizes to high-efficiency cogeneration and DHC infrastructures a significant role for saving primary energy, which is largely untapped in the European Union. Efficient DHC means a system using at least 50 % of renewable energy, or 50 % of waste heat, or 75 % cogenerated heat, or 50 % of a combination of such energies and heat. A wide diffusion and implementation of these infrastructures in cities and towns has a huge potential to strongly reduce the dependence on energy imports, to mitigate the climate change and to overcome the economic crisis, by accelerating innovative technological solutions and by improving the competitiveness of industry in the Union, besides contributing to reach the 20-20-20 energy efficiency goals.

2. ITALIAN NATIONAL ENERGY STRATEGY

The energy efficiency is the first priority, among the seven identified, of the new Italian National Energy Strategy (SEN) recently approved by the Italian Ministry of Economic Development, with roadmap to 2050; the sustainable development of the RES follows as third priority. Specific measures have been planned to pursue these targets, considering that the heat demand for the civil and industrial uses in Italy represents 45% of the total energy consumption. Incentives and fiscal benefits have been introduced or reinforced in several sectors, mainly interesting the new buildings, but not exclusively.

If we will be able to perform a comprehensive and accurate assessment and exploitation of the potential for high-efficiency cogeneration and DHC, there will be a significant potential for thermal energy savings of the order of 10%. Concerning the RES, the SEN demands a more balanced mix, favoring the thermal sources.

3. CLIMATIC ZONES IN ITALY

Italy has three main climatic zones:

a) the northern part of the country, roughly corresponding to the Alps and Po plain, with continental characteristics similar to those of central Europe;

b) the central part of the peninsula which is similar to the northern part, but with slightly higher mean temperatures over the year;

c) the southern part and islands, which have more limited changes in mean temperatures between winter and summer seasons.

Concerning the rational use of energy and energy savings (Italian law D.P.R. 412/93), the country is divided into six climatic sub-zones, on the base of the different number of degree days in the various areas with reference to the average indoor temperature of 20°C:

Area A: number of heating degree days <600;

Area B: heating degree days > 600 and <900;

Area C: heating degree days > 900 and < 1.400;

Area D: heating degree days > 1.400 and <2.100;

Area E: heating degree days > 2.100 and <3.000;

Area F: numbers of heating degree days >3.000.

Figure 1 shows the location and distribution of the six climatic sub-zones.



Figure 1: Distribution of climatic areas in Italy.

4. STATUS OF DHC SYSTEMS IN ITALY

DHC systems, engineered by the Romans more than two thousand years ago, were effective and impressive, but not efficient. The concept of integrated and efficient energy systems was launched much later, in the 1980s, by the Italian Association of the district heating systems (AIRU) to reduce the consumption of fossil fuels by means of the synergic optimization of production, transport and integration of all potential energy sources available locally. These systems represent the only rational model to give value to the local energy sources, integrated where possible with the renewable ones, used to their maximum thermodynamic value. The efficient integration of available resources constitutes the basic idea for all the Italian DHC systems developed in the last 30 years, following the first plant started in Brescia in 1972.

Most of the Italian DHC systems are efficient systems, as defined by UE Directive, or rather they use an integration of RES and high efficiency combined heat and power (CHP), as detailed below.

The data here presented are taken from the annual reports of the *Associazione Italiana Riscaldamento Urbano – AIRU* (AIRU, 2011; AIRU, 2012).

The Italian DHC systems cover the 3,6% only of the total heating demand, thus a substantial growth and improvement are required in the next years. Fig. 2 shows the DHC status to the 2011 in some European countries; Denmark exhibits an excellent performance (61%).

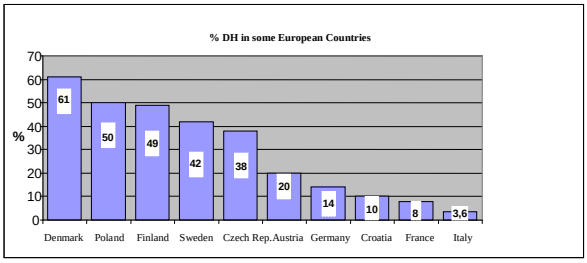


Figure 2: Status of the DHC systems in some European countries by 2011.

