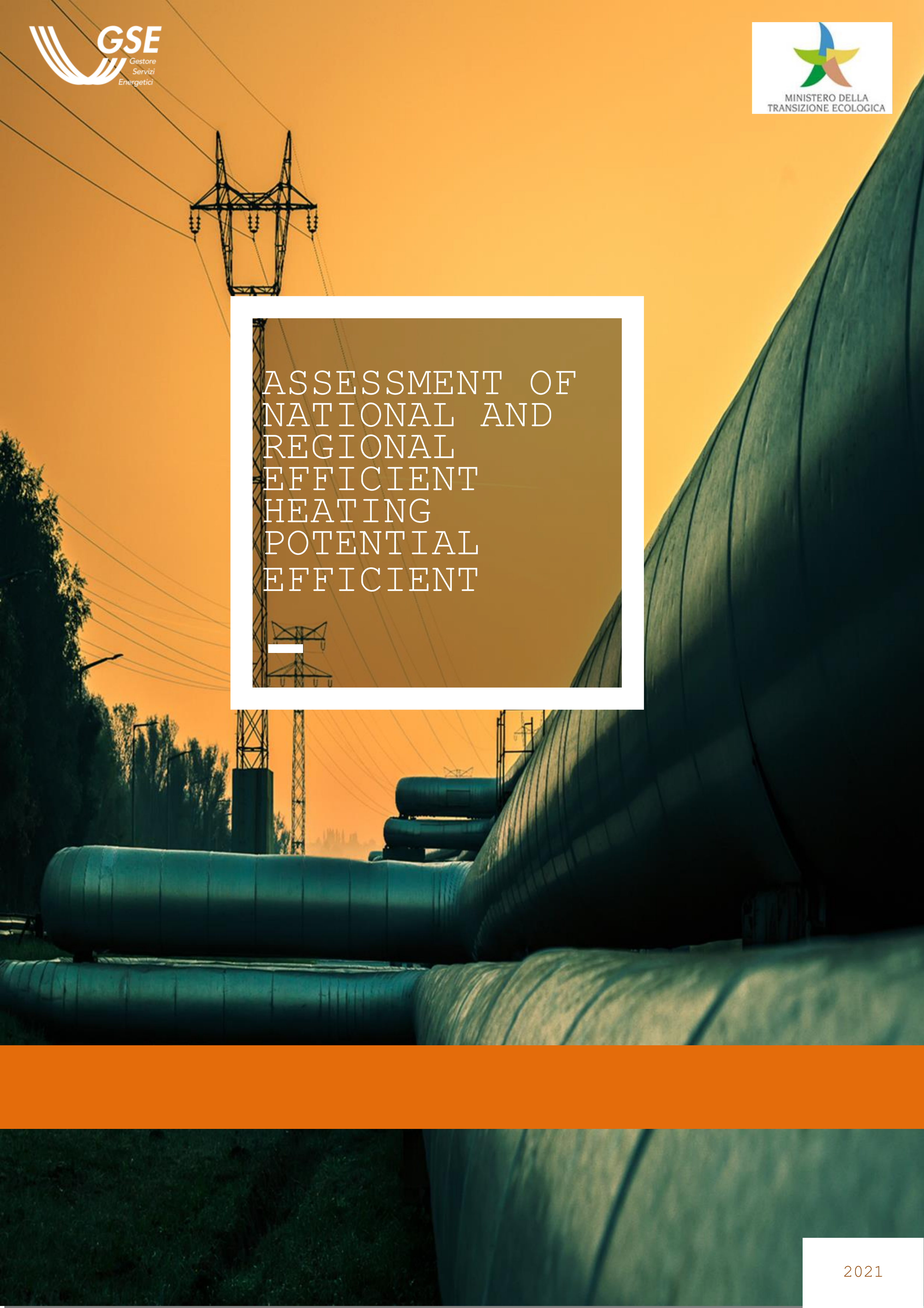

GSE Gestore Servizi Energetici

MINISTERO DELLA TRANSIZIONE ECOLOGICA

ASSESSMENT OF NATIONAL AND REGIONAL EFFICIENT HEATING POTENTIAL EFFICIENT

2021

GSE Gestore Servizi Energetici	GSE Gestore Servizi Energetici
MINISTERO DELLA TRANSIZIONE ECOLOGICA	MINISTRY OF ECOLOGICAL TRANSITION

This study has been prepared by GSE in accordance with Article 10 of Italian Legislative Decree No 73 of 14 July 2020 based on the indications set out in Annex VIII of Directive 2012/27/EU, as replaced by Regulation No 2019/826/EU of 4 March 2019.

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2021
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EXECUTIVE SUMMARY

INTRODUCTION

Legislative Decree No 73 of 14 July 2020 provides for the preparation of a report, to be submitted to the European Commission, which **evaluates the national potential for application of high-efficiency cogeneration (HE CHP) and efficient district heating and cooling.** This report is to be drawn up on the basis of the indications set out in **Annex VIII** to **Directive 2012/27/EU**, as replaced by Regulation No 2019/826/EU of 4 March 2019.
Taking into account the provisions of Recommendation (EU) 2019/1659, the new report provides a **broader scope of analysis** than the previous assessment from 2015, aiming to cover the entire heating and cooling sector and the diversified mix of technological solutions that can be developed, in line with its progressive decarbonisation.
The **results** set out in the report have been **incorporated** into the energy scenario on which the **Integrated National Energy and Climate Plan**, drawn up in 2019, is based, which already made it possible to exceed the energy targets outlined at EU level by the Directives making up the 'Clean Energy for all Europeans' package. Without prejudice to the objectives of the INECP, the analyses developed here provide details of the optimal mix for the thermal sector.
The report is divided into five sections:

- **Heating and cooling consumption and demand:** energy statistics have been processed in order to illustrate heating and cooling consumption and demand in considerable geographical, sectoral and technological detail.
- **Evaluation of the potential for efficient district heating (DH):** a bottom-up approach was used to establish the demand for district heating and national sources for supplying DH networks, in order to identify the technical potential for developing district heating. An economic analysis under market and current regulatory conditions was used to assess the share of this technical potential that can be exploited, i.e. the economic and financial potential.
- **Evaluation of the potential for high-efficiency cogeneration (CHP):** highly detailed case studies were drawn up by sector and user type, and technical potential was identified by calculating the size and simulating the operation of cogenerators on the basis of performance indicators taken from existing plants. An economic analysis under market and current regulatory conditions was used to assess the share of this technical potential that can be exploited, i.e. the economic and financial potential.
- **Scenarios and system optimisation in the heating sector:** regional and sectoral data on heat supply and demand (technical potential) have been processed in the national energy system planning and optimisation model (TIMES) in order to update the technological mix proposed in the INECP in light of new HE CHP and DH potential, while ensuring that energy and climate targets are reached.

- **Objectives and measures:** the study was accompanied by a comprehensive review of national and regional targets, strategies and measures in the field of efficient heating.

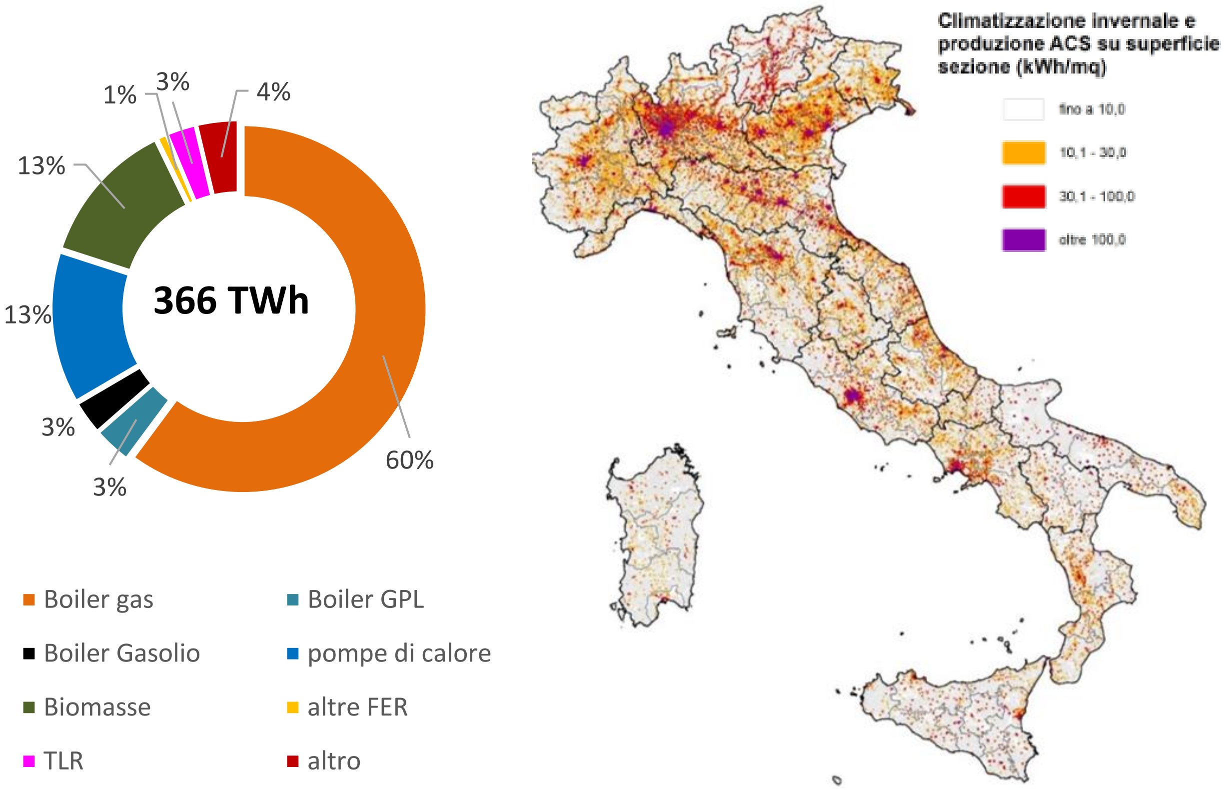
HEATING AND COOLING CONSUMPTION AND DEMAND

In order to assess the potential of district heating and cogeneration, it was necessary to produce a heat supply and demand dataset with a greater level of breakdown by region, sector and use than is available in the national energy statistics. On the basis of statistical data for 2018, an in-depth analysis of the building and plant stock, as well as of demographic data and the productive fabric, was then carried out in order to determine, with a top-down approach, energy consumption for heating and cooling, broken down by sector and by region; particular attention was paid to renewables and to derived heat. Demand was then established using the characteristic conversion efficiency of the various energy carriers. The reference year for the monitored consumption is 2018.

The **demand** for **heating** and **domestic hot water** in the **civil** sector totalled **366 TWh** in 2018. Natural gas is the main energy source used to meet heating requirements (**60%**), with **district heating** contributing **3%**. The four large northern regions (Lombardy, Veneto, Emilia-Romagna and Piedmont) account for more than 50% of the national heat demand.

Heat demand in the residential and service sectors was then distributed among the more than **400 000 census zones** into which the national territory is divided, on the basis of data relating to building stock, its specific needs and climate variables, in order to make the subsequent regional analyses possible.

Figure 1: Civil sector demand by technology and per unit of land area (2018).



