Technical, Financial and Urban Potentials for Solar District Heating in Italy

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Abstract AIRU, the Italian association of district heating, and the Department of Energy of Politecnico di Milano have tried to evaluate the economic, technical, and urban potential of solar district heating in Italy as an efficient and flexible system to spread the use of solar thermal energy in urban areas. This potential has been estimated with the analysis of five case studies of solar thermal integration in district heating networks in the north of Italy: three with a centralized solar plant in existing district heating, one with distributed solar in an existing network, and finally one of a new solar district heating network. These studies, realized in the framework of Solar District Heating Plus project, aim at verifying the technical and economic feasibility of this integration. Besides the more common economic and technical study, a critical analysis looking at the urban aspects of this technology is proposed in order to analyze local potentialities and barriers for this technology. Centralized solar thermal integration has had positive results, while distributed solar rooftop-plants integration turns out to be not economically sustainable. A need for heat planning and heat mapping in urban design emerges as needed to promote and simplify the spread of large-scale renewable-energy plants.

Keywords Solar energy · District heating · Case studies · Trnsys · Urban energy planning · Legal framework

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1 Introduction

District heating systems, DH, can be described as urban-scale centralized systems that distribute energy from the heating source to residential and commercial buildings over a wider area. This technology has been demonstrated to have great potential and an important role in increasing the efficiency of urban heat-distribution systems in Europe (Persson and Werner 2012). DH is in fact able to extensively use and efficiently distribute heat that would otherwise be wasted (Werner 2006) like cogenerated heat, waste to energy, industrial recovery heat, as well as renewable heat from biomass and solar thermal, reducing the primary energy consumption (Lund et al. 2010). In particular, solar thermal energy has successfully been integrated into existing and new district heating networks, especially in northern European countries like Denmark, Sweden, Germany, and Austria. (Nielsen 2014; SDH project partners 2008).

In Italy, this kind of integration has just started with the first integration of solar thermal collectors in the district heating network of Varese, in the north of Italy.

In the framework of European project on Solar District Heating, SDHplus, AIRU, the Italian association of district heating and the Department of Energy of Politecnico di Milano have tried to assess the feasibility of this kind of application in Italy in terms of technical, economic, and urban planning aspects through the calculations and analysis of several case studies. Two of the cases analyzed in this paper, A and D, have already been presented in Dénarié et al. (2015), plus technical data is available in SDHplus project deliverables on solar-district-heating.eu. At the conclusion of the project, thanks to the presentation of additional analyzed cases, the aim is to reach some consensus on the potential of this technology, in particular from the urban-integration point of view.

2 Opportunities for Solar District Heating—the Italian Framework

High efficiency DH and its integration with renewable-energy sources is a central research issue internationally recognized as an instrument to improve the financial and environmental sustainability of urban energy distribution (Connolly 2014; Lund et al. 2014). In particular, in Italy, the boundary conditions that characterize DH are forcing this system to face big changes, and this is definitely an opportunity for solar thermal energy.

Technical Framework: District Heating Energy Sources

DH systems risk losing their attractiveness in terms of energy efficiency, CO_2 emissions savings and financial profitability because of the current national energy context. First of all, the actual Italian DH networks are in great part fed by steam-cycle cogeneration plants (CHP) and internal combustion engines, which are much less efficient then modern steam-gas combined heat and power (GCC) plants

(AIRU 2014). In addition, actual networks are for the majority fed by fossil fuels with very little contribution from waste and renewable heat and almost no contribution from industrial heat recovery (see Fig. 1).

Secondly, electrical consumption has considerably decreased, 9.2 % from 2008 (Terna 2014), because of the economic crisis and efficiency measures, while the share of renewables in the electric grid has increased, and photovoltaic covers 7.5 % (Terna 2014) of electricity needs. All these conditions cause longer and longer periods of inactivity for CHP plants, in particular in summer, so that DH companies are forced to increase the use of their back-up gas boilers, which has a very bad impact on energy efficiency, environmental sustainability, and economic profitability. Consequently, DH utilities are looking for a more environmentally friendly and cheaper thermal source, and solar heat can definitely satisfy these requirements.

