Review of District Heating Systems in Italy for Future Enhancement

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Abstract: District heating (DH) is an energy service based on the centralized production of heat, and its supply to final users. Most DH networks are currently located in the Northern hemisphere, while very few are located in the Southern hemisphere. For what concern the European Union, most networks are operating in northerner and eastern countries. Italy, with less than 10% of the population reached by DH systems, has still a significant, but quite low, market share in the European context. The purpose of this review is to present the current situation of the Italian DH sector. The first introductory part concerns the historical evolution of DH systems in a global perspective. Later, the attention moves on the European situation, with focus on the system geographical distribution, the level of technological development, and the implementation of renewables. Italy still plays a marginal role because of climatic differences in the country, the complexity for some areas to access renewable energy sources, and the lack of interest in this technology showed until the 70s. The conclusions of this work underline a large untapped potential that DH systems have in Italy, requiring adequate investments and researches to enhance the use of renewables as energy source.

Keywords: District Heating; Italy; Sustainable Energy Planning; Smart Cities

1.Introduction

The word "district heating" (DH), according to Mackenzie-Kennedy (Mackenzie-Kennedy, 1979), is universally applied to the principle of the utilization of a central thermal source for the heat production and a network of pipes for the distribution of the produced heat to all the different costumers connected to the grid. The thermal source is usually a fossil fuel such as gas, coal or oil, but the production of heat for these kinds of systems can easily integrate renewable sources (RES). In 2012, DH provided 9% of the total hating EU needed for that year but using gas as main primary energy source (40%) and coal as second most used (29%) ('An Eu Strategy for Heating and Cooling', 2016). Recently, some RES have been found profitable for the production of energy for heating networks, and sources as geothermal wells, biomass and solar collectors started to enter in the DH businesses. The shift from fossil fuels to RES can be achieved also taking into consideration the use of waste heat from plants and industrial processes, in this way the primary merit of DH networks of providing heating at lower costs than fossil fuels is coupled with fulfilling European directives about lowering environmental impact and contrasting climate changes caused by fossil fuels.

DH is not a new technology for what concern accommodating heating demands: a pioneering example of the utilization of this principle existed already in the XIV century in Chaude-Aigues, a medieval spa-village in France, where a piping network distributed hot water from geothermal source to town's buildings (P. Raynal, J. Gibert, 1992). In modern times, the world's first commercial system was developed in Lockport, New York in 1877. This system used a central boiler plant in order to provide steam to few neighbor houses and small businesses. By the end of the XIX century DH systems were gaining popularity and in a short time frame numerous small city and industrial centers in the northeast of USA started to install such systems to support local development and people's heating demands.

The network created in Lockport inspired the first European commercial heat distribution systems developed during 1920s in German cities. However, already at the turning of the XX century in Dresden a steam based DH system was initiate to supply heat to priority government buildings in a convenient and practical way and at the same time to reduce fire risks linked to on site generation plants (Council, 1985b).

In the years between 1920 and 1940, the idea of passing from single decentralized heating system to a DH network spread across the European continent. The already existing networks in various German cities (i.e. Dresden, Hamburg, Kiel, and Berlin) became examples for new installments in cities like Copenhagen (1925), Utrecht (1927), Paris (1930), Brno (1930), and Zurich (1933) (Collins, 1959).

After these first examples, DH experienced a considerable development after the end of World War 2. The need of providing the continent with new housing and services after the destruction caused by the war enhanced the possibility for developing networks to deliver heat to the newly built neighborhood. In the 50s extensive networks were laid down in Scandinavian countries (i.e. Finland, Norway and Sweden), Denmark; Germany and in the ex USSR, where in 1976 almost two-third of all the buildings were connected to DH network (Mackenzie-Kennedy, 1979). In the 70s, the oil embargo proclaimed by the OAPEC (Organization of Arab Petroleum Exporting Countries) pushed European countries to improve their energy efficiency further to reduce their dependence on imported oil. In this scenario, both central and local government started to award loans, grants and subsidies to encourage the sprout of new heating network systems (Council, 1985a).

2. An overview of Europe

Heating and cooling in industries and buildings represent half of the energy consumption of the European Union (EU). They account for the 50.7% of the final energy consumption, corresponding to 561.3 Mtoe of the total 1,107 Mtoe consumed by Member States (MS) in 2016 ('Review of Available Information on an EU Strategy for Heating and Cooling', 2016).

European households use the 79.2% (222.7 Mtoe) of their total energy use for heating and domestic hot water. Even if it represent a small share of the total final energy use, cooling need to be added to the energy use count, with its 0.8 Mtoe, it affects just for the 0.3% (*Energy consumption in households - Statistics Explained*, 2015). For what concern industry, 70.3% (196.9 Mtoe) of the energy is used for heating and industrial processes, 26.7% (74.8 Mtoe) for electrical processes and lighting, and 2.7% (7.6 Mtoe) is used for cooling (*Heating and cooling - European Commission*, 2013).

As for the last available data, in 2016 still 85% of the total amount of energy needed for heating and cooling was provided by employing fossil fuels, while just the remaining percentage was generated using renewable energy sources. To reach the targets set within the EU 2020 Climate and Energy Package, the emissions caused by fossil fuels and the energy consumption for heating and cooling need to be reduced as much as possible. For this reason, in 2016, the European Commission (EC) launched its first plan to curb energy use and boost RES use in heating and cooling for Europeans households, service sector buildings and industry sector. The strategy includes plans to ease the processes to renovate buildings, guidelines for retrofit projects and modernization of the already existing district heating and district cooling (DC) networks or creation of new networks with the integration, in both cases, of electrical systems ('An Eu Strategy for Heating and Cooling', 2016).