Climatizzazione invernale e produzione ACS su superficie sezione (kWh/mq)	Winter heating and domestic hot water (DHW) production by land area of census zone (kWh/m^2)
fino a 10,0	up to 10.0
oltre 100,0	over 100.0
Boiler gas	Gas boiler
Boiler Gasolio	Diesel boiler
Biomasse	Biomass
TLR	DH
Boiler GPL	LPG boiler
pompe di calore	Heat pump
altre FER	Other renewables
altro	Other

EVALUATING THE POTENTIAL FOR EFFICIENT DISTRICT HEATING

Operating data from district heating networks processed by GSE as part of its statistical activities in the sector were used to assess the levels of coverage of regional heat demand and a series of parameters characterising the operation of existing networks. Heat demand in the civil sector, calculated on a geographical basis, was characterised by a wide set of parameters (density, winter heating hours, natural gas distribution, presence of DH networks, etc.) in order to assess the potential for connection to a district heating network. The share of heat demand that could be covered by district heating was then determined for each municipality, according to technical feasibility criteria based on the existing networks and the availability of sources in the area. Analyses have resulted in an estimate of **technical potential** for exploiting district heating of **57 TWh** (around **6 times** the **current levels of development**), which is mainly concentrated in northern Italian regions.

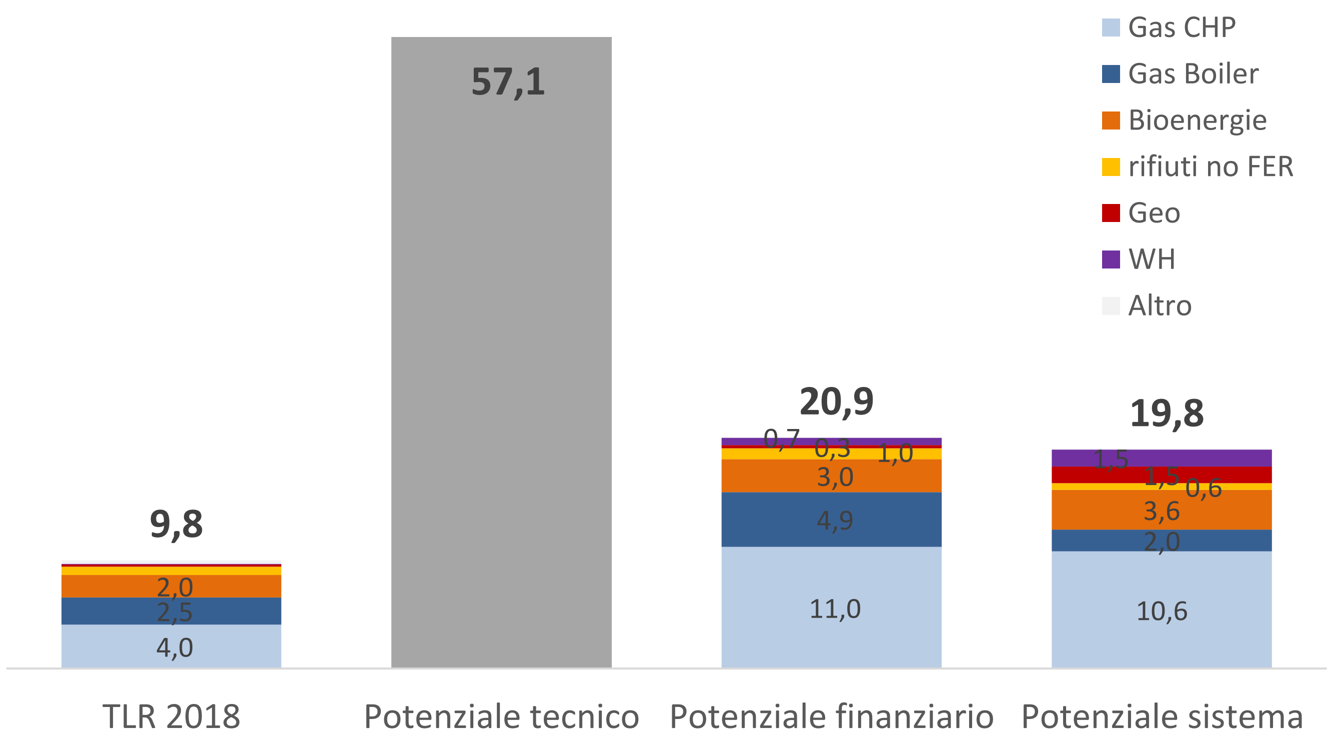
By contrast, as regards evaluating the technical potential for the provision of energy sources and technologies to supply district heating networks, the availability of resources for each type of generation technology was analysed by geographical area and compared with the local demand for district heating in order to verify the maximum exploitation potential (the lower of the two) to be used as a reference in the economic analyses. It was therefore estimated that industrial and thermoelectric installations emit **67 TWh** of **waste heat**, of which **38 TWh was available in the winter season (26 TWh in climate zones D, E and F)**, and of which around **6 TWh** was estimated to be **recoverable** to meet the district heating demand of the municipalities adjacent to the plants. As far as renewable sources are concerned, the amount of renewable heat that could potentially be used to supply DH networks is estimated at **3.4 TWh** for medium and high-enthalpy **geothermal energy** and **3.3 TWh** for **forest biomass**, considering the areas deemed most suitable for this type of use according to various analysis criteria, including the availability of resources, infrastructure, geomorphological characteristics and other parameters, including air quality. Lastly, indicative evaluations have been carried out to determine the potential of sources less tied to local energy resources, estimating **3.7 TWh** of energy from **solar power**, **11.3 TWh** from geothermal and hydrothermal **heat pumps**, and **48 TWh of thermal energy from gas cogeneration** in municipalities served by methane pipelines.

The size of the district heating networks has been calculated such as to be able to supply the technical potential, and the investment and operating costs were then estimated. The costs of generating heat to supply the networks using each form of technology were thus assessed on a local basis, identifying, on **economic merit**, the **mix of sources** capable of meeting district heating demand at the lowest cost. The **economic and financial potential** was then assessed from the point of view of a potential investor, considering the sustainability of the DH initiative for each municipality by means of a project business plan, on the basis of the current prices of commodities and existing measures to support the sector. This economic and financial potential was determined by considering the percentage of the technical potential implemented, calculated **on the basis of the IRR** (100% implementation for IRR>= 15%, 0% implementation for IRR <= 7%, linear interpolation for IRR between 7% and 15%). The results were compared with current development, determining the incremental economic potential, and also keeping track of the corresponding environmental benefits in terms of primary energy savings and emissions prevented.

The **economic and financial potential** of efficient district heating, under current regulatory and market conditions, is estimated to be around **21 TWh**, more than double the current degree of penetration, almost **half** of which – according to the analyses carried out – is attributable to **CHP gas technology** (including the potential recovery of waste heat from existing thermal power plants). Among thermal renewable technologies, there is an incremental development potential for **bioenergy** (up to **3 TWh**), in particular in areas not served by methane pipelines, and for developing systems for recovering **industrial waste heat (0.7 TWh).** Implementing this incremental economic potential would deliver environmental benefits, including **0.3 Mtoe** of **primary fossil energy saved** and **0.6 $MtCO_2$** of **greenhouse gas emissions prevented** in the non-ETS sectors.

In addition to the economic and financial potential, the **optimal system potential** was also assessed, updating the optimised energy scenario to achieve the INECP targets in the light of the technical potential for district heating. The system potential estimates that **20 TWh** of thermal energy can be supplied by district heating, thus achieving results similar to the economic and financial potential. According to this analysis, **high-efficiency gas CHP** still makes a predominant contribution (**11 TWh**), but there are also greater contributions from renewables, in particular **geothermal energy** (**1.5 TWh**) and **bioenergy** (**3.6 TWh**), plus **1.5 TWh** of **waste heat.**

Figure 2: Comparison between the heat currently produced by DH and its technical, financial and system potential (TWh)



Gas CHP	GAS CHP
Gas Boiler	Gas boiler
Bioenergie	Bioenergy
rifiuti no FER	non-renewable waste
Geo	Geo
WH	WH
Altro	Other
TLR 2018	DH 2018
Potenziale tecnico	Technical potential

Potenziale finanziario	Financial potential
Potenziale sistema	System potential

POTENTIAL FOR HIGH-EFFICIENCY COGENERATION

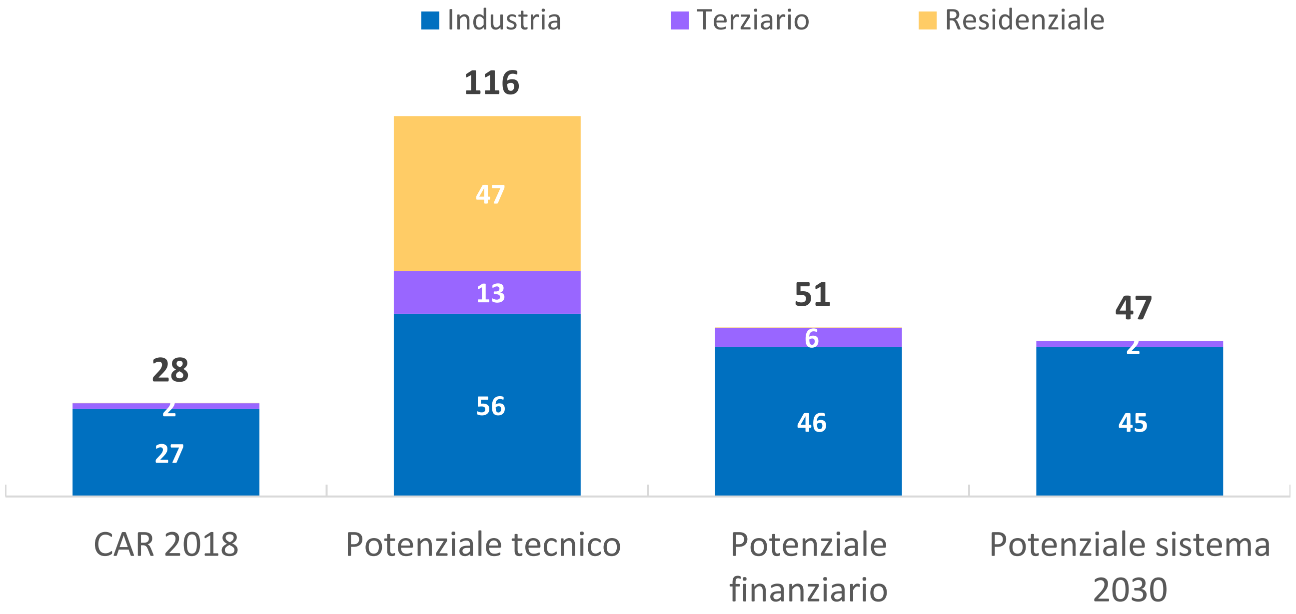
The evaluations carried out on high-efficiency CHP were based on a survey of the current situation, which was obtained through a detailed analysis of the HE CHP recognition database available to GSE. A total of **35.5 TWh** of **HE CHP heat** was generated in **2018**, mostly (**75%**) for **industry**, followed by cogenerated heat for district heating (20%) and for the service sector (5%), while generation for the residential sector was mostly negligible. In terms of sources, **gas** is by far the most common fuel used (95%).

The methodology of the study for determining potential included, first of all, analysing the characteristics of the demand for energy from the residential, service and industrial sectors, and selecting the subsectors and **typical users** of greatest interest for HE CHP, which were also identified thanks to existing plants. For each typical case, technical indicators and constraints were taken into account, such as the extent of the heating and electricity requirements, the timing and contemporaneity thereof, and the temperature at which the heat is required; the size of the cogenerator was then calculated and its operating conditions simulated at typical user premises for each subsector, using specific performance indicators (efficiency, equivalent operating hours, self-consumption, ECHP/Etot, technology) obtained from systems operating at similar user premises in terms of energy requirements. The **technical potential** was thus evaluated by extending the resulting estimates obtained for cogenerating heat and electricity in the individual case studies to the entire reference area. The technical potential should be interpreted as a theoretical maximum of demand that can be covered by CHP heat based on purely technical conditions.