Political Framework: Legislation

European Directive 2012/27/EU, transposed in the Italian D. lgs. n. 102/2014, promotes “efficient district heating”, a system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat, or 50 % of a combination of such energy and heat. Renewable-heat-sources integration in DH networks is now a real possible solution for utilities also because the diversity in heat supply options enables the use of the most suitable and favorable heat source depending on the market conditions and the heat costs. (Frederiksen and Werner 2013).

In addition to that, energy performance of new buildings and major renovations requirements have become increasingly ambitious. The promoters of this change are the European directives such as 2010/31/EC and the 2009/28/EC, both implemented in Italy, respectively, by D. lgs. 63/2013 and D. lgs. 28/2011.

The two directives give renewable energy a key role in achieving the goals of efficiency, requiring the introduction of an increasing share of renewable energy for heating and cooling in buildings. Solar district heating is an efficient way to meet these requirements, shifting the obligation of installing solar thermal from building

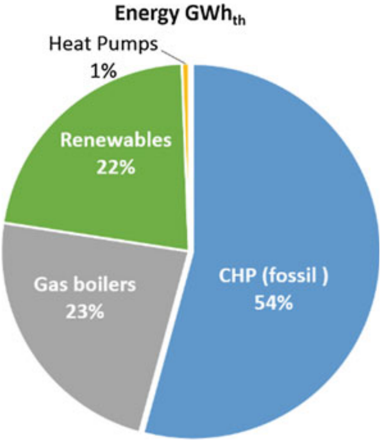

Fig. 1 Generation systems of Italian DH (AIRU 2014)

owners to DH utilities. Annex I of the 2010/31/EC also prescribes that the method of calculation of the energy performance of buildings, which defines their energy label, takes into account the presence of district heating for its primary energy-conversion coefficient. In the calculation of this coefficient, the heat sources feeding the DH network are considered, and the presence of renewable thermal energy has direct impact on this parameter.

On the other hand, successful Swedish examples (Dalenbäck 2012), suggest an opportunity for building owners that have already installed solar thermal to become *prosumers.* By connecting to DH networks, it is possible to avoid use of individual storage, to sell the excess solar-heat production to the DH networks, and to buy heat from this network instead of installing an individual back-up boiler.

Economic Framework: Incentives

Two parallel phenomena are happening that represent an opportunity for solar district heating (SDH).

Past incentives that supported the birth of DH plants fed by fossil fuels cogeneration systems, like *Green Certificates* D.M. (2008)*, white certificates* (D.M. 2004) and *CIP 6* (CIP 1992), are expiring in the next few years, and consequently CHP systems risk being less economically interesting.

Meanwhile, the actual incentive system, *Conto Termico* (D.M. 2012), subsidizes solar thermal fields up to 1,000 m^2, making the integration of both large-sized centralized and multiple, distributed, medium- size solar thermal fields interesting. The revision of the same incentive schemes will support solar thermal fields up to 2,500 m^2 in future years (D.M. 2016).

After having analyzed some case studies in a previous paper (Dénarié et al. 2015), two of which are also mentioned in this paper, the subsidized surface of 1,000 m^2 seems to be too big for individual systems, but too small to have a big impact on DH plant size. Nevertheless, according to more experienced northern-country partners of the SDH plus project (Dénarié 2015), for a typical medium Italian network, a bigger-size solar field of at least of 5000 m^2 could be a really interesting solution in terms of energy output and economic profitability, benefitting from the cost reduction caused by the scale effect and even without incentive.

Local Framework: Urban Planning

From the experience gained and shared with involved utilities during the SDH project, urban aspects are crucial in the process of designing and building a SDH plant. In the design phase, while looking for space availability, and in the authorization phase, the DH utilities have to confront local authorities on urban issues. The legislative framework previously presented promotes the integration of renewables, but speaking about solar energy means speaking about available space that is not easy to find if not properly considered in the planning phase of an urban territory (SDH project partners 2015). For matters requiring a high-level legislative framework, national or regional, some urban tools are available to plan renewable energies. At the regional level, PEAR—Programma Energetico Ambientale Regionale is the strategic energy and environmental tool with which energy savings and objectives in the field of renewable energies development are defined by every region (L. 10/1991, January 9).