Although EC's plans for the developing of DH systems in Europe are quite recent, the old continent is one of the places where the highest number of DH network are located (Figure 1). It is a wide spread technology across the whole continent with more than 10,000 different networks installed just in the countries part of the EU27 (Euroheat & Power, 2013)

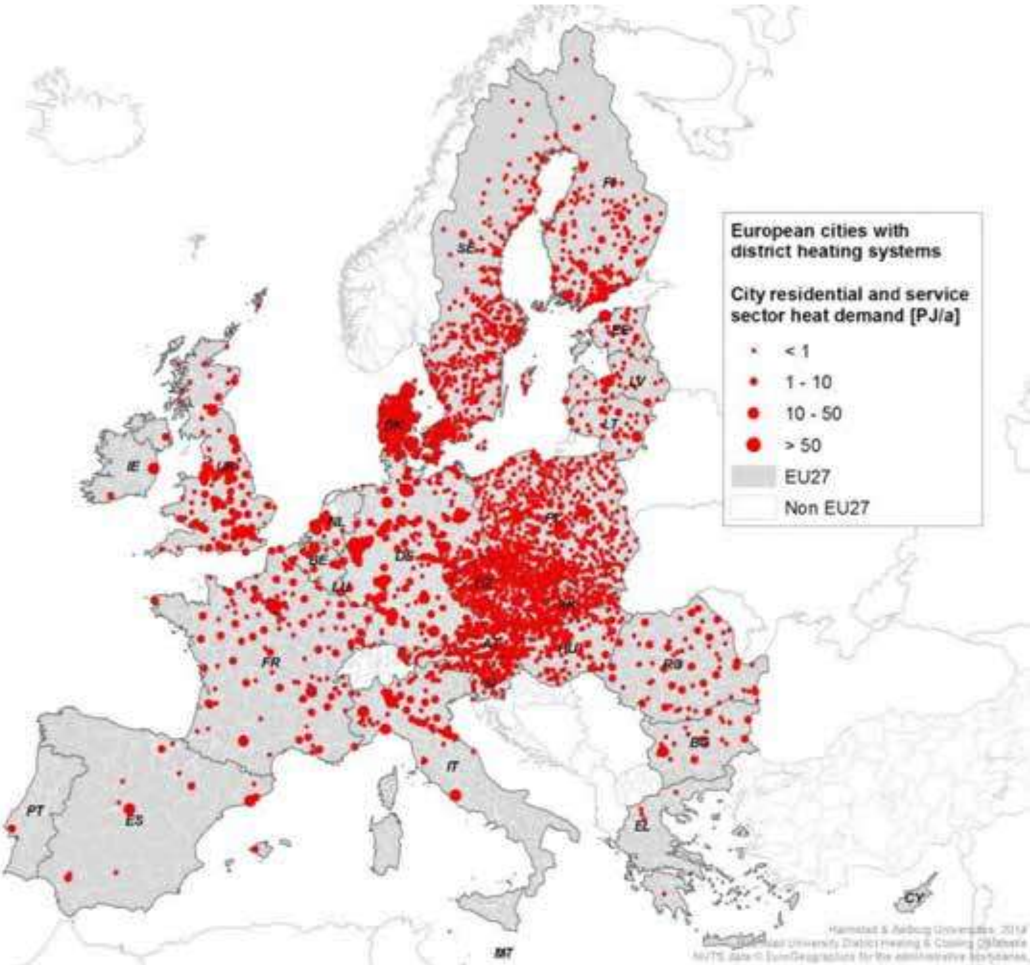


Figure 1 - Map showing European cities with DH systems and heat demand for each system (from Halmstad University District Heating & Cooling Database)

Historically modern DH systems came in Europe after experiencing a technological development in the US because of the commercial nature given to this type of systems in their first applications. However, in EU it experienced a development and expansion different from what would have happened in the US. In the latest nineteenth century, several small systems found application in Germany, mainly in cities where outdated hating systems were replaced by DH systems to reduce fire hazards in historical building containing art fortunes (Frederiksen and Werner, 2013). Scandinavian and Baltic countries and Central Europe present a higher degree of DH systems expansion since from the beginning of the twentieth century environmental and energy independence aspects were held in high consideration: the use of MSW in conjunction with coal was a common practice in cogeneration plants. Furthermore, planning practices in Nordic cities used to establish incinerator facilities close to residential areas in order to serve heating in a better way to the housing complexes. The climatic characterization is another important aspect: with its long and cold winter, Central and Nordic Europe have a high heat demand index, this aspect affected the policy makers and private energy societies pushing them to invest into expanding and improving the existing systems (Biele *et al.*, 2014). The oil crisis in the 70s, and the consequent inflation of the oil price promoted by the OPEC (Organization of the Petroleum Exporting Countries) had a devastating effect on the heating sector in the EU. It was not until this time that European countries started to realize the importance of developing regulation for the promotion of sustainable energy sources and the development of alternative systems to single building heating devices. In this situation heat prices were regulated by involving the government in keeping them competitive in the status quo (Amos, Hutchinson and Denman, 1996). As the time passed and the heating demand from the DH grid improved this system first became competitive with traditional heating systems and in the time, it become even more performing justifying initial investments and government involvement. The aforementioned conditions made possible to have a huge expansion of the DH networks in Scandinavian, Baltic and Central European countries (Mazhar, Liu and Shukla, 2018).

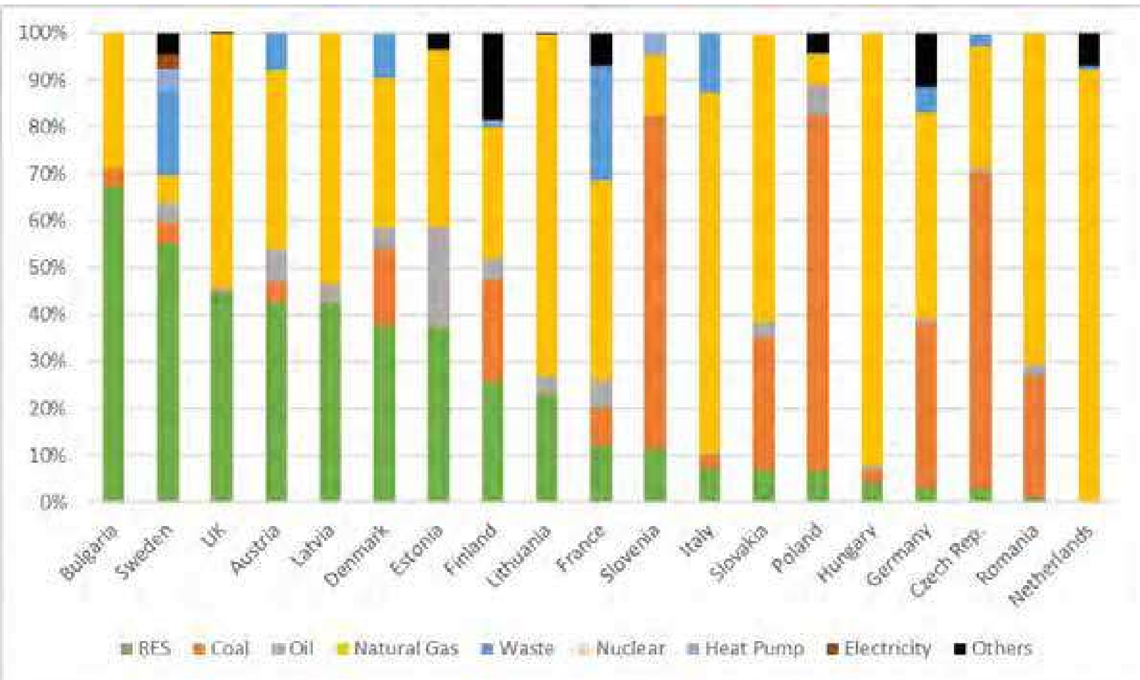
For these reasons, a high share of DH applications for residential buildings characterizes Central and eastern EU regions. The success of these systems happened mainly in urban areas where there are reserves of local sources for the production of heating; also, the cost of DH is highly dependent on the scale of the network. If the density of buildings and heat demand is high then this type of technology is more economical compared to others (Persson and Werner, 2011). This context is not so common in southern European regions where the dominant energy sources are gas and fuel oil and the density of buildings is lower, an exceptions of this considerations are cities: in countries where climate is more temperate the majority of DH systems can be found in densely built-up areas (Sayegh *et al.*, 2017). Urban areas represent an untapped potential: 50% of the demand for heating in Europe is located in areas with a similar heat density to those areas already connected to a DH system. Exploiting this potential by means of district network will increase the share of European demand satisfied di DH systems, that in these days is stationary at around 10% (International Energy Agency IEA, 2017).