The **economic and financial potential** was then assessed, considering the sustainability of the initiative for each case study using the project business plan, under current regulations. Consideration was given to investment and maintenance costs, the prices of commodities (retail by consumption band), and incentives currently available (for example, white certificates, net metering, tax deductions, etc.) This economic and financial potential was determined by considering the percentage of the technical potential implemented, calculated on the basis of the IRR (100% implementation for IRR>= 15%, 0% implementation for IRR <= 7% (5% in the residential sector), linear interpolation for IRR between 7% and 15%). The results were compared with current development, determining the incremental economic potential, and also keeping track of the corresponding environmental benefits in terms of primary energy savings and CO_2 emissions prevented. The analyses were broken down on a **regional scale**, based on the regional heat demand for each subsector.

The potentials calculated in this way were placed side by side and compared with the system potential for 2030 obtained from the energy system optimisation model which, as has been mentioned, takes INECP decarbonisation and energy efficiency targets into account.

Figure 3: Comparison between the current level of high-efficiency CHP (excluding HE CHP-DH plants) and its technical, financial and system potential (TWh)



Industria	Industry
Terziario	Services
Residenziale	Residential
CAR 2018	HE CHP 2018
Potenziale tecnico	Technical potential
Potenziale finanziario	Financial potential
Potenziale sistema 2030	System potential 2030

The results show a **technical potential** of **116 TWh**, of which 56 TWh relates to industry, 47 TWh to the residential sector (given the residential demand that can theoretically be cogenerated) and 13 TWh to the service sector. In terms of what is financially viable for an investor under current regulations, there is an **economic potential of 51 TWh**, of which 89% relates to **industry (45.5 TWh**) and **5.8 TWh** to the **service sector.** In particular, the **paper and basic chemicals** sectors have the greatest economic potential in industry for CHP heat (**10-11 TWh**), followed by refining. Given current development, the subsectors with the greatest incremental potential are **ceramics (4.6 TWh), basic chemicals (4.5 TWh)** and **paper (3.6 TWh)**, followed by food (1.9 TWh) and mechanical engineering (1.4 TWh). In the service sector, **hospitals** account for the greatest share of economic potential **(3.4 TWh of heat**) and incremental potential (**2.4 TWh**), followed by **swimming pools** and **large sports centres** with 1.6 TWh of incremental heat. Universities and research centres, and hotels, also show significant margins for growth, with incremental economic potential for CHP heat of 0.3 and 0.2 TWh respectively. By contrast, under current regulations, which provide for HE CHP to supply electricity only for common utilities, the case studies examined for the residential sector, which are representative of the average requirements of single-family homes, medium-sized apartment blocks and large apartment blocks, do not show any economic advantage, despite the high technical potential of the sector.

As regards the **system potential**, the energy scenario optimisation model shows a potential for HE CHP of **47 TWh**, almost entirely in **industry (45.5 TWh)**, with the results being fairly closely aligned with those of the financial analysis. From a system perspective, there are no significant margins for growth for HE CHP in the service and residential sectors, partly due to the expected breakthrough of other technologies, including heat pumps, which are part of the strategy for achieving renewables targets by 2030, possibly in conjunction with photovoltaics.

THERMAL RENEWABLES AND WASTE HEAT IN THE 2030 SCENARIO

Table 1: Final consumption from renewable sources and recovered heat in the thermal sector in 2030 in relation to the optimal system scenario

Consumption per source (ktoe)	2018	Scenario 2030
Numerator (A)	**10 678**	**14 976**
Gross heat production from renewables and waste heat	956	1 282
of which is DH	*257*	*675*
Final consumption from renewables for heating	9 722	13 694
of which from biomass	*6 780*	*7 016*
of which from solar power	*218*	*675*
of which from geothermal	*128*	*180*
of which from heat pumps	*2 596*	*5 772*
Denominator (B)[1]		
Final energy consumption for heating	52 792	43 722
Share of renewables (%)	**20.2%**	**34.3%**

The mix of technologies for achieving the renewables target in the thermal sector at the lowest cost to the system (**33.9% by 2030** as set out in INECP), according to the analyses conducted in this study, may be composed of **14.8 Mtoe** of **thermal renewables: 7 Mtoe** from **solid biomass** (in line with the current level), **5.8 Mtoe** from **heat pumps** (almost twice the current level), **0.9 Mtoe** from **solar and geothermal combined** (almost three times the current level), **0.5 Mtoe** of heat from **renewable district heating** (twice the current level) and **0.6 Mtoe of non-DH derived heat from renewables.** If the contribution from recovered **waste heat** is also included (a possibility under Directive 2001/2018), the renewables + waste heat share in the thermal sector is **34.3%**[2].

The analyses carried out in order to assess the potential for efficient heating lead to the conclusion that the forecasts set out in the INECP for thermal consumption in 2030 can be slightly revised (cf. comparison between Table 96 and Table 100 and between Figure 158 and Figure 169). These assessments will be taken into consideration as part of the INECP update, in

[1] Final consumption for heating does not include electricity consumption nor ambient energy from heat pumps, in line with Directive 2018/2001. Only if the recovery of waste heat is to be counted (case shown in the table) is it added to both the numerator and the denominator.
[2] Without accounting for waste heat, the renewables target in the thermal sector is 33.9%.

the broader context of its partial revision to take into account the more ambitious European decarbonisation targets for 2030.

CONSULTATION

Legislative Decree No 73 of 14 July 2020 stipulated that GSE, when preparing the report containing the assessment of the national potential for application of HE CHP and of efficient district heating and cooling, should consult the relevant trade associations, including for the purpose of identifying the current obstacles limiting distribution of the technologies in question and proposing the most effective solutions. Within the time frame set by the public consultation, around 20 participants submitted their comments. The results of the consultation have been detailed in Annex 2 to this document.

1 Energy consumption and heating and cooling technologies

This section describes energy consumption for heating purposes by Italian households and businesses in the year 2018, in the context of the national energy system.

The methodological approach is based on the official statistical data published annually by Eurostat on energy consumption by sector; this data, with appropriate processing, can be used to obtain energy consumption values for various uses (space heating, domestic hot water production, cooking, process uses, space cooling and other uses), broken down in turn by geographical area.

The processing in question is particularly complex because, unlike for electricity, there are no analyses or detailed reconstructions of thermal energy production available in Italy. It is also often unmeasured and would in any case be rather difficult to measure (consider, for example, direct consumption of biomass in the residential sector in boilers, chimneys, etc.).

To provide a consistent and homogeneous analysis, this document defines the demand for heating and cooling as the *total consumption of energy products for the following uses: space heating and cooling, domestic hot water production, cooking, and heat for industrial processes.*

1.1National energy context

1.1.1 Energy balance

In 2018, the gross domestic consumption of energy in Italy stood at 153 Mtoe, including more than 7 Mtoe of non-energy uses. The national production of primary sources covers about 24% of domestic consumption and consists mainly of renewable sources (26.7 Mtoe), followed by petroleum (5 Mtoe) and gas (4.5 Mtoe).

Almost 135 Mtoe are used in processing. After processing losses of 23.7 Mtoe, in particular, 111 Mtoe of secondary sources are generated, consisting mainly of refined petroleum products (77.4 Mtoe), electricity (24.9 Mtoe) and derived heat (5.5 Mtoe).

Final energy uses amount to 114.4 Mtoe (from the use of those primary sources that are not processed further and of secondary sources). The sector with the highest consumption is transport (31.1%), followed by the residential sector (28%), industry (21.2%), services (16.9%) and agriculture (2.6%).

Table 2: Summary energy balance for Italy in 2018 (figures in ktoe)

	All products	Solid fuels*	Manufactured gases	Oil products	Natural gas	Renewables	Derived heat	Electricity
+ **Primary production**	**37 342**	**1 133**	**0**	**5 091**	**4 462**	**26 657**	**0**	**0**
+ Net import **	121 923	8 625	0	51 634	55 268	2 622	0	3 775
+ Stock changes	449	-84	0	745	-216	3	0	0
- International maritime bunkers	2 721	0	0	2 721	0	0	0	0
- International aviation	3 835	0	0	3 835	0	0	0	0
Total energy supply	**153 158**	**9 675**	**0**	**50 914**	**59 513**	**29 282**	**0**	**3 775**
Transformation input	**134 876**	**0**	**652**	**80 803**	**23 385**	**19 579**	**0**	**199**
+ Electricity and heat generation	53 920	7 285	652	4 107	23 385	18 291	0	199
+ Refineries and petrochemicals	76 696	0	0	76 696	0	0	0	0
+ Other (coke oven, blast furnace...)	4 260	2 973	0	0	0	1 288	0	0
Transformation output	**111 205**	**1 297**	**795**	**77 439**	**23**	**1 257**	**5 483**	**24 910**
+ Electricity and heat generation	30 393	0	0	0	0	0	5 483	24 910
+ Refineries and petrochemicals	77 439	0	0	77 439	0	0	0	0
+ Other (coke oven, blast furnace...)	3 372	1 297	795	0	23	1 257	0	0
Consumption of the energy branch	**7 605**	**64**	**11**	**3 004**	**1 583**	**0**	**1 203**	**1 739**
+ Own use in electricity, CHP and heat plants	850	0	0	0	0	0	2	848
+ Oil and natural gas extraction plants	1 188	0	0	0	1 133	0	21	34
+ Oil refineries	4 396	0	0	3 004	347	0	549	495
+ Other (coke ovens, coal mines, etc.)	1 171	64	11	0	103	0	632	362
Distribution losses	**1 929**	**0**	**0**	**0**	**324**	**0**	**58**	**1 547**
Final non-energy consumption	**7 153**	**49**	**0**	**6 488**	**616**	**0**	**0**	**0**
Final energy consumption	**114 422**	**882**	**132**	**39 398**	**33 629**	**10 960**	**4 221**	**25 200**
+ Industry	24 302	882	132	2 019	8 649	406	2 234	9 980
+ Transport	35 579	0	0	32 244	1 093	1 250	0	992
+ Services	19 338	0	0	543	7 250	2 706	714	8 125
+ Residential	32 056	0	0	2 200	16 499	6 514	1 242	5 601
+ Agriculture/forestry	2 798	0	0	2 129	137	50	11	472
+ Fishing	234	0	0	170	0	34	0	31
+ Non-specified (other)	113.16	0	0	92.433	0	0	20.7	0
Statistical differences	**-1 622**	**-281**	**0**	**-1 341**	**0**	**0**	**0**	**0**

* Includes non-renewable waste.
** Note that this value relates to net imports of petroleum products, i.e. imports of crude and refined products, less exports of refined products. For this reason, gross domestic consumption is lower than processing sector inputs.
Source: processing of Eurostat data

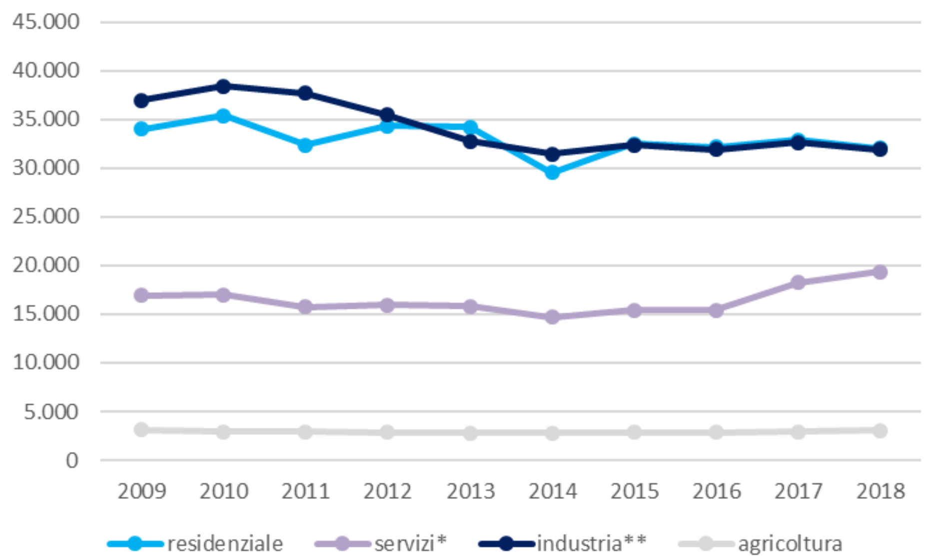
Energy consumption in the transport sector is not taken into account for the purposes of this study. Consumption trends in the sectors examined below, understood as the sum of final consumption in industry, services, the residential sector and agriculture and consumption by the energy sector, are shown in the table below.