Moving to the lower local level, the PAES, Piano di Azione Energetica Sostenibile (SEAP Sustainable Energy Action Plan), is the planning and policy document for the reduction of greenhouse-gas emissions that the City Council has agreed to set up as part of the Covenant of Mayors. These tools define objectives and goals by implementing European directives, but, at the same time, they seem to lack consequent action measures, and they are not reflected in concrete indications nor requirements on how to reach these objectives from an urban point of view. The main focus of these plans is a buildings' efficiency, but they don't deal with urban energy issues (Zanon and Verones 2013).

At least in Italy, urban planning executive documents still do not have heat-and-energy-planning tools with clear indications on renewable energies. That implies that new SDH systems still have difficulties in the design and authorization phases because there is no clear reference to this kind of plant in urban planning documents or how the local utilities should deal with them. From the experience of the first SDH plant in Italy in Varese (Fidanza 2015), it's possible to conclude that this plant was built following a specific and singular authorization path that cannot be generalized. In order to reduce the weights of personal interests and political influence on the decisional process that leads to SDH plants, there's a need for legislative tools, instruments, and action guidelines to support the positive decision towards solar large-scale plants and to generalize the authorization procedure.

3 Methodology of the Analysis

In the framework of the just-ended European project SDHplus, the Energy Department of Politecnico di Milano with the support of AIRU has analyzed the potentiality of SDH in Italy from what concerns the energetic technical point of view, its economic feasibility, and the opportunities and barriers in the urban-planning field.

In particular, the elaboration of several case studies in collaboration with several utilities has given a concrete perspective to the analysis, raising issues and facing aspects that utilities have to deal with in implementing this kind of technology. From a technical point of view, cases A and D have already been presented in Dénarié et al. (2015). Here is the outline of the used methodology.

First, contacts with utilities are important to define the basic information required to start a preliminary project of integration in the solar field:

- motivation
- expected impact on the existing network
- space availability
- economic availability

Answering these questions raises some points and issues that can immediately expose the opportunities and barriers with which the Italian framework can consider this kind of plant.

Table 1 Characteristics of the analyzed DH networks

Case	Length (km)	Energy delivered (GWh_{th}/year)	Generation system		Temperatures (°C)	Type
			Technology	(MW_{th})		
A	26	45	Gas boilers	11.6	W 105–65 S 80–60	Existing
			Gas combined cycle (3rd party)	28.0		
B	20	49	Gas boilers	30	W 92–68 S 92–68	Existing
			Waste-to-energy plant	16		
C	4.4	5.8 heat 0.4 cold	Gas boilers	2.8	W 85–70 S 85–70	Existing
			Gas Cogeneration	0.75		
			Biomass-cogeneration recovery (3rd party)	0.8		
			Absorption chiller	0.4		
D	12.5	36	Gas boilers	29	W 115–65 S 85–65	Existing
			Gas Cogeneration	4		
			Biomass-cogeneration recovery (3rd party)	4.0		
E	–	13.8 heat 7 cold	Solar Thermal existing DH as backup		70–50	New

In particular, the choice of the location for the integrated solar field is an important factor, influenced by urban regulations, that deeply influences the installation technology and consequently the installation price and business model.

For the technical feasibility, DH-network monitoring data are collected from the utility and used to simulate the system in the energy-dynamic-simulation software, Trnsys. Thanks to the simulations performed, the solar heat production and the influence of the solar field on existing network temperatures and energy-plant production are evaluated during the whole year. After an optimization phase, the best solution is presented to the utility, which calculates the economic feasibility of the investment according to its own specific parameters.

In this analysis, five case studies have been analyzed: four regarding solar integration in existing networks and one of a new network fed by solar heat. Technical details of cases A and D are presented in Dénarié et al. (2015); Table 1 describes the four existing networks that have been investigated for solar integration.