By the end of 2011 there were 104 cities and towns supported by DHC, totalizing a space heating of 260 millions of m^3 (Fig. 3), 1,32 million tons of avoided CO_2 emissions and a primary energy savings of 405.000 TOE. The annual increment rate during 2010 and 2011 was of about 16 millions m^3 per year (+ 6,5 %). It should be noticed that 93% of the 2011 increment corresponds to extension of existing district heating networks, rather than to new networks and installations. The space heating by DHC infrastructures in Italy has steadily increased on average by about 16 Mm^3/y over the last 7 years, with respect to about 8 Mm^3/y in the previous 14 years.

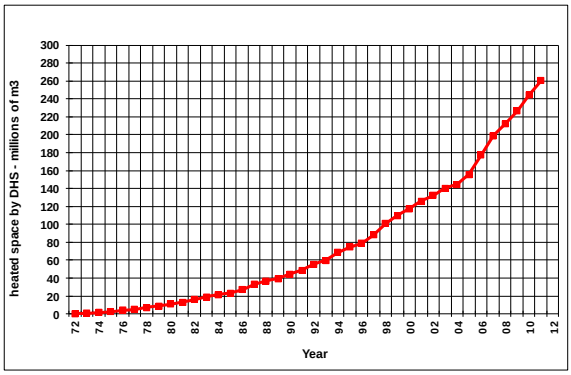


Figure 3: Space heating (in Mm^3) by DHC systems in the last 40 years in Italy.

Among the energy sources used to feed the DHC systems, the natural gas covers over 75 % of the total. The heat recovery from Waste-to-Energy (WtE) plants

represents the second energy source for the DHC. The CHP portion alone was considered for the cogeneration groups, in agreement with the Directive 2004/8/CE and with the national DM of August 4, 2011.

The contribution of RES (recovery of industrial heat, WtE, biomass and geothermal sources) increased substantially from 3% in 1995, to 14,6 % in 2010, to 20% in 2011. The latter increment is mainly due to the new entry of the biomasses (6,3 % of the total input) and to a consistent increment of the heat recovery from WtE plants. The contribution of the geothermal resources and of the industrial heat recovery is nowadays still marginal (0,8 %). Large margins of potential improvement in the near future are expected from geothermal sources, solar thermal and heat pumps.

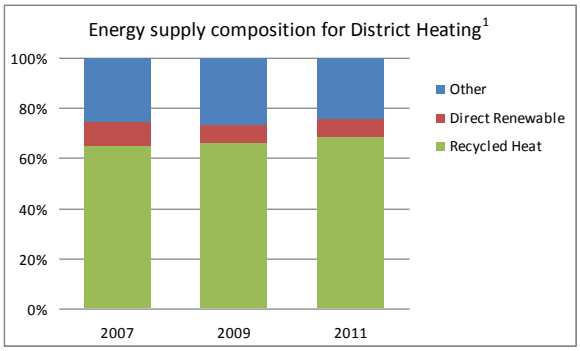


Figure 4: Energy supply composition for DHC systems in Italy, in 2007, 2009 and 2011.

Figure 4 shows as the recycled heat contributes almost 70% of the heat sources for DHC systems in Italy. "Recycled heat" includes surplus heat from electricity production (CHP), WtE plants and industrial processes, independently from the fuel used for the primary process. Two-thirds of the energy delivered by heat pumps is also considered as recycled heat. "Direct Renewable" includes the use of renewables in heat-only boilers and installations other than CHP. "Other sources" includes heat-only boilers, electricity and one-third of the heat originating from heat pumps.

4.1 – Volume linked to DHC networks

The space heating linked to the DHC systems has significantly increased from 109,8 Mm^3 in 1999 to 260,3 Mm^3, with a yearly increment in 2011 of 15,9 Mm^3 (+ 6,5%), with respect to 2010 (Table 1).

Year	linked volume		
	Annual Mm3	At 31th December Mm3	Increase %
1999	9,1	109,8	9,0%
2000	7,5	117,3	6,8%
2001	8,6	125,9	7,3%
2002	6,4	132,3	5,1%
2003	7,8	140,1	5,9%
2004	4,2	144,4	3,0%
2005	11,2	155,6	7,8%
2006	21,7	177,3	14,0%
2007	21,3	198,7	12,0%
2008	13,2	211,9	6,7%
2009	14,6	226,5	6,9%
2010	17,9	244,4	7,9%
2011	15,9	260,3	6,5%
average 2000-2011	12,53		7,5%

Table 1: Heated volume trend for the DHC systems in Italy from 1999 to 2011.