Table 3: Energy consumption in the sectors examined in this study (ktoe)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
residential	34 041	35 393	32 378	34 348	34 231	29 546	32 494	32 185	32 899	32 056
services*	16 919	16 979	15 751	15 931	15 847	14 667	15 391	15 440	18 242	19 338
industry**	36 978	38 454	37 719	35 497	32 796	31 453	32 371	31 925	32 624	31 907
agriculture	3 122	2 940	2 924	2 824	2 785	2 776	2 851	2 871	2 918	3 033
Other	141	160	147	159	137	111	143	155	102	113
Overall total	**91 201**	**93 926**	**88 920**	**88 758**	**85 795**	**78 553**	**83 252**	**82 577**	**86 784**	**86 447**

* it should be noted that recent changes to Eurostat rules have made it possible, as of 2017, to account for the consumption of the renewable share of energy transferred by heat pumps for heating purposes. This change largely explains the increase noted in the services between 2016 and 2017.
** Includes consumption by the energy industry considered to be of interest for this study. This therefore includes consumption for energy purposes (net of the consumption of raw materials), for example by refineries, coke ovens and hydrocarbon plants.
Source: processing of Eurostat data

Figure 4: Trends in energy consumption over the 2009-2018 period in the sectors covered by this study (ktoe)



residenziale	residential
servizi*	services*
industria**	industry**
agricoltura	agriculture

Despite the introduction of ambient heat into energy accounting in 2017, energy consumption trends show a rather clear decline. In 2018, specifically, the value stood at 86.5 Mtoe. A driving factor in consumption trends is the industrial sector, which is not affected by the change relating to ambient heat and which has been on a downward trend since 2010. Consumption in the residential sector has been largely stable over the last five years, totalling 32 Mtoe in 2018, similar to the industrial sector.

1.1.2 Geography

Energy consumption for heating is significantly influenced by both geographical factors – in particular the significant differences in climate between different parts of the country – and seasonal factors, which diversify overall consumption between the different months of the year.

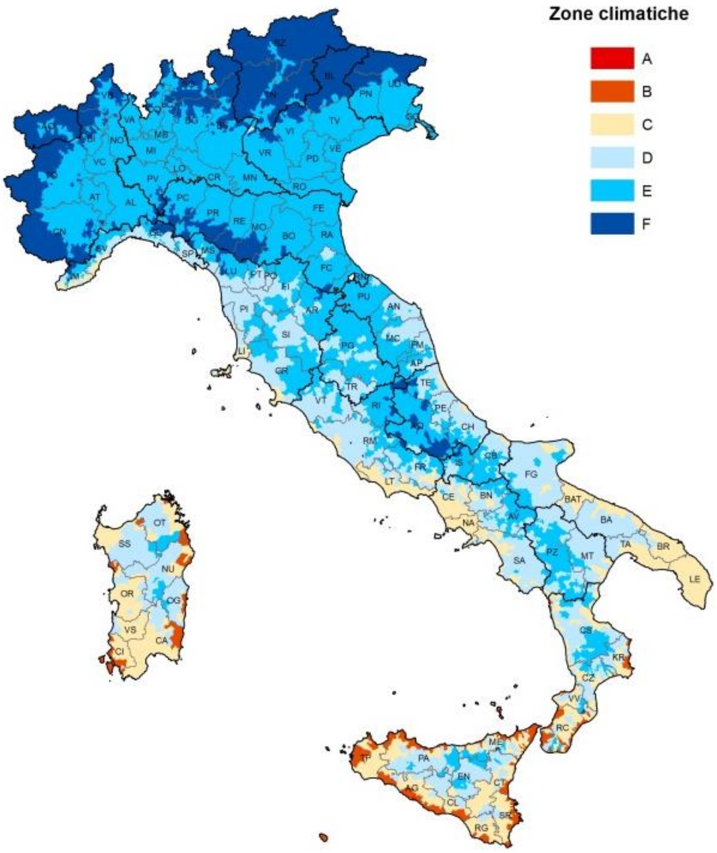
A good representation of climate conditions is provided by the Degree Days indicator (DD), which is defined in Presidential Decree No 412/1993 as *'the sum, extended to all the days of an annual conventional heating period, of the positive daily differences only between indoor temperature, conventionally set at 20°C, and average daily outdoor temperature'*.

The same Presidential Decree provides a conventional degree-day value for each Italian municipality, and groups Italian municipalities into six climate zones.

Table 4: Climate zones defined by Presidential Decree No 412/1993

Climate zone	Degree days
A	up to 600
B	from 600 to 900
C	from 900 to 1 400
D	from 1 400 to 2 100
E	from 2 100 to 3 000
F	over 3 000

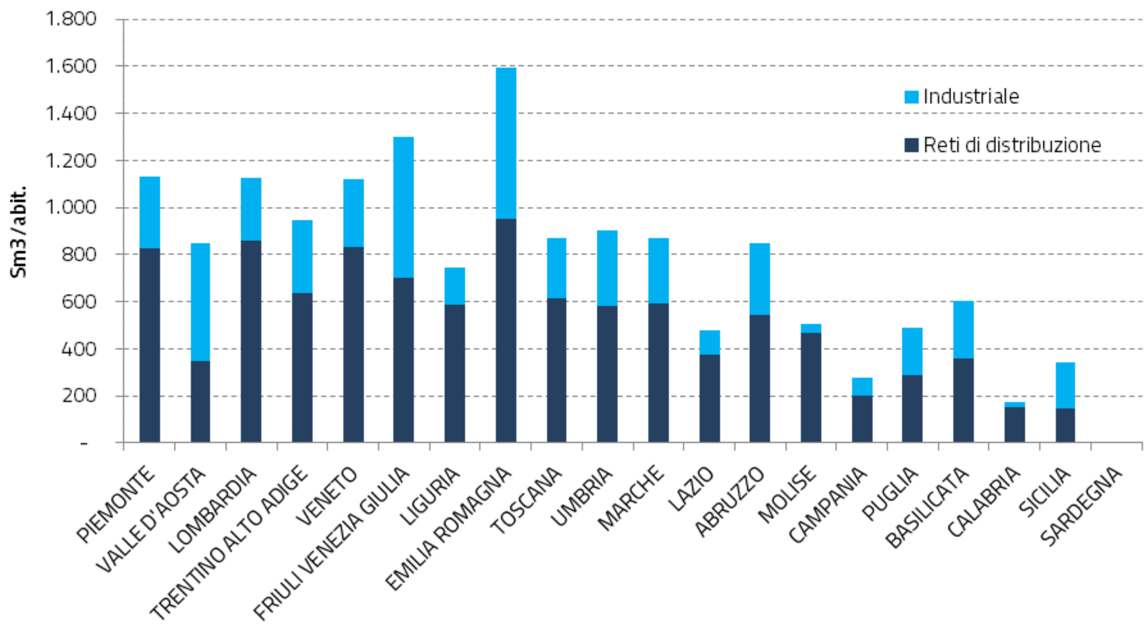
Figure 5: National map of climate zones



Zone climatiche	Climate zones

A reliable indicator of the variability of consumption across the national territory is provided by the regional data on natural gas consumption by inhabitant, for uses other than thermoelectric. As illustrated by the following graph, higher volumes of gas are supplied to local distribution networks in central and northern Italy than to the South, with the exception of the Valle d'Aosta and Trentino regions where gas is often replaced by biomass. It should also be noted that Sardinia has no methane gas supply.

Figure 6: Natural gas conveyed per inhabitant in 2018 (graph drawn up by the Ministry of Economic Development using data from SNAM Rete Gas, S.G.I. s.p.a. and other companies) (standard cubic metres at 38.1 MJ/m³)



Industriale	Industrial
Reti di distribuzione	Distribution networks
PIEMONTE	PIEDMONT
VALLE D'AOSTA	VALLE D'AOSTA
LOMBARDIA	LOMBARDY
TRENTINO ALTO ADIGE	TRENTINO ALTO ADIGE
VENETO	VENETO
FRIULI VENEZIA GIULIA	FRIULI-VENEZIA GIULIA
LIGURIA	LIGURIA
EMILIA ROMAGNA	EMILIA-ROMAGNA
TOSCANA	TUSCANY
UMBRIA	UMBRIA
MARCHE	MARCHE
LAZIO	LAZIO
ABRUZZO	ABRUZZO
MOLISE	MOLISE
CAMPANIA	CAMPANIA
PUGLIA	APULIA
BASILICATA	BASILICATA
CALABRIA	CALABRIA
SICILIA	SICILY
SARDEGNA	SARDINIA
sm3/abit.	sm^3/inhabitant

1.1.3 Demographics

In 2018, 46% of the Italian population lived in regions falling mainly in climate zone E, 25% in zone D, 21% in zone C and only 3% in zone F. The remaining 5% of the population lived in zone A or B.