4 The Case Studies of Existing District Heating Networks

4.1 Centralized Solar Thermal Field

The networks involved are experiencing a quite common situation for Italian networks because they are suffering the crisis of traditional CHP systems. Because of the situation previously described, the utilities look for an alternative heat source that enables increasing the share of renewables in the networks and for a cheaper alternative to gas boilers. Considering the requests, the previously mentioned incentives scheme and the availability (of all the utilities involved in centralized solar thermal integration) of a unused area of 2,500 m^2 around the generation plant, the solar integration proposed consists of a ground-mounted solar field of 1,000 m^2 integrated in the return line.

4.1.1 Case Study a—Solar Thermal + Natural Gas

The first case study concerns a medium network in the north of Italy that exemplifies a typical Italian DH network, which delivers 45 GWh/year and which recovers heat from a third party, gas, combined-cycle plant.

The solar plant is directly connected to the return line, using the network as storage (see Fig. 2).

4.1.2 Case Study B—Solar Thermal + Waste-to-Energy

The second case study deals with a utility of medium dimension similar to the previous one, which delivers 49 GWh/year, but with a different generation system: a waste–to-energy (WTE) plant. The utility is looking for a new heat source for potential future extensions (Fig. 3).

The WTE plant, however, changes the framework completely: Since the WTE plant has priority in feeding the electric grid, the plant operates during the whole year, also in summer. Cogenerated heat is usually in competition with a solar source, because increasing the return temperature reduces the efficiency of CHP. In this case, the integration is designed to reduce the amount of steam bled from the turbine, without affecting the heat recovery from condensation and the cooling process. The solar integration helps the electrical efficiency of the WTE plant with a double benefit: thanks to the incentive provided to electricity through the green certificates mechanism, thus reducing the pay-back time of the solar plant.

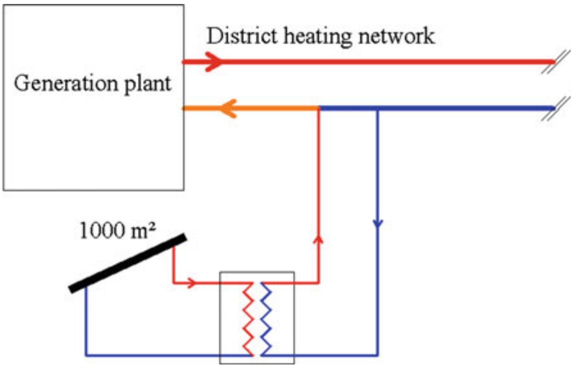

Fig. 2 Integration of the solar field in the network of case study A

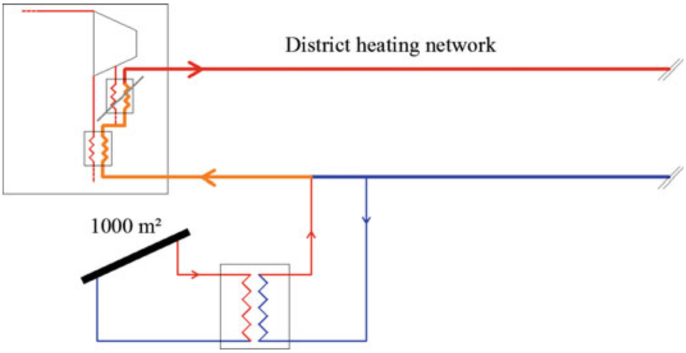

Fig. 3 Integration of the solar field into the network of case study B

4.1.3 Case Study C—Solar Thermal + Natural Gas Cogeneration + Biomass-Cogeneration Heat Recovery

The third case study analyzed has another different background in which the solar thermal source is foreseen among various different production technologies. It represents an interesting case of diversification of heat sources and the flexibility of the generation system, and it shows district heating is a crucial system for the energy transition, able to collect various and different kinds of heat that would otherwise be wasted (Frederiksen and Werner 2013). The DH system consists of a small network with extension planning fed by a natural-gas CHP and heat recovery from a third-party-biomass CHP plant on the return line. In addition to that, an absorption chiller feeds a small cooling network that needs 400 MWh of cooling energy cold per year. The solar field is foreseen again on the return line but feeding the supply line of the DH network, and placed in an empty nearby area surrounding the central plant location, and subsequent to the heat recovery for the third party biomass CHP plant located along the distribution return line. The generation systems consisting of solar integration is presented in Fig. 4. The solar pump is regulated to guarantee a supply temperature for the network (75–80 °C) in winter and 85° in order to feed the absorption chiller in the summer.