In pre-expansion EU countries, there is a more limited use of coal and a slight increase in the use of natural gas and renewable sources, the latter result from the policies of energy containment and environmental protection. However, in the countries of Central and Eastern Europe, new small production units have been commissioned using natural gas. The use of natural gas as a fuel has increased mainly in Austria and the Netherlands (the latter is a producer). In some of these countries, the problem of the monopolistic presence of a single natural gas supplier provokes rigidity in the primary energy supply system.

Despite this, the use of renewable sources in the territories favored by particular environmental conditions has increased, with the largest increase still being in Austria, Denmark, Finland and Sweden. Coal is the most used fuel in the DH of the newly acquired EU countries with an average of 50% heat produced with this energy source (Euroheat & Power, 2013, 2015).

Considerations previously done emerge from Table 1. The countries that have a higher share of RES for supplying DH systems are from Central, Eastern, and Nordic Europe, but in this case, data are quite fragmented and mostly focused on CHP generation for district systems. In these cases, RES share in producing heat for DH are higher than 30% and the country relies on a quite differentiate energy portfolio: there is not a predominant energy source.

Table 1 - Energy sources used in some European countries to fuel DH systems

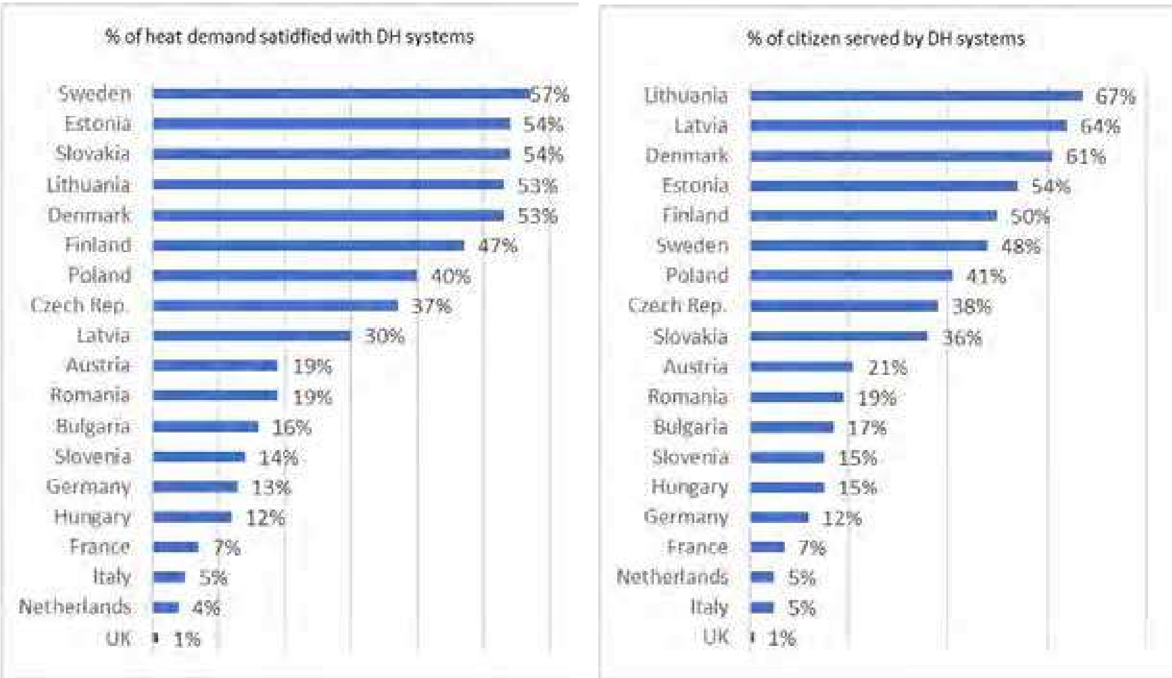


In Central and Northern European countries, the environmental conditions, which are reflected in a high number of degree-days (above 3,000), have led to the development of district heating in the residential sector. The most significant percentages of the presence of district heating in some European countries are as follows: Iceland 95% (not an EU country), Lithuania 67%, Latvia 64%, Denmark 61%, Estonia 54%, Finland 50%, Sweden 48%. In Southern countries as Italy and France there are significant shares in some regions (up to 10% of the heat market) (Euroheat & Power, 2015).

Table 2, instead, presents the percentage of heat demand satisfied by DH systems and the percentage of people served by district systems, data for these tables are taken from Euroheat and Power surveys on European DH systems (*District Energy in Bulgaria | Euroheat & Power*, 2013; *District Energy in Latvia | Euroheat & Power*, 2013; Euroheat & Power, 2013).