Table 5: Resident population at the end of 2018

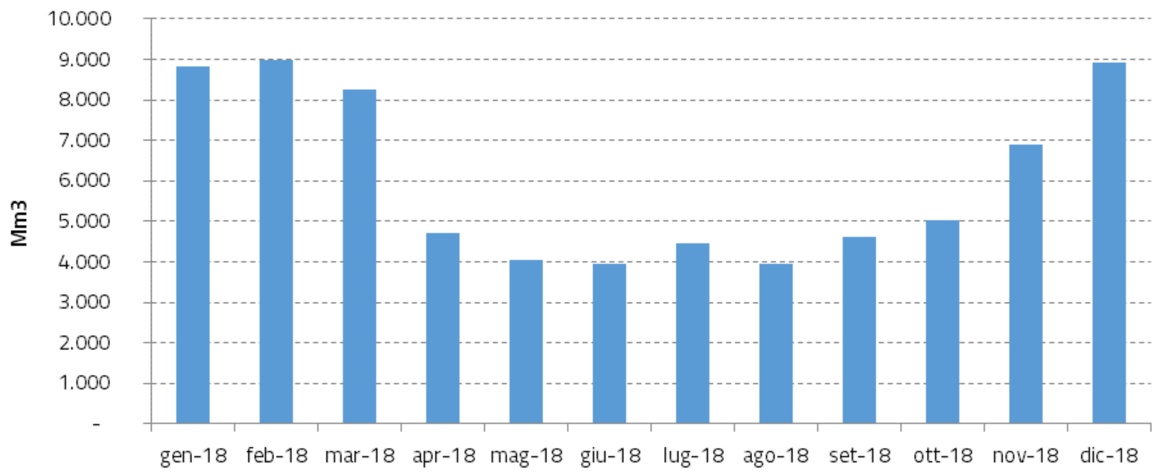
Regions	Population	Number of family households*	Number of cohabiting households
Piedmont	4 328 565	2 009 101	3 388
Valle d'Aosta	125 653	60 918	117
Lombardy	10 010 833	4 460 150	4 262
Trentino-Alto Adige	1 074 034	456 645	940
Veneto	4 884 590	2 076 323	2 763
Friuli-Venezia Giulia	1 210 414	561 946	779
Liguria	1 532 980	771 387	1 386
Emilia-Romagna	4 459 453	2 003 011	3 272
Tuscany	3 701 343	1 650 863	2 279
Umbria	873 744	385 209	694
Marche	1 520 321	646 820	905
Lazio	5 773 076	2 656 942	3 637
Abruzzo	1 300 645	559 087	710
Molise	303 790	130 961	249
Campania	5 740 291	2 179 279	2 041
Apulia	3 975 528	1 602 803	1 401
Basilicata	558 587	236 114	322
Calabria	1 912 021	805 352	995
Sicily	4 908 548	2 002 737	3 389
Sardinia	1 622 257	726 348	877
Italy	59 816 673	25 981 996	34 406

* The number of family households reported here refers to 2017. Data for 2018 are being validated by the Italian National Institute of Statistics (ISTAT) at the time of writing.
Source: processing of ISTAT data

1.1.4 Seasonal variations

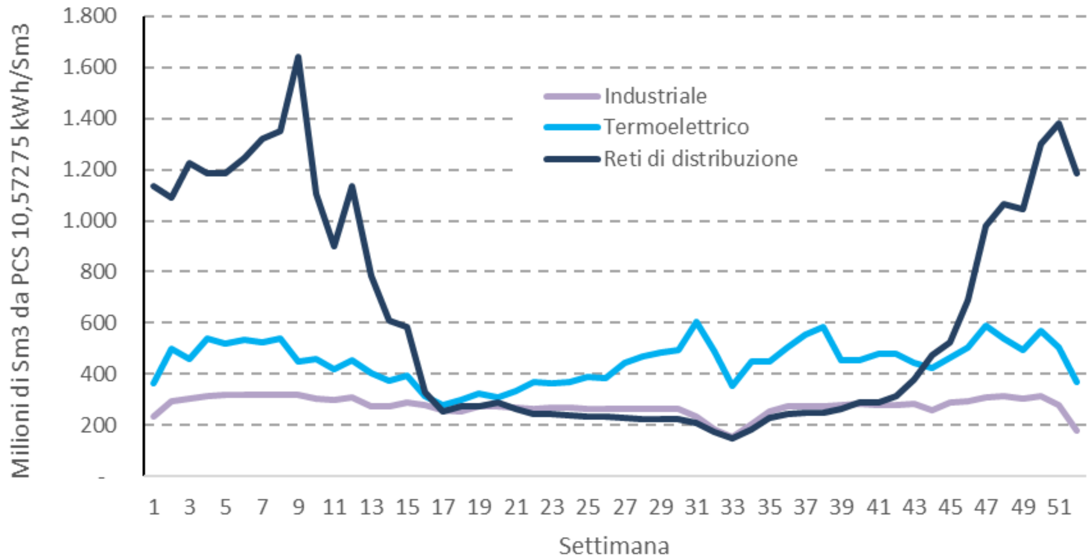
The two figures below show the variations in natural gas consumption over the different months of the year. In particular, the reduced consumption observed between April and October is mainly associated with the residential and service sectors, due to the generally higher temperatures compared to the other months and the consequent reduction in heating demand.

Figure 7: Monthly consumption of natural gas in 2018 (Eurostat monthly data)



gen-18	Jan-18
feb-18	Feb-18
mar-18	Mar-18
apr-18	Apr-18
mag-18	May-18
giu-18	Jun-18
lug-18	Jul-18
ago-18	Aug-18
set-18	Sep-18
ott-18	Oct-18
nov-18	Nov-18
dic-18	Dec-18

Figure 8: Balance sheet for transported and redelivered gas (GSE processing of SNAM daily operating data)
(Standard cubic metres at 38.1 MJ/m^3)

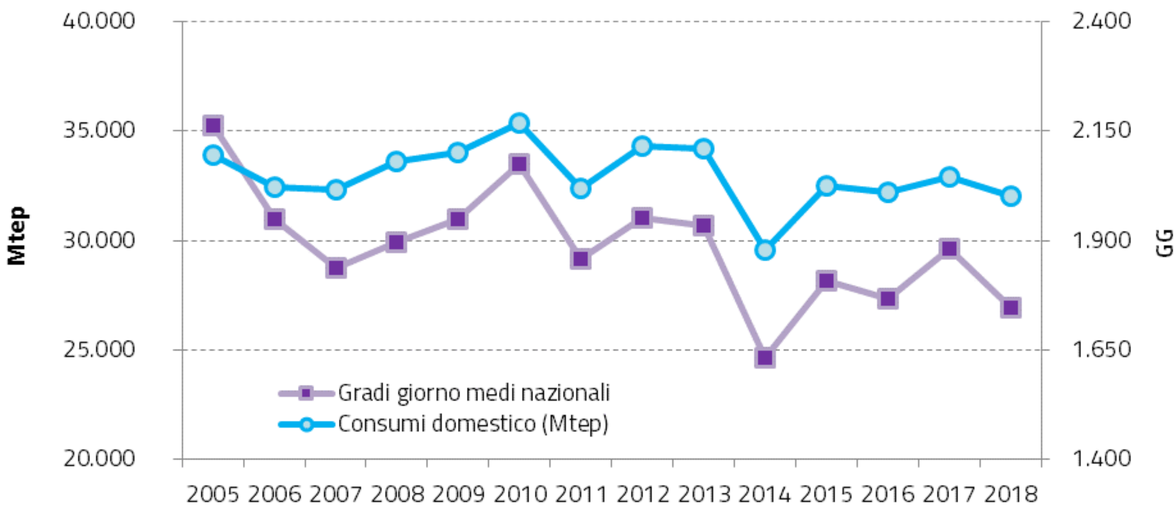


Milioni di Sm3 da PCS 10,57275 kWh/Sm3	Million sm^3 from gross calorific value 10.57275 kWh/Sm^3
Industriale	Industrial
Termoelettrico	Thermoelectric
Reti di distribuzione	Distribution networks
Settimana	Week

1.1.5 Evolution of climate conditions

As is well known, energy consumption for heating purposes is closely related to winter weather conditions.

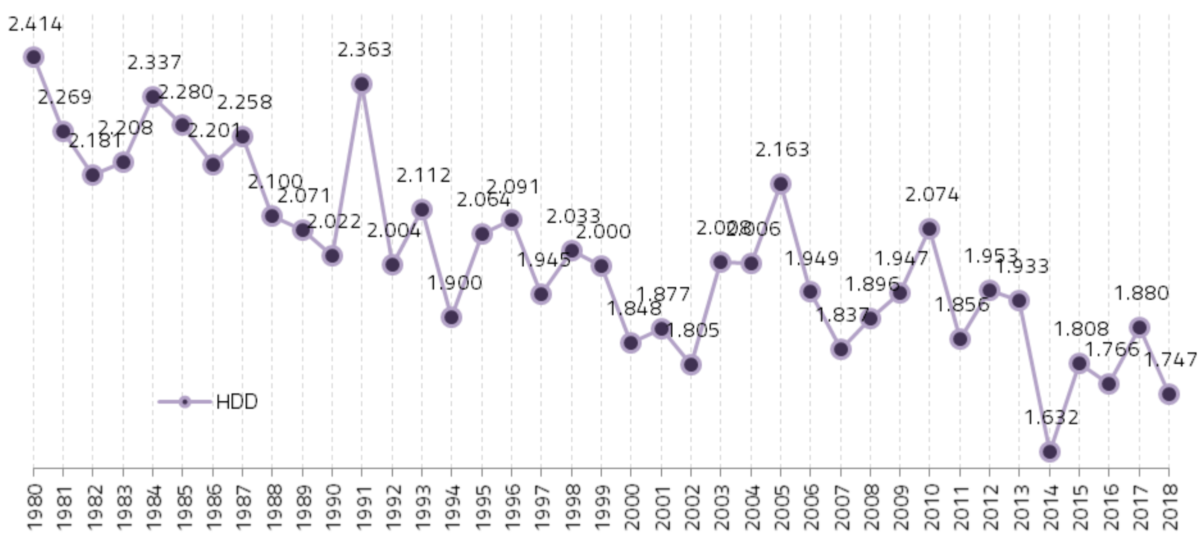
Figure 9: Consumption trends in the residential sector and national average degree days



Mtep	Mtoe
Gradi giorno medi nazionali	National average degree days
Consumi domestico (Mtep)	Domestic consumption (Mtoe)
2.400	2 400
40.000	40 000

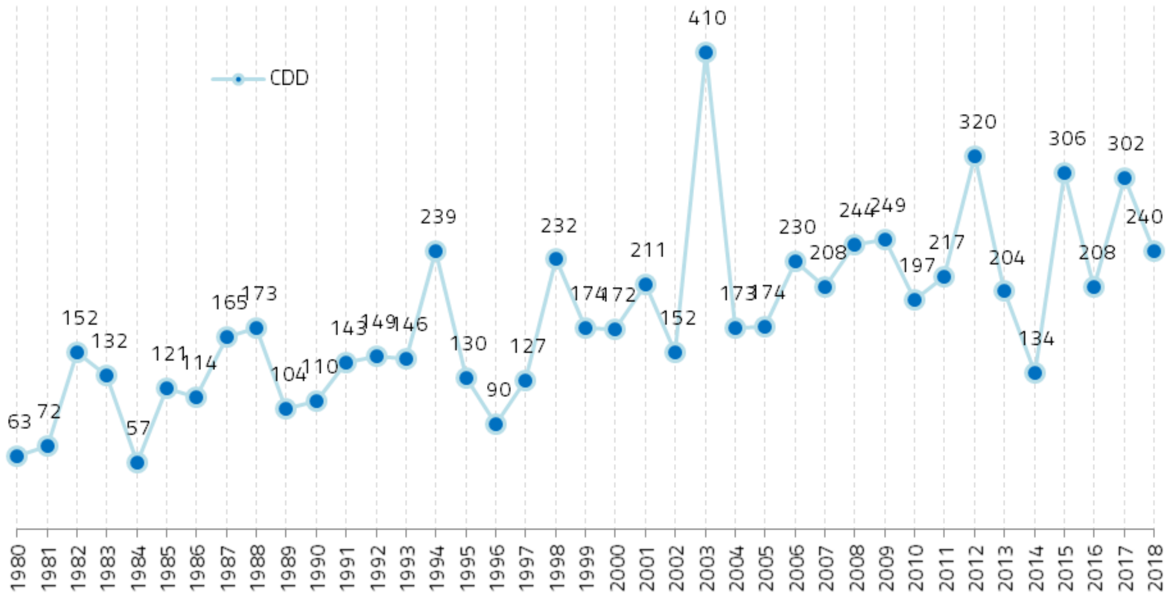
Considering the period 1980-2018, a downward trend in the national average degree days emerges, whereas restricting the scope of the analysis to the last five years reveals the opposite trend, i.e. an upward trend in degree days (graph below).

Figure 10: Trend in national average heating degree days for heating from 1980 to 2018



The opposite is true of cooling degree days, which show a clear upward trend, even with large annual fluctuations.