4.2 – Development trend of DHC networks

The extension of the DHC networks has reached 2.951 km of primary pipeline networks in 2011. The growing trend of pipeline deployment from 1999 to 2011 is shown in Table 2.

Year	annual increase km	Development at 31th December km
1999	115	996
2000	95	1.091
2001	151	1.242
2002	121	1.363
2003	108	1.471
2004	38	1.509
2005	158	1.667
2006	286	1.953
2007	218	2.171
2008	85	2.256
2009	148	2.404
2010	368	2.772
2011	179	2.951
average 2000-2011	163	

Table 2: Development trend of DHC networks in Italy from 1999 to 2011.

The installation of final consumer substations reached altogether the number of 51.150, at the end of 2011, with an increase of 2.582 substations in the last year.

The request for combined installations that provide both heating and hot water supply are presently prevailing (about 63%); it was 60% of the installed substations in 2007 and only about 50% in 1997. This indicates that the installations in new buildings take better advantage from the DHC networks.

4.3 – Regional distribution of space heating

Table 3 shows the regional aggregation of space heating in Italy, comparing the increment between 2010 and 2011. The DHC systems are concentrated in Northern Italy with almost all of the district heated volume (252 millions of m^3, equal to 97% of the total volume) concentrated in six northern regions: Lombardia, Piemonte, Emilia Romagna, Veneto, Trentino Alto Adige e Valle d'Aosta.

The Trentino Alto Adige region, with nowadays 15 million m^3 of heated space (thanks to the biomass heat feeding DHC systems), is now at the fourth place among the Italian DHC regions.

	Region	spaced heat		
		Year 2010	Year 2011	
		Mm3	Mm3	%
1	Lombardia	112,0	117,6	45,2%
2	Piemonte	62,2	70,5	27,1%
3	Emila Romagna	36,8	37,7	14,5%
4	Veneto	13,4	13,8	5,3%
5	Trentino A. A.	10,8	10,9	4,2%
6	Valle d'Aosta	1,2	1,5	0,6%
7	Lazio	3,5	3,6	1,4%
8	Liguria	2,8	3,0	1,2%
9	Toscana	1,0	1,0	0,4%
10	Marche	0,6	0,7	0,3%
	TOTAL ITALIA	244,4	260,3	100%
	TOTAL NORTH	236,4	252,0	
		97%	97%	

Table 3: Regional aggregation of the space heating in Italy, showing the comparison between 2010 and 2011.

4.4 – Energy sources used in DHC plants

Some statistics about the energy sources used by the DHC systems in Italy is summarized in Table 4, comparing three reference years: 1995, 2004 and 2011. The natural gas is the main source (about 76%, with a large increase compared to previous years) followed in the order by: urban solid waste 12,6%, coal 2,9% (so far used by the Brescia plant only), biomass 6,3% and fuel oil 0,4%. It is important to notice that the urban solid waste has realized the "overtaking" of the fuel oil 1995 and it has been since the second source used by the DHC systems in Italy.

The other RES (geothermal and industrial recovery) are still marginal, totalizing altogether around 1%. The importance of these RES is however less marginal when referred to the net energy run into the pipeline systems, as results from the following section.

energy sources	Year 2004		Year 2011		Year 1995	
	Tep	%	tep	%	tep	%
Natural gas	721.794	60%	1.179.913	75,9%	383.521	68,9%
energy from WTE	252.794	21%	195.813	12,6%	6.708	1,2%
biomass	105.909	9%	98.577	6,3%	-	0,0%
coal	91.772	8%	45.576	2,9%	69.810	12,5%
oil	5.662	0%	6.046	0,4%	79.726	14,3%
geothermal	10.952	1%	10.933	0,7%	4.472	0,8%
industrial recovery	17.827	1%	2.322	0,1%	4.644	0,8%
primary energy from SEN (1)			15.589	1,0%	7.750	1,4%
Fossil fuel total	919.475	76%	1.247.125	80%	540.807	97%
Renewable total	287.235	24%	307.645	20%	15.824	3%
Total	1.206.710	100%	1.554.770	100%	556.631	100%

[1] SEN: consumed power from National Energy System

Table 4: Energy sources used by DHC plants in Italy, data comparison among 1995, 2004 and 2011 data.