Presented scenarios in DH systems and their differences in European countries confirm that it is hard to create a universal action plan for all EU members to implement and enhance district energy systems, each EU country should have an individual analysis that should take into consideration their own peculiarities. In the next paragraph, the focal point of the work will be the Italian current situation on DH systems.

Table 2 - Percentage of heat demand satisfied by DH systems and the percentage of people served by district systems

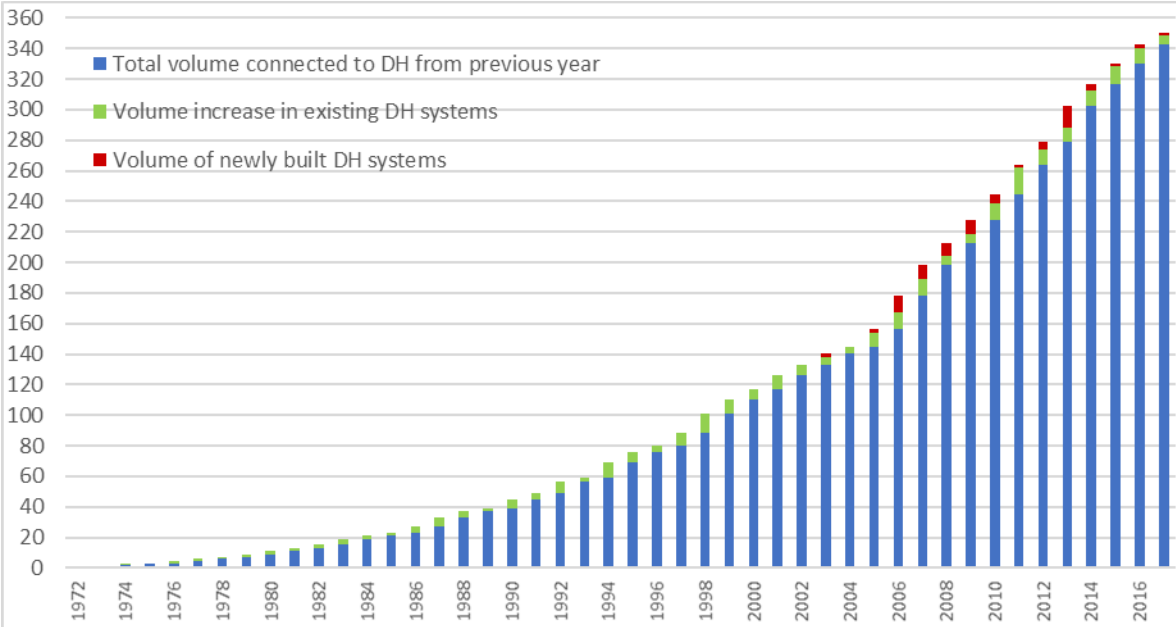


3. The Italian situation

The development of DH networks in Italy started in the 1970s, following the examples of other European and extra-European countries that invested in studying, testing and evolving this particular technology. Specifically, the technology flourished in the north part of Italy after the planning and construction in 1971 of the first DH in the city of Modena (International Energy Agency IEA, 2016). The length of the considered network is of about 10 km and assures the distribution of the heat produced by 4 gas fired boilers, installed in 2015 in substitution of the outdated diathermic oil boilers, to both residential and tertiary buildings. After this first experience in Modena other examples raised before the 80s in new cities: in Brescia (1972) 378 km of piping network supplied by 3 steam turbines, a municipal waste incinerator, and a cogeneration plant. Verona followed in 1973, when a cogeneration system using a gas engine was built to provide heat for a network of 79 km of pipes, Mantua (1978) in which a cogeneration plant provides heat for a network of 65 km, and Reggio Emilia (1979) a network of 213 km supplied by a gas turbine and a cogeneration plant (AIRU, 2017).

During the 1980s and 1990s, other cities adopted DH systems following the success obtained by the pioneer developers in reducing energy costs and CO_2 emissions, passing from 15 Mm^3 of heated volume in 1980 to 45 Mm^3 in 1990. This trend was not about to stop here. Table 3 shows that between 1990s and 2000s, the heated volumes attached to DH networks had more than doubled arriving to 110 Mm^3, showing an increment rate of 12% per year. The increment rate continued to increase even after 2000s: in 2010, the heated volume by DH was 250 Mm^3 with an estimated 200 networks working mainly in the northern part of Italy. The last available data is from 2016, at the end of that year, 235 networks were operating in Italy, providing heat for more than 340 Mm^3, showing again an increasing interest for this type of heating supply technology (Bottio *et al.*, 2015; AIRU, 2017).

Table 3 - Increase in the amount of volumes connected to DH system in Italy from 1972 to 2017



3.1 Geographical distribution

However, the interest in this type of technology is not equally distributed in all Italian regions. With a deeper analysis at the site where DH plants are located, it is clear that most of the DH networks are in norther Italy with about 200 out of the 236 total existing networks located in norther regions of Italy (Valle d'Aosta, Piedmont, Liguria, Lombardy, Trentino Alto Adige, Veneto, Friuli Venezia Giulia, and Emilia Romagna) (Figure 2). In support of this consideration, it is possible to state that almost the total amount of the volumes heated with a DH network can be found in 4 norther regions: Lombardy, Piedmont, Emilia Romagna, and Trentino Alto Adige. These regions account for 96% of the total heated volume that corresponds to 300 million of m^3.

3.2 Networks extension

Considering now the extension of the networks, which supply hot water for the heating of the connected volumes, in the past 15 years it has become 4 time larger than it was in the early 2000s. The total extension at the end of 2016 was 4,270 km. Thanks to a series of investments from local policymakers and stakeholders, the expansion of the piping net for DH systems in Italy, between 2000 and 2016, grew of 193 km per year. In the period after 2010, the yearly increase rate was of 250 km per year, thus demonstrating the great importance that this kind of heating system was, and still is, gaining in the Italian heating sector.