Figure 11: Trend in national average cooling degree days from 1980 to 2018



1.2 Residential sector

1.2.1 Breakdown of consumption by use

The total consumption recorded in Italy in the residential sector between 2009 and 2018 is shown in the following table, by energy source. It should be noted that, until 2016, the data do not take into account the consumption of renewable thermal energy[3] supplied by heat pumps.

Table 6: Consumption by the residential sector in Italy (figures in ktoe)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Solid fossil fuels	4	4	4	2	0	0	0	0	0	0
Other bituminous coal	*4*	*4*	*4*	*2*	*0*	*0*	*0*	*0*	*0*	*0*
Natural gas	16 821	18 698	17 990	18 117	18 073	15 151	16 986	17 097	17 261	16 499
Oil and petroleum products (excl. biofuel)	3 789	3 325	3 079	2 809	2 709	2 243	2 375	2 290	2 087	2 200
Liquefied petroleum gases	*1 382*	*1 371*	*1 245*	*1 206*	*1 192*	*1 080*	*1 086*	*1 118*	*1 148*	*1 116*
Other kerosene	*9*	*9*	*9*	*0*	*7*	*4*	*1*	*2*	*2*	*2*
Gas oil and diesel oil (excl. biofuel)	*2 314*	*1 907*	*1 792*	*1 588*	*1 506*	*1 158*	*1 287*	*1 168*	*937*	*1 082*
Fuel oil	*84*	*38*	*33*	*14*	*4*	*1*	*1*	*1*	*1*	*0*
Renewables and biofuels	7 449	7 263	4 707	6 754	6 759	5 809	6 535	6 322	7 014	6 514
Geothermal	*2*	*1*	*1*	*2*	*1*	*0*	*1*	*1*	*1*	*1*
Solar thermal	*66*	*99*	*104*	*115*	*124*	*133*	*141*	*148*	*154*	*162*
Ambient heat (heat pumps)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*102*	*100*
Primary solid biofuels	*7 336*	*7 113*	*4 552*	*6 594*	*6 592*	*5 631*	*6 352*	*6 129*	*6 718*	*6 206*
Charcoal	*44*	*50*	*50*	*43*	*41*	*44*	*42*	*44*	*40*	*45*
Electricity	5 926	5 980	6 031	5 972	5 760	5 525	5 691	5 529	5 631	5 601
Heat	52	123	568	694	931	818	908	947	905	1 242
Total	34 041	35 393	32 378	34 348	34 231	29 546	32 494	32 185	32 899	32 056

Source: processing of Eurostat data

Regarding the breakdown of consumption by use, for the residential sector reference can be made to the data collection set up by Eurostat for this very purpose (annual 'Energy consumption in Households' questionnaire, henceforth simply 'Households'); on the basis of the Eurostat data, consumption of each source for each use has been defined, in order to isolate consumption for heating.

[3] Difference between the (thermal) energy supplied overall by the equipment and the energy (usually electricity) used to operate it.

In 2018, the total demand for heating and cooling by Italian households was around 27.5 Mtoe, including almost 21.5 Mtoe for space heating and about 3.9 Mtoe for domestic hot water production.

It should be noted that the following table shows different derived heat consumption values from the previous one. This discrepancy is linked to the fact that the data were updated during 2020, and this revision will be communicated to Eurostat together with the final data for 2019; the value to be considered correct is, therefore, the one shown in the table below.

Table 7: Consumption in the residential sector in Italy (figures in ktoe) in 2018, broken down by use

	Petroleum products	Natural gas	Coal	Electricity	Derived heat	Renewable sources	Total
Heating and cooling	**2 200**	**16 499**	**0**	**1 156**	**1 092**	**6 514**	**27 460**
Winter heating	*1 660*	*12 448*	*0*	*91*	*951*	*6 042*	*21 192*
Domestic hot water	*320*	*2 572*	*0*	*532*	*140*	*378*	*3 943*
Kitchen uses	*219*	*1 479*	*0*	*319*	*0*	*95*	*2 112*
Summer air conditioning	*0*	*0*	*0*	*214*	*0*	*0*	*214*
Other electrical uses				**4 445**			**4 445**
Total	**2 200**	**16 499**	**0**	**5 601**	**1 092**	**6 514**	**31 906**

Since the aim of this study is to assess the potential for expansion of efficient district heating or high-efficiency cogeneration systems, further investigations had to be carried out in order to establish the heating consumption components which can be technically and practically covered by those systems. Therefore, cooking uses have been excluded from the overall heat demand, as on initial assessment they are not considered to be easily replaceable by efficient district heating or high-efficiency cogeneration. The thermal consumption relevant to subsequent assessments is thus 25.1 Mtoe for the residential sector, 84.5% of which is for winter heating and the remaining 15.5% for domestic hot water consumption.

1.2.2 Energy consumption for heating and cooling: regional distribution

A top-down approach was adopted in order to illustrate regional energy consumption for heating and cooling purposes, starting with data reported in the 2018 national energy balance and developed on the basis of the following sources:

- **Energy Consumptions in Households questionnaire** sent annually by Italy to Eurostat (residential consumption by use, on a national scale),
- **TERNA** (regional and sectoral statistics on electricity and cogeneration),
- **GSE** (statistics on thermal renewables and district heating, in cooperation with the Italian Urban Heating Association (AIRU)),

- **MISE** (provincial sales of petroleum products for heating and gas distributed per Region),
- **ARERA** (natural gas distributed by sector per Region),
- **ISTAT** (building stock by census zone, resident population, availability of services and type of systems in dwellings, results of household energy consumption survey),
- **RSE** (residential consumption for different building types and climate conditions).

In a first step, through processing the data from the sources mentioned, residential consumption from each source was broken down into Regions and Autonomous Provinces; in a second step, this consumption was broken down into different uses, in order to isolate those of interest.

The results of the work to break down consumption for each source and use of interest, which were developed also taking into account the need to ensure their consistency with official statistics, are summarised in the table below.

Table 8: Consumption (2018) for heating and air conditioning, hot water production, and cooling in the residential sector by Region and Autonomous Province (ktoe)

	Consumption		
	Heating	DHW	Cooling
Piedmont	2 423.8	324.4	5.2
Valle d'Aosta	78.0	8.2	0.0
Lombardy	4 264.6	688.0	34.1
Bolzano	288.5	54.2	0.1
Trento	316.7	44.6	0.1
Veneto	2 290.9	338.4	30.2
Friuli-Venezia Giulia	650.4	81.0	4.4
Liguria	577.1	112.5	2.7
Emilia-Romagna	2 103.6	313.8	29.1
Tuscany	1 364.5	241.6	7.6
Umbria	412.5	59.8	0.9
Marche	545.4	101.6	2.6
Lazio	1 521.7	378.8	15.5
Abruzzo	625.8	96.6	2.2
Molise	141.7	20.1	0.4
Campania	897.9	333.7	17.4
Apulia	838.0	238.3	15.9
Basilicata	234.9	43.7	1.0
Calabria	617.2	107.9	6.8
Sicily	570.2	263.1	29.1
Sardinia	428.3	92.5	8.7
Italy	**21 191.5**	**3 942.7**	**214.0**

1.3 Service sector

1.3.1 Breakdown of consumption by use

The total consumption recorded in Italy in the service sector between 2009 and 2018 is shown in the following table, by energy source.

Table 9: Consumption in the service sector in Italy (figures in ktoe)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Solid fuels	-	-	-	-	-	-	-	-	-	-
Lignite/Brown coal	-	-	-	-	-	-	-	-	-	-
Total petroleum products	836	829	756	633	611	586	564	560	546	543
Liquefied petroleum gas (LPG)	*592*	*588*	*534*	*445*	*450*	*431*	*411*	*432*	*443*	*431*
Gasoline (without bio components)	-	-	*17*	*13*	*8*	*8*	-	*2*	*2*	*2*
Gas/diesel oil (without bio components)	*244*	*241*	*206*	*175*	*153*	*147*	*153*	*126*	*101*	*110*
Total fuel oil	-	-	-	-	-	-	-	-	-	-
Gas	8 610	8 614	7 254	7 276	7 259	6 012	6 499	6 542	6 590	7 250
Natural gas	*8 610*	*8 614*	*7 254*	*7 276*	*7 259*	*6 012*	*6 499*	*6 542*	*6 590*	*7 250*
Derived heat	62	49	139	105	154	266	221	245	308	714
Renewable energies	163	125	128	154	171	194	190	205	2 759	2 706
Solar thermal	*18*	*27*	*28*	*31*	*34*	*36*	*38*	*40*	*42*	*44*
Solid biofuels (excluding charcoal)	*13*	*21*	*21*	*21*	*35*	*59*	*51*	*64*	*66*	*64*
Biogas	-	*1*	*3*	*25*	*25*	*25*	*25*	*24*	*23*	*23*
Geothermal energy	*132*	*76*	*76*	*77*	*77*	*74*	*76*	*76*	*80*	*79*
*Ambient heat (heat pumps)**	-	-	-	-	-	-	-	-	*2 549*	*2 496*
Electrical energy	7 248	7 362	7 473	7 763	7 651	7 609	7 918	7 888	8 039	8 125
Total	**16 919**	**16 979**	**15 751**	**15 931**	**15 847**	**14 667**	**15 391**	**15 440**	**18 242**	**19 338**

*It should be noted that recent changes to Eurostat rules have made it possible, as of 2017, to account for the consumption of the renewable share of energy transferred by heat pumps for heating purposes. This change largely explains the increase noted in the services between 2016 and 2017.
Source: processing of Eurostat data

Unlike the residential sector, the service sector lacks an adequate breakdown of data by type of use and geographical area. The breakdown of consumption by use (table below) is therefore based on Eurostat data, supplemented by detailed calculations for heat pumps[4].

[4] Electricity consumption for heat pumps has been calculated using the following steps:

It should be noted that the following table shows derived heat consumption values that differ from those in the previous table. As already stated for the similar table included in the chapter on the residential sector, this discrepancy is linked to the fact that the figure was updated during 2020, and this revision will be communicated to Eurostat together with the final data for 2019; the value to be considered correct is, therefore, the one shown in the table below.

Table 10: End-use consumption in the service sector in Italy (figures in ktoe) broken down by use (2018)

	Solid fuels	Petroleum products	Gas	Derived heat	Renewable energies	Electricity	Total
Heating and cooling	**0**	**541**	**7 251**	**444**	**2 706**	**3 244**	**14 186**
Winter heating, DHW and other uses	*0*	*541*	*7 251*	*436*	*2 706*	*1 612*	*12 547*
Summer air conditioning				*8*		*1 631*	*1 639*
Other electrical uses						**4 881**	**4 881**
Total	**0**	**541**	**7 251**	**444**	**2 706**	**8 125**	**19 066**

1.3.2 Energy consumption for heating and cooling purposes: sectoral and regional distribution

As for the residential sector, regional consumption for heating purposes has been calculated using a top-down approach, starting with the data reported in the 2018 national energy balance and developed on the basis of the following sources:

- **TERNA** (regional and sectoral statistics on electricity and cogeneration),
- **GSE** (statistics on thermal renewables and district heating, in cooperation with the Italian Urban Heating Association (AIRU)),
- **MISE** (provincial sales of petroleum products for heating and gas distributed per Region),
- **ARERA** (natural gas distributed by sector per Region),
- **ISTAT** (building stock by census zone, employees in services subsectors by census zone),
- **RSE** (consumption of services subsectors by use).

- calculation of total installed capacity in Italy in the non-residential sector, obtained as the difference between total installed capacity and the total residential capacity previously calculated;
- application of standard performance data to capacity installed in the non-residential sectors; ensuring that the average equivalent hours of the entire installed national stock are consistent with the parameters set out in Commission Decision No 2013/114/EU.