4.2 Distributed Solar Thermal

In the last analyzed case, the idea is to make peripheral users completely independent from the network during summer thanks to small fields of distributed collectors on building roofs: maintaining the temperature at a nominal level in distant peripheral branches, indeed, leads to high distribution losses, especially in summer when demand is lower (only for domestic hot water). In such conditions, distributed solar thermal installations are analyzed in order to evaluate the feasibility of this summer "disconnection" for some branches of the network, in order to

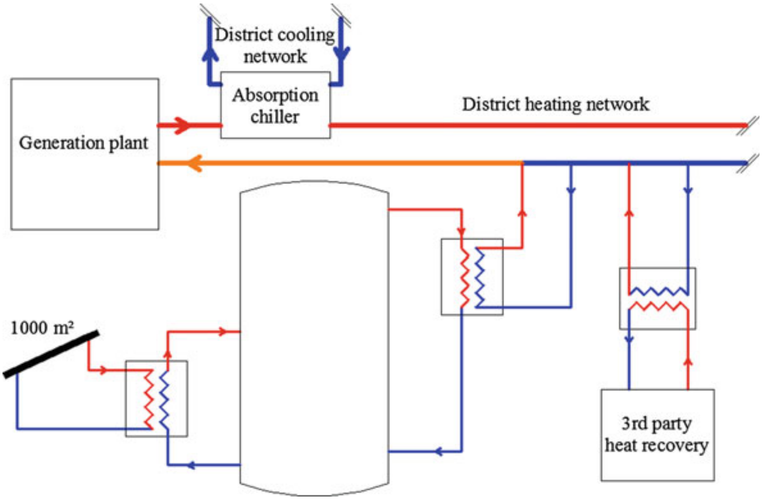

Fig. 4 Integration of the solar field in the network of case study C

reduce summer heat losses. It's not a solar integration though, but a case in which solar energy helps reducing DH losses and consequently fossil-fuel consumption. For every branch analyzed, the solar collector surfaces and storage volumes are dimensioned in order to fully cover summer loads, using district heating as a backup integrated in storage tanks (Fig. 5).

Fig. 5 Integration of the solar field in the network of case study D

Table 2 Solar energy performances

Case	Solar field (gross) (m^2)	Solar yearly yield (MWh)	Yearly solar fraction	Solar average efficiency
A	1,000	541	1.2 %	42 %
B	1,000	412	0.83 %	32 %
C	1,000	353	7.3 %	–
D	160 + 140 + 80 + 315	Tot. 180	0.5 % (av. ~50 % for single branches)	33 %

5 Energy Performances

Energy performances of the simulated solar integrations are described in Table 2.

The energy production for all the cases ranges between 300–500 kWh/m^2 per year.

It can be noticed that even with the same collectors' area and in the same climate conditions, the solar energy yield of case B is lower than the case A one because of the higher return temperature of the network and the consequent decrease of the collectors' performances. Looking at the solar fraction (SF) of case C, it is apparent that, considering the same convenience from the economic point of view of a collector surface of 1,000 m^2, the solar contribution here has much more impact because of the reduced network dimension and because of the absorption cooling system that enables better exploitation of solar energy. The "disconnection" of the buildings from the networks, thanks to the solar in case D, enables fossil-fuel savings for the district network: not only the amount for building needs, but also a big share of the network heat losses that these demands cause.