However, since 2013 the number of new connections is constantly decreasing. In 2016, the increase in the connections' number reached 12.5 Mm^3, a value 1.1 Mm^3 lower than the one recorded for 2015, and this trend is likely to continue in this way. In fact, when considering the heated volumes in direct relation to the network's extension (called linear density of users), it is possible to observe that this

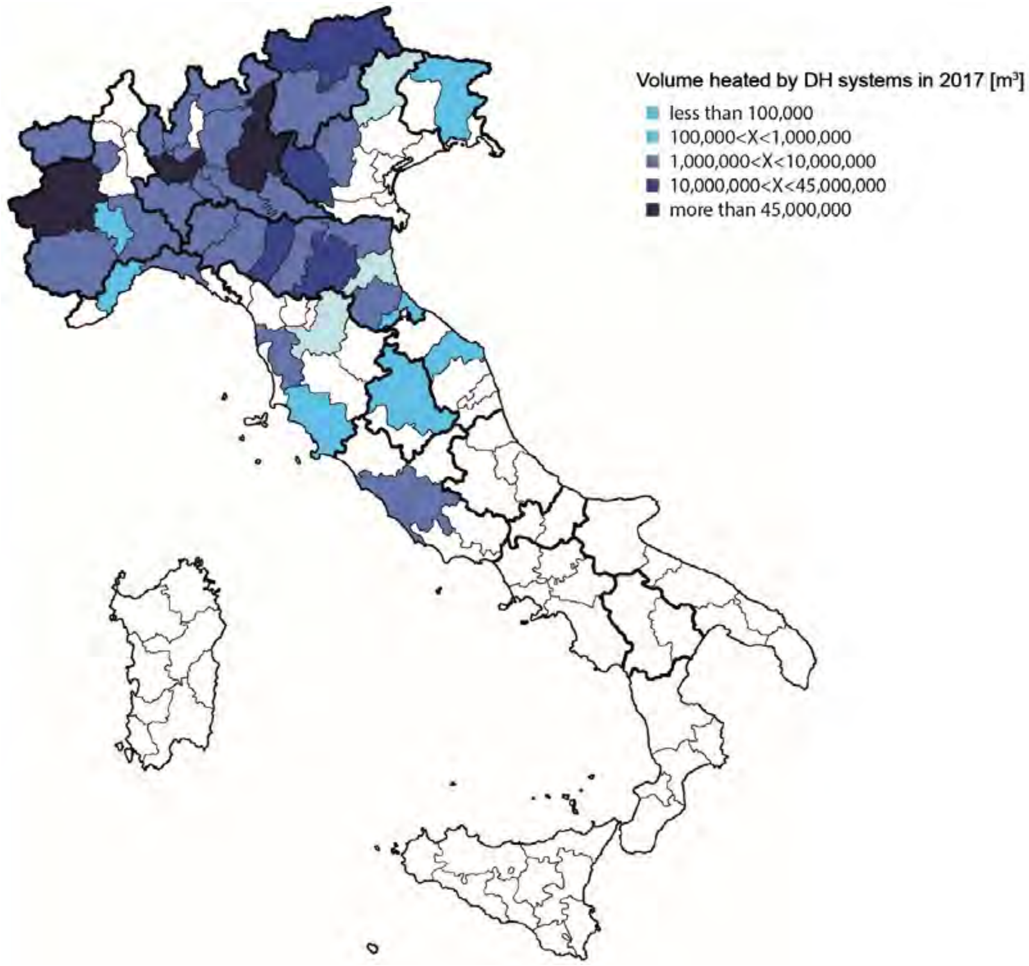


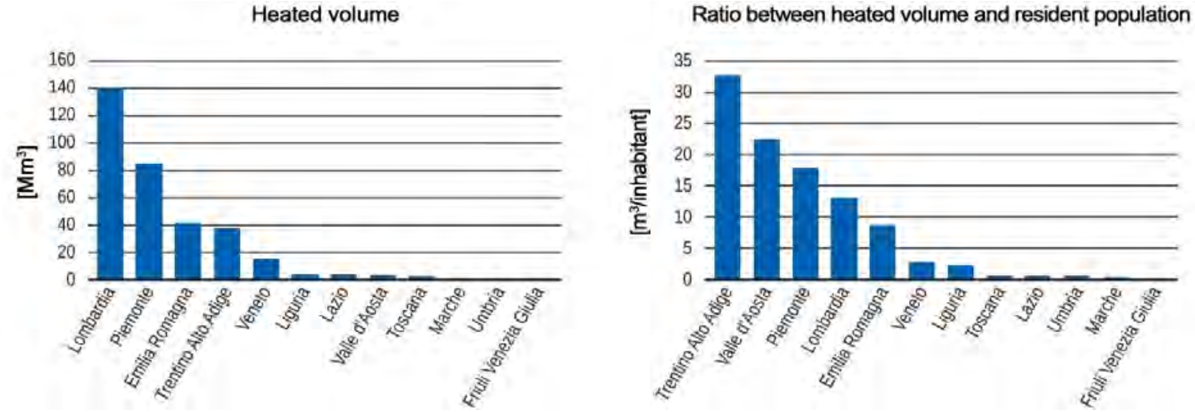
Figure 2 - Volume heated by DH systems in 2017 for each Italian province

particular datum is decreasing year after year. In the last years, the diffusion of DH systems happened mostly in low-density areas, such as rural zones, mountains villages, and small dimension communities. Nonetheless, at the end of 2016 the total volume connected to DH networks was 342.3 Mm^3, a value doubled in the last 10 years (in 2006 the total heated volume was 177.3 Mm^3), representing a yearly increment equal to 6.8%. As state before the diffusion of DH systems is mostly a trait of norther regions of Italy. This strongly emerge when taking into consideration the ratio between buildings reached by DH and the residing population: the region in which the DH has most diffusion is Trentino Alto Adige with 36.2 m3/inhabitant, followed by Valle d'Aosta with 24.8 m^3/inhabitant (Table 4).

3.3. Energy sources

For what concern the energy production in the DH systems, in Italy the most widely used technology is cogeneration systems fired by fossil fuels, particularly more than 1000 MW_t come from thermoelectric power plants, and more than 950 MW_t come from dedicated cogeneration plants that produce also about 800 MW_e. Another type of cogeneration system, which does not rely on fossil fuels, is powered by incineration of municipal solid waste (MSW) and it is responsible for more than 550 MW_t, even if just 13 networks present this type of technology installed. In the last years, cogeneration systems started to include bioenergy derived from biological sources as primary energy,

Table 4 - Heated volume (left) and population reached (right) by DH systems in Italian regions in 2017



reaching 250 MW_t and almost 90 MW_e, but still, these types of biological energies are mostly used as fuel for boilers, producing 370 MW_t at the national level.