4.5 – Production capacity of plants

The production capacity of the different type of plants feeding the DHC pipeline systems is reported in Table 5, showing the increase between 2010 and 2011.

Plants Type	capacity installed At 31th December 2011		installed capacity At 31th December 2010		capacity increase	
	Power MWe	Heat MWt	Power MWe	Heat MWt	Power MWe	Heat MWt
CHP Plants	772	1.031	820	1.110	- 47,86	- 78,6
Power Plants	-	1.065	-	845	-	220,0
WTE Plants	-	392	-	351	-	40,9
Biomass plants	-	197	-	184	-	13,3
Biomass CHP Plants	33,3	67	32,6	64	0,70	3,10
Geothermal plants	-	41	-	41	-	-
industrial recovery	-	10,6	-	10,6	-	-
Heat pumps	-	20,3	-	20,3	-	-
integration boilers		4.115	-	3.676	-	438,6
TOTAL	805	6.940	853	6.303	- 47,16	637

Table 5: Production capacity of the plants feeding DHC systems in Italy, 2010 and 2011 data.

The prevailing type of units is constituted by CHP plants feed by fossil fuels and by integration and reserve boilers also feed by fossil fuels.

There are several WtE plants (Bologna-Frullo, Brescia, Como, Cremona, Ferrara, Reggio Emilia, Milano-Figino, Bolzano, Bergamo, Desio, Sesto San Giovanni e Forlì), all of cogenerative type. Biomass DHC networks have also a relevant role (264 MWt installed).

If we exclude some very localized "historical" plants located in the area of Lardarello, Tuscany, the city of Ferrara remains the only case in the northern regions of geothermal RES feeding by more than 50% the DHC system. Even less significant is the amount of energy regeneration from industrial processes: the Mantova city pipeline system is the only one using the waste heat by the IES SpA refinery.

Table 6 summarizes the typology and capacity of the co-generative units: the steam turbine (plants of Brescia and Reggio Emilia) constitutes, in terms of installed power, the prevailing typologies with about 32%.

CHP plants	Installed capacity At 31th December 2011			Installed capacity at 31th December 2010			varation 2010-2011		
	Power MWe	Heat MWt	unit number	Power MWe	Heat MWt	unit number	Power MWe	Heat MWt	Number N.
Steam turbine (fossil fuel)	157,7	347,4	4	157,7	347,4	4	0,00	-	0
gas Engine	273,1	274,6	136	265,9	269,6	130	7,26	5,07	6
Combined cycle (ST- GT)	258,4	267,3	8	258,8	268,3	8	- 0,40	- 1,00	0
Gas turbine	82,3	141,2	9	106,0	178,9	12	- 23,68	- 37,70	-3
Steam Turbine (biomass)	29,9	63,3	3	29,2	60,2	2	0,70	3,10	1
Biogas engine	3,318	4,122	3	3,318	4,122	3	-	-	0
Gas microturbine	0,225	0,476	3	0,225	0,476	3	-	-	0
Diesel engine	0,430	0,430	1	0,000	0,000	0	0,43	0,43	1
Combined Cycle (GE- ST)	0,000	0,000	0	31,640	45,300	1	- 31,64	- 45,30	-1
TOTAL	805	1.099	167	853	1.174	163	- 47,34	- 75,40	4

Table 6: Type and capacity of the cogenerative units feeding DHC systems in Italy, 2010 and 2011 data.

4.6 – Energy produced by DHC plants

The plants connected to DHC systems working in Italy (2011) produced 5.435 GWhe and 8.645 GWht. The net delivered energy (deducting the systems heat losses and the station auto consumption), amounts respectively to 5.201 GWhe and to 7.322 GWht, corresponding to 96% and to 85,5% of the produced energy.

The difference in heat production (-4%) is related to a specific climatic situation, with a particularly mild winter.