6 Economics of the Case Studies

Concerning the economic assessment of the case studies, the financial sustainability of solar integration in existing DH network (case A, B, C, D) is done by verifying the economic indicators: payback time, internal rate of return, and net present value of the investment (Duffie and Beckman 1992; Kandpal and Garg 2003). In order to reach more realistic results for these indicators, authors have asked utilities to perform the calculation of these indicators in order to be free to use their own internal and confidential parameters: fuel costs, customers' tariffs, and revenues for heat and power sold. Each utility has been given the solar costs:

- Incentive scheme: 55 €/m^2 of collector surface for 5 years, with a limit of 65 % of the investment cost (Conto Termico, Italian D.M. 2012).
- Collectors field: 350 €/m^2 aperture area for ground mounted; 700 €/m^2 aperture area for roof mounted (based on authors' experience and Nocera 2015; Fidanza 2015)

Table 3 Economic indicators of the foreseen solutions

Case	Load (GWh/year)	Solar field (m^2)	Cost of installation (€) (excl. incentive)	Payback time (years)
A	45	1,000	395,000 (solar field + ground)	~20
B	49	1,000	267,000 (solar field + pipes)	<10
C	5.8 heat 0.4 cold	1,000	352,000 (solar field + storage)	~10
D	36	160 + 140 + 80 + 315	536,500 (rooftop solar fields + storages)	>20

- Operation and maintenance costs: precautionary cost hypothesis of 1 % of the initial investment (Battisti 2013).

Considering a life time of 20 years, utilities involved the cases have calculated the previously mentioned indicators: payback time, internal rate of return, and net present value.

The results are summarized in Table 3.

Looking at the energy results and at the economic indicators for the centralized solar thermal cases, payback time results are shorter than 20 years, which is the solar collectors' lifetime. All the analyzed networks are fed by cogenerated heat, but because of the electricity market's adverse conditions, in particular in summer, solar heat enables reducing the use of gas boilers that are running instead of CHP, in the periods were the electricity price is too low. Case B has a particularly short payback time because, as mentioned before, the solar integration enables reducing the amount of steam bled from the turbine, with a double benefit thanks to the incentive provided to electricity through the green-certificates mechanism.

As can also be noticed, the need to buy the ground for the first case makes the investment much less interesting even if the payback time is shorter than the lifetime of the plant. On the other hand, looking at case study C, it is shown that the payback time decreases with the increase of the solar fraction: the utility has to face a higher investment cost, but the investment is much more interesting in terms of lifelong savings.

A negative consideration, looking at the energy results and at the economic indicators, is that the distributed solar fields' solution analyzed for case study D is not feasible in this particular case. Relatively high investment costs for small rooftop plants, and the fact that a certain heat price reduction for the customers must be applied as a reward for using building roofs, make the investment unprofitable, despite relatively high heat-loss savings along the analyzed peripheral branches.

7 New DH Network with ST

The last case study is about a feasibility case study of a new subnetwork. The heating company already operates an existing network, and it will serve a future neighborhood currently in a design stage in a city of the Lombardy region. The new area will be characterized by the presence of buildings with various intended uses: residential, offices, commerce, schools, etc. It is expected that the district will be at the forefront in terms of expectations for energy sustainability and energy performance for buildings, and consistent with the classes A (<29 kWh/m^{2}year) and B (<58 kWh/m^{2}year) (DR Lombardia n. 5796/2003).

With this background, solar heating can definitely be taken into account as a possible source of heat, being a technology that perfectly matches low-energy demand buildings with low-temperature heating systems and considering the surrounding, sloped, empty area of 20,000 m^2 that can be considered available for solar collectors. A second important reason for this choice is also in the outlook for networks in the future: the urban utility, like many other district heating utilities, looks to the future in order to fulfill the new directive requirement for efficient DH that affects the share of thermal renewables in district heating (2012/27/EU) (D. lgs. 102/2014).

7.1 Energy Load Estimation

In order to size the solar field and to simulate properly the hourly contribution of solar energy to cover new buildings' needs, the first step is the analysis of buildings' energy needs. An hourly energy-load profile is necessary: in order to obtain it, some simulations of "typical" buildings have been performed in Trnsys, and the energy results have been used to estimate the entire district-energy needs. The masterplan has provided preliminary information on buildings geometries and use zoning; some hypothesis on materials, properties, and internal occupations have been made in order to simulate energy performances in line with the labelling requirements (A and B), as it can be seen from Table 4.