As stated in the previous paragraph, a mix of different energy sources is used to create the necessary power for the functioning of the DH systems in the Italian territory. The most widely used vector is still natural gas that represent 71% of the total input, equivalent to 1,313,657 toe, showing that non-RES are still the most used systems to supply energy to power DH systems. The second most used are now MSW, which include both biodegradable and non-biodegradable fraction of municipal waste. In the last 10 years this kind of source passed from representing just a small portion of the total energy mix (1.2% in 1995) to be a quite important representative in the use of RES for the DH in Italy: now it is responsible for 13.7% of the total primary energy used.

Another example on the transition from a fossil fuels-based society towards a greener and more sustainable one is proved by the rise in the use of bioenergy (i.e. biomass, biogas, and bio liquids) for the energy supply in the DH systems. Since 1995, when bioenergy was not used at all, the works done in order to provide cleaner energy vectors for DH systems flourished. In this background made of building new systems and updating and adapting existing ones, bioenergy sources became the third largest energy source used for DH, being responsible for 9.3% of the total amount. For what concern other RES types, energy mix data highlight a positive trend in the use of geothermal sources. The last 10 years prove the interests in this kind of technology: thanks to the inauguration of new plants, the percentage increase was significant passing from 0.8% in 1995 to 1.3% in 2016; however, its full potential is still untapped. Similar considerations can be done for the use of solar collector: only one example of this technology exists in Italy and still it is a young experience with just a one-year lifespan, but this bear witness of the interest that Italian stakeholders have in the use of RES for district systems. Even though this trend is diffuse for almost every kind of renewable source, a different tendency characterized industrial energy recovery processes. During the 90s, the use of this type of process was quite common in most systems that used RES, since it was a first try in finding non-fossil fuels suitable for energy network systems. During the following years, new type of clean energy vectors came up on the market establishing a decrease in the use of recovered heat and energy from industrial processes. In the last survey, this very energy source counted just for the 0.1% in the primary energy mix.

In parallel with the increase in the use of renewables, fossil fuels experienced a decrease. In 1995 gas oil and heating oil were the second most use primary energy source with a 14.3% share, and coal was in the third position being used in 12.5% of the cases, showing the low interest that was placed in the implementation of sustainable energy. During the last 10 years, the situation changed: coal is now responsible only for 2.6% of the total and the use of gas oil and heating oil almost become insignificant, representing just the 0.1% in the primary energy mix.

A different argument concerns fossil energy used in the national electrical system (NES). In this case, the transition towards sustainable energy sources is still not implemented, and fossil fuels are still widely used to produce energy for the NES networks.

To sum up, in Italy the thermal energy produced by fossil fuels-fired cogeneration plants constitutes 50% of the total energy that flows in the network; 23% is produced by the use of simple boilers that help integrate the energy production during high demand periods. These appliances are powered by fossil fuels, making 73% of the energy that flows into the network produced by non-renewable sources. Energy produced by the use of RES such as cogeneration from renewables, energy recovered from industrial processes, heat pumps, and other technologies constitute the remaining 27% of the produced thermal energy (Bottio *et al.*, 2015; AIRU, 2017, 2018).

The future of the development of district heating in Italy reside in developing and investing for the transition to RES-based DH systems. The same can be said for the entire EU. Usually in the reports where it is mentioned, DH is not seen having a major role in the future decarbonization of European cities. The International Energy Agency (IEA) instead has a different opinion regarding this topic. In its reports from 2012 entitled "Energy Technologies Perspectives", one of the most important line reads: "Heating and cooling remain neglected areas of energy policy and technology, but their decarbonization is a fundamental element of a low-carbon economy" (International Energy Agency IEA, 2012; Frederiksen and Werner, 2013; Averfalk and Werner, 2017).

4. Energy management in Italy

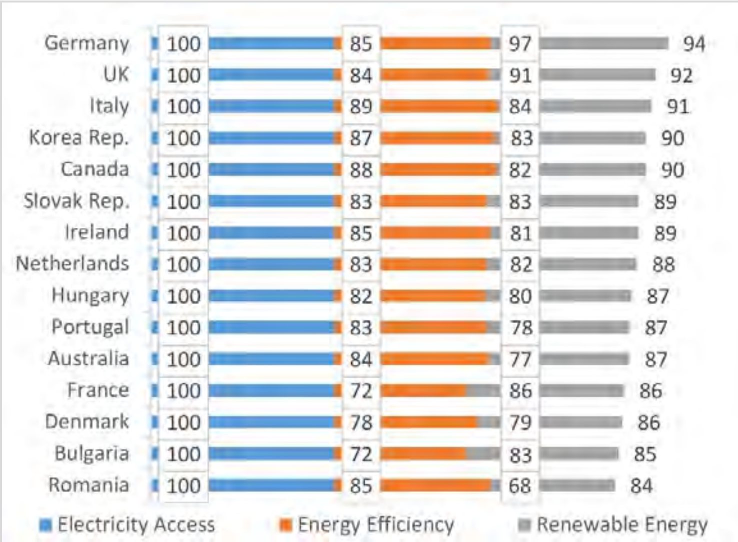
Every year the International Bank for Reconstruction and Development, a branch of The World Bank, compiles a report about global progresses on sustainable energy policies, showing the importance of a planned strategy for the transition to sustainable-energy based communities. This document goes under the name of "Regulatory Indicators for Sustainable Energy" (RISE) and it rates 133 countries, representing 97% of the world's population, on electricity access, renewable energy, energy efficiency, and access to clean cooking in the period from 2010 to 2017. The latest draft of this document was edited in 2018 and it finds that the whole world has seen an increasing interest and huge uptake in what concern sustainable energy policies, but there's still more road ahead: progress is far from where it needs to be to reach global climate goals and Sustainable Development on Energy (SDG7) (*Regulatory Indicators for Sustainable Energy 2018*, 2018; United Nations, 2018).

RISE analyzes the adequacy of the policies for a sustainable development and investments in green energy solutions through three pillars: RES, energy efficiency and access to energy, and it has done the same for Italy, but since the Italian peninsula is one of the High-Income OECD countries this last pillar is not considered, assuming that the situation for this aspect is already adequate.

The data collected for the latest report give a positive image for Italy. Table 5 shows the results for the year 2017: the country position itself in the third spot with a total score of 91 out of 100, 5 points higher than the mean value for OECD countries, and after Germany (94/100) and United Kingdom

(92/100), but the most important datum is the one about energy efficiency. In this category Italy position itself in the first place on the list: its attention for national plans for energy efficiency, minimum energy efficiency performance standards, and energy labelling systems for appliances and buildings made possible for Italy to reach the first position in this list, but there are also some less positive results. Italy needs to improve its policies about information provided to consumers and end users about energy usage for heating and electricity and how to achieve savings and avoid energy wastes, and there's still work to do about improving and make the access easier to incentives for industrial and commercial sectors in switching to RES-based activities (*Scores | RISE*, 2017; *Regulatory Indicators for Sustainable Energy 2018*, 2018; ENEA, 2017).