The heat produced with CHP plants constitutes 50,5% of the total energy supplied to the pipeline systems; the integrative heat produced by simple boilers constitutes 26,3%, while the remaining 23,2% is provided by RES. Altogether almost 74% of the heat supplied to the DHC pipeline systems is produced with low environmental impact technologies.

4.7 – Energy saving and environmental balances

The Italian DHC systems have obtained a primary energy saving of about 405.000 TOE in 2011, corresponding to about 24% of the primary energy consumed by the *"conventional substituted systems*" (building boilers and national electric system).

The emissions balance of the DHC plants in 2011 outstands less CO_2 emissions equal to -1.324.000 tons, compared to the *"conventional substituted systems"*.

The lower savings, in comparison with last year, are due to the new adopted parameters:

- heat efficiency of *conventional substituted systems* changed from 0.80 to 0.90;
- power efficiency of *national electric system* changed from 0.40 to 0.46
- specific emissions of *national electric system* changed from 666 gCO_2/kWhe to 564.

5. DHC PERSPECTIVES

Low temperature geothermal resources (< 90 °C) present in several areas of the country could be easily integrated, as a main RES base load, together with waste industrial heat, thermoelectric plants, waste incineration and others to efficiently supply DHC.

Though there is a large potential for DHC in several northern Italy cities and towns, the main reason why it did not take off yet is mainly related to the high investment required to realize the distribution networks and to the lack of appropriate regulatory schemes and energy policies. The urban and country planning seems the basic step among the stakeholders (public administrations, municipalities and investors) to start with a new integrated strategy for efficient heating and cooling infrastructures, substantially contributing to the large final consumption of heat which represents the 45% of the total energy demand in Italy. The State should encourage local and regional administrations to adopt integrated and sustainable energy efficiency policies and accurate planning, defining clearly objectives, resources assessment, programs, management systems and tariff schemes for DHC.

The comprehensive assessment of potential for high-efficiency CHP and DHC should be carried out by National Government by 2015 to ensure investors with correct and solid information. In this perspective it is necessary to identify and remove the regulatory and non–regulatory barriers, encouraging the use of financial facilities, including incentives, resources and revenues to enable and encourage the private investments. The financial facilities could use innovative financing mechanisms (e.g. loan guarantees for private capital, loan guarantees to foster subsidized loans and dedicated credit lines). The Italian legislative decree 28/11 on RES recently enacted the development of DHC market; in particular, Article 22 states that:

- municipalities must adopt integrated and sustainable energy efficiency plans with clear objectives, where the heating and cooling demand that could be satisfied by district heating and cooling is identified;
- a guarantee fund must be established for DH systems.

Since 1998, incentives in the form of tax credits have been available for customers of biomass/geothermal DH systems, but so far these incentives have not included all DH systems. Italy now must adopt the new European Directive on Energy Efficiency and DHC will have a growing future.

Despite the incentives framework is at present not so important there are a few new projects under realization, or in the design phase, that is worth reporting:

a) Torbole Casaglia (BS): a new district heating and cooling system is under planning at Torbole-Casaglia

(Brescia), supported by an open loop system from the shallow unconfined aquifer at a temperature of 12-13 °C. It is expected to serve 46.097 m^3, to use 449.978 kWh of primary energy and to supply 1.504.065 kWh to the users, with an investment of 710.000 €. The DHC network is in PE, without insulation, to favour the thermal exchange with the ground; it takes the groundwater into the buildings, where low and high temperature heat pumps will heat and cool new and old pre-existing houses, respectively.

b) Pomarance (PI): a feasibility study for a geothermal DHC, integrated by solar thermal, is in progress.

c) Cassano d'Adda (MI): the multi utility company A2A is designing a DHC for a portion of the city of Milan, using a 50 km long feeder recovering industrial heat from an existing thermoelectric plant.

d.) Ferrara Est: the project by Hera S.p.A. will extend the existing Ferrara DHC to the east of the city, by drilling a new triplet (two production and one re-injection boreholes) in a promising carbonatic geothermal reservoir at 80-85 °C.

e.) Grado (GO): the Grado – Phase 2 project for the completion of the DHC for public buildings is due in 2013-2014. The competitive tender for the drilling of the re-injection borehole and the deployment of the main distribution network was issued in April 2013; drilling is planned by the end of 2013, whereas the distribution network will be deployed in early 2014.

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