Regarding electricity consumption for cooling purposes, reference has been made to specific consumption characteristics of the different services subsectors, weighted for their consistency, as described in the following pages.

In a first step, thanks to the above-mentioned sources, consumption in the service sector was broken down by Regions and Autonomous Provinces; then, thermal consumption (for heating and domestic hot water production) was separated out for each source.

In order to provide elements useful for subsequent evaluations and, in particular, to verify the potential for expansion of high-efficiency cogeneration (HE CHP) in the service sector, the energy consumption of each Region or Autonomous Province was then divided into subsectors, to allow a more accurate characterisation of each individual sector, considering the considerable difference between services in terms of structure and consumption profile [5]. Specifically, the different components of consumption by the subsectors were established as follows:

- Thermal consumption, broken down using a top-down approach on the basis of data from the land registry, using the characteristic consumption parameters obtained from ad hoc evaluations carried out by RSE as a proxy[6];
- Consumption for cooling purposes, estimated using a bottom-up method, based on the same sources of information as used for thermal consumption;
- Other electricity consumption, established on the basis of information provided by sectoral and regional statistics from the operator of Italy's national grid, Terna.

The following table shows the national surface area of the subsectors in the service sector, obtained by processing the information available at provincial level and for the relevant capitals about the number and/or size (square metres or cubic metres) of buildings belonging the main subsectors published by the Real Estate Market Observatory (OIM), operated by the Land Registry/Revenue Agency;

Table 11: Surface area of services in Italy, broken down by subsector

	National surface area (m^2)
Commercial	212 432 606
Education	89 984 407
Offices*	89 712 502

[5]While the breakdown of thermal consumption by subsector aims to characterise individual sectors on a regional scale, the breakdown of heating and domestic hot water requirements aims to accurately illustrate their geographical distribution. Please refer to Section 2.2 for a more detailed description.

[6] RSE, 'La pompa di calore. Una soluzione efficiente e sostenibile' [Heat pumps: an efficient and sustainable solution]. RSEView, editrice ALKES, December 2018.

F. Carrara 'I consumi energetici della Pubblica Amministrazione Stima dei consumi e scenari di riqualificazione energetica, Rapporto RSE GSE', [Energy consumption by public bodies: estimated consumption and energy retrofitting scenarios, RSE and GSE report] December 2014.

RSE, Madonna et al. 'Studio sulla domanda di climatizzazione: influenza del comportamento dell'utenza sui consumi ed effetto rebound nel caso di riqualificazioni energetiche' [Study on the demand for heating and air conditioning: influence of user behaviour on consumption and rebound effect in energy retrofitting]. RSE report 16002288, 2016.

RSE, Lorenzo Croci et al. 'Fabbisogno di climatizzazione invernale ed estiva degli edifici residenziali e del terziario' [Winter and summer climate control in residential and services buildings], RdS Report No 18007687, December 2018.

Health	72 016 919
Government	59 896 545
Hotels	49 736 750
Sports and sports complexes	37 242 518
Leisure activities	14 504 870
Other	86 853 308
Total	**712 380 425**

*Includes offices in land registry category A10.

Source: GSE processing of data from the Land Registry/Revenue Agency

The following table shows the total consumption by services, determined as described above, broken down by Region and Autonomous Province and by use.

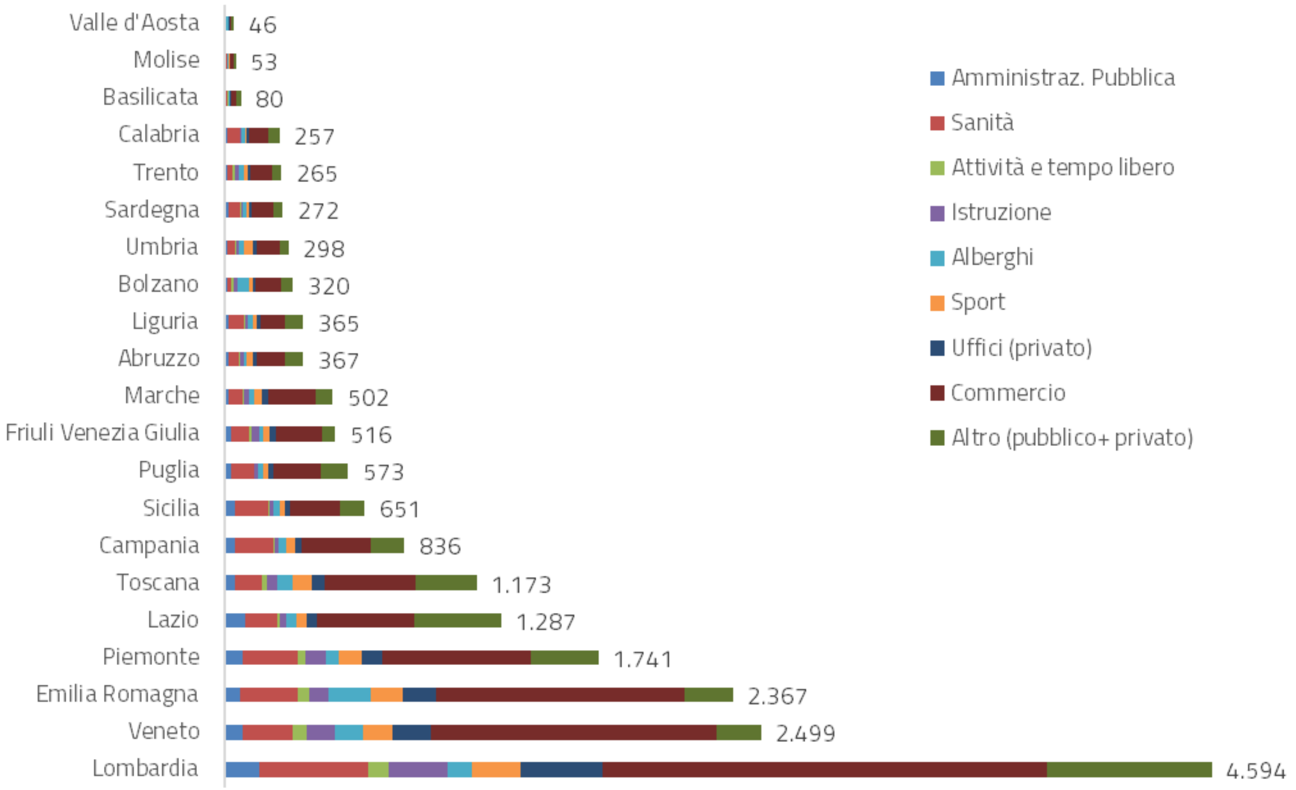
Table 12: Summary of total consumption by the service sector in Italy (figures in ktoe)

	Thermal consumption for heating and DHW	Electricity consumption for cooling purposes (*)	Other electricity consumption not for heating and cooling purposes	Electricity consumption for public lighting and communications(**)	Total
Piedmont	1 262	93	316	69	1 741
Valle d'Aosta	23	2	17	3	46
Lombardy	3 361	260	832	141	4 594
Autonomous Province of Bolzano	222	14	78	6	320
Autonomous Province of Trento	186	12	57	9	265
Veneto	2 040	133	271	55	2 499
Friuli-Venezia Giulia	391	28	80	17	516
Liguria	166	38	135	26	365
Emilia-Romagna	1 888	130	280	68	2 367
Tuscany	632	102	391	48	1 173
Umbria	202	21	63	12	298
Marche	349	39	94	21	502
Lazio	529	178	477	104	1 287
Abruzzo	214	33	96	23	367
Molise	24	8	16	5	53
Campania	361	155	261	60	836
Apulia	215	122	186	50	573
Basilicata	28	13	30	9	80
Calabria	93	53	78	34	257
Sicily	252	135	202	62	651
Sardinia	108	63	75	25	272
Italy	**12 547**	**1 631**	**4 034**	**848**	**19 060**

(*) The consumption of derived heat for district cooling described in chapter 3 is not considered.
(**) Electricity consumption in the public lighting and communications sectors is reported separately, as it is not relevant to this study.

The following graph shows the total consumption by the individual sectors, broken down by Region and Autonomous Province.

Figure 12: Consumption by the service sector in Italy, broken down by Region/Autonomous Province and subsector (figures in ktoe)



Valle d1 Aosta	Valle d'Aosta
Molise	Molise
Basilicata	Basilicata
Calabria	Calabria
Trento	Trento
Sardegna	Sardinia
Umbria	Umbria
Bolzano	Bolzano
Liguria	Liguria
Abruzzo	Abruzzo
Marche	Marche
Friuli Venezia Giulia	Friuli-Venezia Giulia
Puglia	Apulia
Sicilia	Sicily
Campania	Campania
Toscana	Tuscany
Lazio	Lazio
Piemonte	Piedmont
Emilia Romagna	Emilia-Romagna
Veneto	Veneto
Lombardia	Lombardy

Amministraz. Pubblica	Government
Sanità	Health
Attività e tempo libero	Leisure activities
Istruzione	Education
Alberghi	Hotels
Sport	Sport
Uffici (privato)	Offices (private)
Commercio	Commercial
Altro (pubblico+ privato)	Other (public and private)

1.4 Industry

The table below shows the energy consumption trends in the industrial sector in Italy over the last 10 years, as recorded by Eurostat. It should be noted that, for the purposes of this study, the industrial sector includes consumption by the energy industry, which in turn includes consumption by auxiliaries of electricity generation plants and derived heat systems, consumption by pumping plants and consumption for energy purposes (net of raw material consumption) by refineries, coking plants and hydrocarbon extraction plants. In 2018, total consumption by the industrial sector was almost 32 Mtoe.

Table 13: Consumption by the industrial sector, including the energy industry, in Italy, broken down by source (figures in ktoe)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Solid fossil fuels	607	658	1 031	989	739	744	542	688	537	693
Coking coal	*40*	*38*	*44*	*38*	*35*	*4*	*2*	*0*	*0*	*0*
Other bituminous coal	*111*	*64*	*335*	*300*	*234*	*306*	*136*	*225*	*147*	*207*
Lignite	*2*	*2*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*0*
Coke oven coke	*454*	*554*	*650*	*650*	*469*	*433*	*403*	*406*	*342*	*422*
Coal tar	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*57*	*47*	*64*
Manufactured gases	5	4	7	230	179	300	228	239	168	143
Coke oven gas	*5*	*4*	*7*	*212*	*168*	*156*	*141*	*112*	*117*	*105*
Blast furnace gas	*0*	*0*	*0*	*18*	*10*	*12*	*6*	*1*	*1*	*0*
Other recovered gases	*0*	*0*	*0*	*0*	*0*	*133*	*81*	*127*	*50*	*37*
Natural gas	10 356	11 001	10 477	10 231	9 851	9 739	9 394	9 540	10 287	10 232
Petroleum products (excl. biofuel)	9 178	8 773	8 237	7 188	5 784	4 836	6 102	5 262	5 016	5 024
Refinery gas	*2 501*	*2 796*	*2 748*	*2 022*	*2 075*	*1 750*	*2 431*	*1 996*	*2 185*	*2 256*
Liquefied petroleum gases	*316*	*357*	*333*	*289*	*247*	*179*	*235*	*251*	*247*	*228*
Motor gasoline	*244*	*174*	*25*	*482*	*312*	*315*	*17*	*150*	*138*	*141*
Gas oil and diesel oil	*341*	*496*	*740*	*437*	*341*	*393*	*408*	*360*	*343*	*398*
Fuel oil	*3 021*	*2 236*	*1 652*	*1 621*	*838*	*725*	*975*	*1 095*	*820*	*766*
Petroleum coke	*2 697*	*2 667*	*2 708*	*2 314*	*1 954*	*1 461*	*2 027*	*1 403*	*1 276*	*1 228*
Other oil products n.e.c.	*59*	*47*	*32*	*23*	*16*	*13*	*9*	*7*	*7*	*7*
Renewables	394	217	253	271	275	327	402	393	393	406
Geothermal	*0*	*3*	*3*	*2*	*2*	*2*	*2*	*2*	*2*	*1*
Solar thermal	*0*	*7*	*7*	*8*	*8*	*9*	*10*	*10*	*10*	*11*
Primary solid biofuels	*375*	*201*	*236*	*234*	*237*	*289*	*364*	*353*	*354*	*368*
Charcoal	*19*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*
Biogases	*0*	*0*	*0*	*20*	*20*	*20*	*20*	*20*	*19*	*19*
Industrial waste (non-renewable)	62	223	249	281	281	272	269	276	245	252