Table 5 - First 15 countries in RISE 2017 list. 12 out of these 15 Countries are in Europe



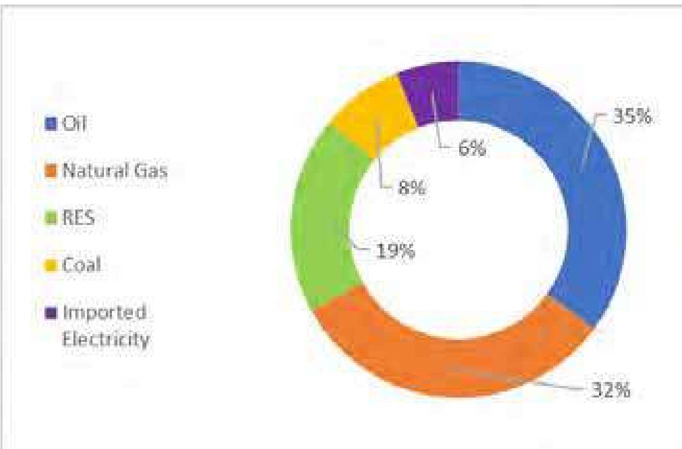
According to the parameters and analyzes of the World Bank, Italy does not seem to show a bad political-regulatory framework for the investments in renewable sources and energy efficiency. Indeed, in many cases the regulations in force are in line with international best practices and even more advanced than those adopted in other OECD countries. What perhaps penalizes investments in Italy and creates the basis for a less positive perception of the situation in the country is the implementation of this political-regulatory framework, which not always is as adequate as the legislative decree. Moreover, the uncertain political context, with its unfavorable situation for potential investments seems to have an even higher negative impact (ENEA, 2018a).

To reach the objectives set by the EC for the reduction of harmful emissions and use of energy, Italian policy makers developed *Strategia Energetica Nazionale* (National Energy Strategy) or *SEN*, a ten years policy document intended as a general guidance and planning tool for the national energy strategies; the aim is to indicate the priorities for the short and the long term to achieve the promotion of renewable sources and energy efficiency (Ministero dello Sviluppo Economico and Ministero dell'Ambiente e della Tutela del Territorio e del Mare, 2017).

Following these directives Italy has reached European targets in advance, with a 17.5% penetration of RES over total consumption by 2015 compared to the 2020 target of 17%, and important technological advances have been made that offer new possibilities to reconcile the containment of energy prices and sustainability and by 2030 the share of renewables on the total energy use is expected to be at least 27%. To make this prevision possible the policy makers are proposing interventions in various categories such as the use of RES on electricity production, founding programmes to switch fuels to biofuels and most important develop the potential of urban and extra-urban DH systems according to efficiency criteria (*Ecco la Strategia Energetica Nazionale 2017*, 2017; ENEA, 2018b).

To tackle the objective of energy efficiency, from 2021 to 2030 there's the need for a reduction of the consumption of about 9 Mtoe primarily in the residential and in the tertiary sectors, to do so SEN identifies a series of actions. They are all focused on the importance of giving founding for renovation of the existing building stock both from an building point of view and from energy systems aspects, higher the standards for new buildings, promotion of energy efficiency measures also at local levels and switching to sustainable energy sources, but this last aspect, as we can see from Table 6 still need to be implemented, being oil and natural gas still the mostly used fuels in Italy (Ministero dello Sviluppo Economico, 2017; Ministero dello Sviluppo Economico and Ministero dell'Ambiente e della Tutela del Territorio e del Mare, 2017).

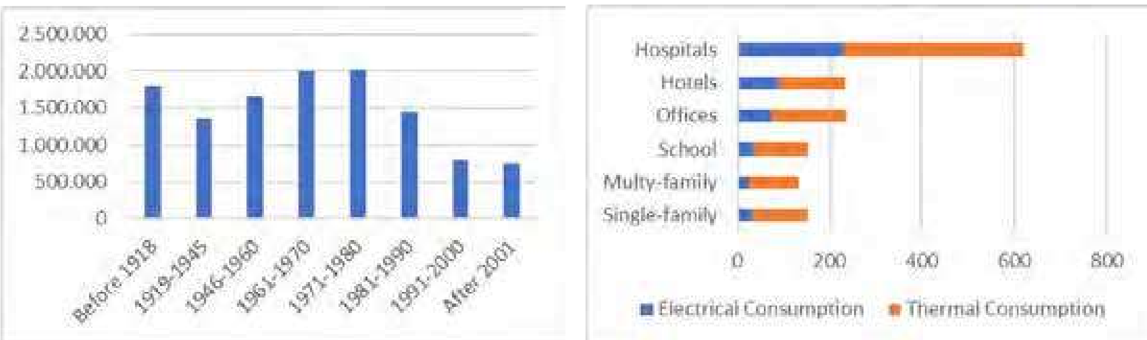
Table 6 - Type of fuels used in Italy in 2016 for heating and electricity production



5. Housing stock and consumption

In Italy there are around 31 million houses and 14.5 million buildings, and 84% of them (12,187,698) are housing complexes. These residential units were mostly built before 1976, year in which the first energy saving law came into effect. As Table 7A shows, 65% of the residential complexes used today date back before 1980 and 15% more were built before 1918 (*Edifici residenziali*, 2015).

Table 7 – A (left) shows the construction year of residential building in Italy; B (right) depicts the electrical and thermal consumption for building categories in Italy



In the residential sector the mostly use energy source is natural gas which is responsible for 47% of the total energy consumption, equivalent to 30 Mtoe; electricity and wood are both responsible for a little less than a quarter of the total. Consumption in the non-residential sector has experienced continuous and strong growth over the years, held back only by the economic crisis of 2008, reaching around 20 Mtoe in 2013.