Buildings simulations results follow:

- Heating needs: 7,000 MWh$_{th}$/year
- Cooling needs: 6,800 MWh$_{cool}$/year
- Domestic hot water needs: 7,000 MWh$_{th}$/year

Considering the needs and ground availability for solar collectors, the proposed solution is simulated with low temperature DH with 4,500 m^2 solar plant for heating purposes, space heating, and domestic hot water. The cooling loads are covered by individual chillers and consequently lie outside this work.

7.2 Case E—Solar DH—Central Plant 4,500 m^2

As mentioned in the previous paragraph, the solution proposed is to cover the heating needs of new buildings with a lower-temperature district-heating

Table 4 Hypothesis on buildings

Use	Gross floor area (m^2)	Average net height (m)	U_{opaque} (W/m^2K)	$A_{window}/A_{lat.\ env}$	U_{window} (W/m^2K)	Occupancy (n°/m^2)	Air change (m^3/h pers)	Internal gains (W/m^2)
Residential	185,626	20	0.22	35 %	1.40	0.04	40	10
Tertiary	62,132	25	0.28	45 %	1.40	0.07	40	15
Hotel	20,506	25	0.22	45 %	1.40	0.05	40	15
Commerce	105,500	10	0.32	20 %	2.00	0.13	25	30
Events	36,741	10	0.32	10 %	2.00	0.13	25	30

subnetwork (Olsen et al. 2014). After some preliminary analysis, the idea of using the "solar network" also for cooling purposes with reversible heat pumps was abandoned because of heat rejection predominantly in summer. A new DH subnetwork with a supply temperature of 70 °C, lower than the existing one, delivers heat for domestic hot-water production (produced at 60 °C to avoid Legionella risk in centralized storages) and low-temperature heating (radiant floor at 35 °C, fan coils at 50 °C, and AHU batteries at 50 °C). The subnetwork supply temperature is chosen in order to satisfy space heating and domestic hot-water production, being the last one the main design constraints. Lower temperature could have been considered in case of direct production of DHW without storage (Dalla Rosa 2012), different configuration than the one here analyzed. For cooling needs, each building is equipped with an air-cooled chiller.

A large solar-thermal plant is foreseen to maintain the subnetwork at 70 °C all year long. The existing DH network is used as a backup and is connected to the subnetwork through a heat exchanger in order to make the two networks independent of the hydraulic point of view. See Fig. 6.

The energy-performance results of the yearly simulation of the solar integration in Trnsys are:

- Solar energy yield: 2,100 MWh/year
- Solar average efficiency: 30 %

Considering the solar-energy production in the subnetwork and the share of renewable energy in the existing main district-heating network used as a backup and provided by waste and a heat pump, the total share of renewables in the subnetwork is 50 %.

The estimated cost of the solar integration is approximately €1.5 million.

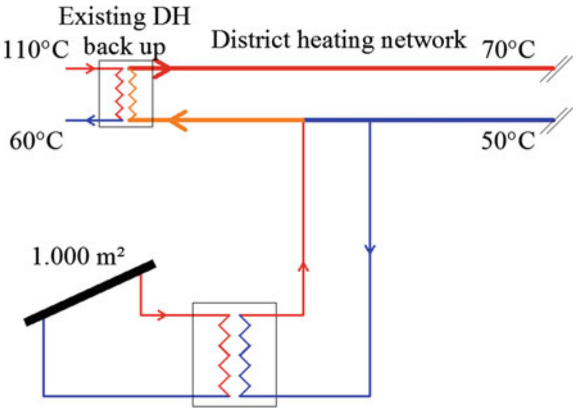

Fig. 6 Configuration for case E

8 The Urban Aspects of the Case Studies

As mentioned before, the main urban issues of a SDH plant is space availability and its characteristics: in the case of ground installations, the necessary area should be at list 2.5 times the collectors' area (Nielsen 2012) in order to enable proper distances and avoid shadow effects.