Energy consumption for the heating and cooling in residential spaces absorbs about 76% of total consumption, a value that has grown in recent years. Consumption for lighting and electrical appliances, like food preparation and domestic hot water (DHW), is almost constant over time (Table 8 and Table 9). But there are differences for what concerns other sectors: in health establishments, offices, and tourist accommodations, the electrical consumption is almost as high as the thermal (Table 7B). This derives from the high number of appliances and instruments that work thanks to electrical energy. Even though in the recent years the shares of RES used for electricity production increased considerably, thanks to the importance given since the 50s to hydro generation and the growth of sources like solar, wind, and geothermal, still there's work to do in order to make the electricity production in Italy greener: the first two sources used are natural gas (39%) and coal (17%) (International Energy Agency IEA, 2016; Portale 4E, 2016).

Table 8 - Shares of primary energy sources used for heating and cooling in the residential sector

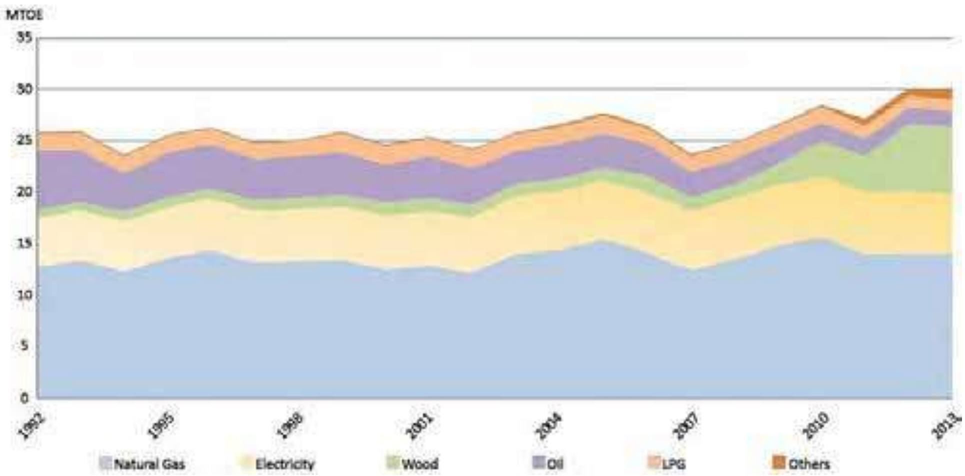
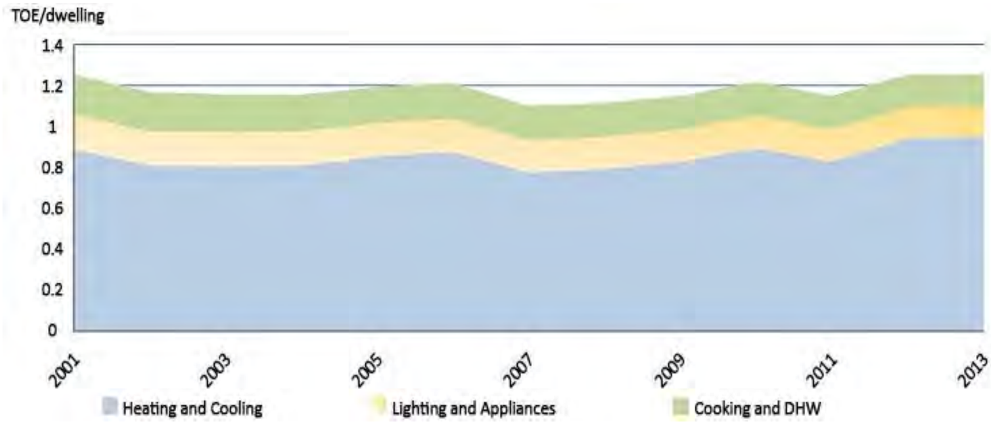


Table 9 - Energy per dwelling used for heating and cooling, lighting and appliances, and cooking and DHW in the residential sector



6. Conclusions

In the previous paragraphs the European and Italian situation regard DH systems was described, after that we saw how network systems, even if not so spread in all the Italian territory, can still play an important role in the reduction of energy use towards a more sustainable future.

For what concern Italy we saw that the expansion of DH networks in the country is still limited to few examples and most of them are located in the norther regions and in mountain areas. This is mainly caused by the climatic differences that divide the country: DH are used mainly for heating reasons and supported by small appliances for DHW located in the single dwellings or in the single apartment block. This division creates a seasonality in the use of DH that makes the investment for the construction of new networks an investment that does not seem smart. Moreover, the fact that generation for district networks systems are still focused on heat, and not combined heat and power doesn't provide a strong motivation in starting works for developing network solutions in areas where heating demand are just focused in small period of time and, instead, demand for electricity is higher because of the hot climate. Regarding this consideration, "established expertise of district heating has paved the way for introduction and deployment of district cooling systems, mainly for covering space-cooling demands in buildings. However, this district cooling development has been more recent compared to the development of district heating. District cooling systems are therefore neither as common nor as extensive as district heating systems" (Werner, 2017). Being Italy still in the development of vast scale networks for heating, is difficult to imagine that district cooling system will make their way to the top priority works for energy consumption reduction and CO_2 savings without a proper support from researchers and institutions.

Technologies analyzed in this paper, regarding how power is produced show that Italy still rely too much on fossil fuels, being oil and natural gas the two most used sources, and the fact that in the SEN still a major importance is devoted to the use of natural gas in the next years, denote the lack of effort that the institutions are giving in try to find alternative renewable sources with which change the current trend.

This is not enough though. To reduce consumption, energy requalification interventions must be planned on buildings, starting from public building stock such as schools, hospitals, and offices without forgetting about housing complexes. With the same goal, it is necessary to reduce the consumption of primary energy: to do this the spreading of district heating technologies is forecasted.

A reduction on the final energy consumption can be done not only by fostering retrofit works, but also with a rational use of all energy sources and investing on the use of RES in every sector. Subsidies need to be granted in order to increase the share of electricity produced by RES and decrease the number of decentralized energy systems. The same goes for thermal energy: the goal set by SEN in 2017 of reaching 16 Mtoe produced by RES in 2030 passes by a high increase in the use of geotherm sources, heat pumps, solar systems, but mostly through an advancement in the number of biomass-fueled systems in the residential and tertiary sector and the development and spreading in the whole Italian territory of high performance DH networks.

The challenge outlined above is so demanding that, to be successful, it will require the contribution of all the technologies available today, and from now on until 2030, without exceptions (*Come l'Italia può raggiungere gli obiettivi rinnovabili al 2030. Report Free*, 2017).

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