For all the cases analyzed which forecast centralized plants, some available space can always be found around the generation plant because of appurtenant tolerance of surrounding lands, enough to foresee the maximum incentivized surface of 1,000 m^2, but not enough to design a much bigger plant. In order to design a solar field with "Danish size" of several thousands of square meters, the utilities are often in the need of buying or renting surrounding land, often property of the local authority.

As for cases A and E: in both cases, a large free-ground surface surrounding the area concerned is available but owned by the local administration, so the estimated renting or buying investment can definitely have a negative impact on the payback time of the whole project. In both cases, from an urban legislative point of view, the surfaces are defined as non-constructible where only superficial excavation is possible because of the previously buried landfill. This makes them suitable places for a ground-mounted solar-thermal field, depending on how the local administration considers the construction of the solar plant. This is quite a common situation in Italian peripheral urban areas, often characterized by the presence of ex-industrial or ex-landfill land which are actually unused grass fields where no construction and no public green use is possible because of the pollution of the ground. Case B is interesting because it represents a common situation of the bad reputation of WTE and DH plants in the citizens' community. Thanks to the information collected in SDHplus through surveys circulated by Italian utilities, it is clearly evident that many utilities suffer from a bad reputation. The main causes are the generation systems, in particular, WTE incinerating plant or biomass burners, from antiquated technologies even if their systems have undergone big renovation and are currently in the best available technological configuration regarding gas emissions. The integration of "clean", zero emission systems as solar thermal is also considered by these utilities as a strategic integration to show their effort towards an environmental development that improves the reputation of their DH systems thanks to the green image of renewables.

Case D raises a complete different set of urban issues dealing with distributed solar integration.

In this case, roof mounting has been foreseen which implies private customer's relations more than urban issues, but nevertheless the possibility of installing solar systems on roofs is often subject to urban regulations on buildings.

Finally, case C is an interesting case of third-party heat recovery on the local territory. The utility recovers heat from a biomass CHP owned by a different actor. The same business model could be applied to solar thermal (Dénarié 2015) with a solar ESCO model.

Third-party heat recovery represents a great potential source of waste and renewable heat. In this process, heat planning and heat mapping could be useful tools to interject this kind of opportunity at the local level, identifying the territory of overlapping of heat demand and waste-heat recovery offer. An opportunity for local administrations to adopt this tool can be identified in 2012/27/EC and D. lgs. 28/2011 that ask the local community to perform heat planning and cost/benefit analysis of DH. In particular, georeferenced energy mapping is an important tool to identify energy synergy between generation and demand (Persson et al. 2014; Sansoni and Gussoni 2015).

9 Conclusions

The energetic and economic conditions of actual Italian district-heating systems, and the renewable-energy requirements and incentive schemes actually present, create a particular framework in which solar- thermal energy can see potential growth.

From the analyzed cases of integration of solar in existing networks, the incentivized maximum-solar surface of 1,000 m^2 has been considered for economic sustainability. Considering the high temperatures of the Italian DH networks, energy performances of simulated solar fields are in the range of 300–500 kWh/m^2 per year with collector's efficiency around 30–40 %. Payback-time values show that even when not so short, around 10 years on the average, they are positive and they decrease with the increase of the solar fraction. The case study on distributed-rooftop-solar plants turns out to be not economically interesting because of relatively high investment costs despite very interesting energy savings. In the case of new networks in newly constructed building areas, this is definitely an opportunity to find, starting from the master plan design phase, the proper location and space for solar thermal so that the DH network can be sized with lower temperatures.

The main urban issue of SDH plant is space availability. For all the cases analyzed that forecast centralized plants, some available space can always be found around the generation plant because of appurtenant tolerance of surrounding lands, enough to foresee the maximum incentivized surface of 1,000 m^2, but not enough to design a much bigger plant. In order to design bigger solar field and to have higher solar fractions, the utilities are often in need of buying or renting surrounding land, often property of the local authority.

What emerges after analyzing the urban legislative framework is that some urban tools from renewable-energy promotion are available in Italy, but they seem to lack consequent action measures, and they don't reflect concretely indications or requirements on how to reach these objectives.

Deeper heat planning and heat mapping is essential in urban design in order to promote and simplify the spread of large-scale renewable-energy plants.

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