Electricity	12 213	12 877	12 999	12 234	11 681	11 452	11 430	11 419	11 702	11 719
Derived heat	4 162	4 702	4 466	4 074	4 008	3 783	4 005	4 108	4 277	3 437
Total	**36 978**	**38 454**	**37 719**	**35 497**	**32 796**	**31 453**	**32 371**	**31 925**	**32 624**	**31 907**

Source: processing of Eurostat data

As regards the breakdown of consumption by use, it was considered appropriate to separate consumption for heating on the basis of the energy carriers used: all sources other than electricity are assumed to meet a demand for thermal energy relevant to this study (space heating and cooling and process heat). A share of electricity consumption relates to heating (e.g. electric ovens), although it was decided that this would not be calculated since its estimate would be unreliable due to a lack of organic data. Furthermore, such uses are not felt to be easily replaceable by district heating or cogeneration, since they usually have precise process needs.

The analysis therefore focuses on uses of fuels and derived heat (see the following table), which amount to about 20.2 Mtoe.

Table 14: Consumption by the industrial sector, including the energy industry, in Italy, broken down by use, for the year 2018 (figures in ktoe)

	Solid fuels and derived gases	Petroleum products	Gas	Derived heat	Renewable energies	Electricity	Total
Space heating and cooling, process uses	1 088	5 024	10 232	3 437	406		20 188
Electrical uses						11 719	11 719
Total	**1 088**	**5 024**	**10 232**	**3 437**	**406**	**11 719**	**31 907**

Heating consumption is broken down by sector, as shown in the table below. It is noted that the highest energy consumption in industry is by the refineries and non-metallic mineral products sector, followed by chemicals and petrochemicals and by the steel industry.

Table 15: Consumption for heating purposes by the industrial sector, including the energy industry, in Italy, broken down by subsector, for the year 2018 (figures in ktoe)

	Solid fuels*	Manufactured gases	Oil products	Natural gas	Renewables	Derived heat	Total
Iron & steel	417	132	78	1 284	0	90	2 000
Chemical & petrochemical	79	0	373	942	7	633	2 034
Non-ferrous metals	31	0	62	403	0	0	497
Non-metallic minerals	320	0	899	2 033	133	147	3 531
Transport equipment	0	0	0	0	0	103	103
Machinery	3	0	260	1 365	3	28	1 659
Mining & quarrying	0	0	36	30	0	1	67
Food, beverages & tobacco	0	0	162	1 130	48	382	1 723
Paper, pulp & printing	0	0	47	618	0	666	1 332
Wood & wood products	6	0	0	32	167	33	237
Construction	0	0	19	215	1	0	236
Textile & leather	11	0	60	576	0	39	686
Other industries	15	0	23	21	47	111	216
Own use in electricity, CHP and heat plants	0	0	0	0	0	2	2
Oil and natural gas extraction	0	0	0	1 133	0	21	1 154
Oil refineries	0	0	3 004	347	0	549	3 900
Other energy (coke ovens...)	64	11	0	103	0	632	809
Total	**946**	**143**	**5 024**	**10 232**	**406**	**3 437**	**20 188**

*Includes non-renewable waste
Source: processing of Eurostat data

1.5 Agriculture and fishery

Statistical data show that consumption in the agricultural sector (including fisheries) has remained largely stable over the last 10 years.

Table 16: Energy consumption by the agricultural sector in Italy, broken down by source (figures in ktoe)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total petroleum products	2 401	2 266	2 228	2 129	2 107	2 112	2 143	2 169	2 171	2 299
Liquefied petroleum gas (LPG)	*66*	*68*	*66*	*59*	*57*	*49*	*58*	*23*	*21*	*22*
Gasoline (without bio components)	*12*	*12*	*9*	*9*	*9*	*9*	*8*	*3*	*3*	*3*
Gas/diesel oil (without bio components)	*2 324*	*2 187*	*2 153*	*2 060*	*2 040*	*2 053*	*2 077*	*2 143*	*2 147*	*2 274*
Natural gas	142	142	130	129	128	121	138	130	136	137
Derived heat	13	1	9	15	20	22	9	11	10	11
Renewable energies	80	48	48	41	42	58	71	82	85	84
Solar thermal	*1*	*1*	*1*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
Solid biofuels (excluding charcoal)	*1*	*2*	*2*	*2*	*2*	*21*	*34*	*35*	*35*	*34*
Geothermal energy	*79*	*45*	*45*	*38*	*38*	*35*	*35*	*45*	*48*	*47*
Electrical energy	486	482	508	509	488	462	489	479	515	502
Total	3 122	**2 940**	**2 924**	**2 824**	**2 785**	**2 776**	**2 851**	**2 871**	**2 918**	**3 033**

Source: processing of Eurostat data

Consumption data from the sector are broken down by flow to separate out the share used for heating. As with industry, the estimate is based on the nature of the energy products consumed. It is therefore assumed that natural gas, derived heat, renewable energy and LPG are used for space heating or thermal process uses; for diesel, a conservative 5% share of consumption is estimated to be used for heating purposes[7], with the remainder attributed to motor use.

Table 17: Energy consumption by the agricultural sector in Italy in 2018, broken down by use (figures in ktoe)

	Petroleum products	Gas	Derived heat	Renewables	Electricity	Total
Heating and cooling	136	137	11	84	-	367
Space heating and cooling, drying, other uses	136	137	11	84		367
Electrical uses					502	502
Operation of agricultural machinery	2 164					2 164

[7] Ministry of Economic Development, sales of petroleum products, 2018.
Italian National Agency for Agricultural Mechanisation (Enama), Fuel consumption guide for subsidised use in agriculture, 2005.

Total	2 299	137	11	84	502	3 033

Heating consumption by agriculture is not broken down geographically, because there is a lack of sufficiently reliable data for identifying the centres of consumption for energy products (mainly greenhouses, dryers, livestock farms). Furthermore, pinpointing distribution of consumption across Italy is not felt to be strictly useful for assessing the potential for district heating, since farms are usually located at a distance from urban centres and are rarely reached by district heating networks (as shown by the current proportion of agricultural customers using district heating networks). It should also be noted that energy consumption for heating by the agricultural sector makes up a tiny fraction of total consumption.

1.6 Energy consumption for heating and cooling: summary as of 2018

The consumption described above includes some components not associated with heating (operation of traction machinery, lighting and other electrical uses, etc.) If these uses are removed, the heating and cooling consumption identified as being relevant to the subsequent analyses stands at around 60.1 Mtoe in 2018; it represents 67% of the total energy consumption by the sectors analysed (industry including the energy industry, services, residential, agriculture).

Taking only consumption for the purposes of heating and cooling into account, the sector with the highest concentration is the residential sector (42% of total heating and cooling consumption), followed by industry (34%) and services (24%). The agricultural sector accounts for less than 1%.

Table 18: Total energy consumption by the sectors analysed and the corresponding share of consumption for heating and cooling purposes in 2018 (ktoe)

	Total energy consumption	Consumption for heating purposes	Consumption for cooling purposes*	Share of energy consumption used for heating and cooling purposes
Industry	31 907	20 188		63%
Residential	32 056	25 134	214	79%
Services	19 338	12 547	1 639	73%
Agriculture	3 033	367		12%
Total	**86 334**	**58 236**		67%

* It should be noted that consumption for cooling purposes refers only to space cooling, and has been evaluated only for buildings in the service sector and for dwellings. In addition, consumption for cooling purposes linked to absorption machines other than those used in district cooling systems are not included, because it is low and thus of little statistical significance.

Considering, by contrast, consumption for heating and cooling purposes as a proportion of overall energy consumption (86.3 Mtoe), the highest figure is once again found in the residential sector (79%), followed by services (73%) and industry (63%).

It is important to stress that the heating and cooling consumption shares given above, on which this study focuses, do not represent the total energy consumption for cooling and heating purposes; as already mentioned, cooking in residential buildings, electric heating in industry and agriculture, and lastly consumption for process cooling have not been considered.

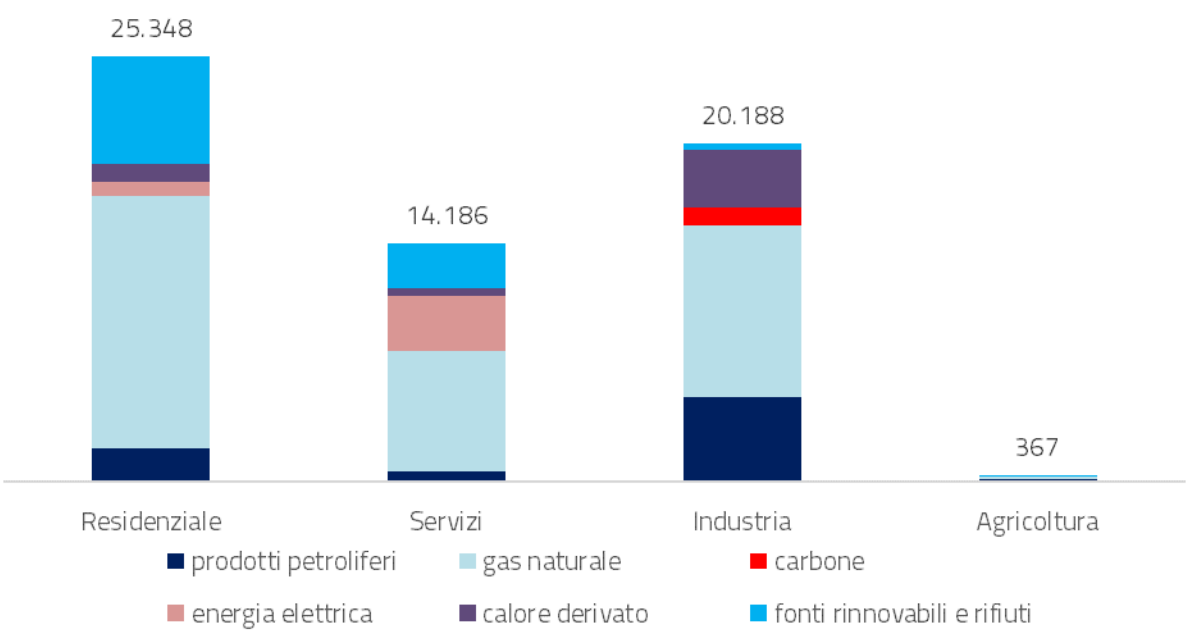
Table 19: Energy consumption for heating and cooling purposes in Italy (ktoe) relevant to this study

	Petroleum products	Natural gas	Coal	Electricity	Derived heat	Renewable sources and waste	Total
Residential	1 980	15 020		837	1 092	6 419	25 348
Services	541	7 251		3 244	444	2 706	14 186
Industry	5 024	10 232	1 088		3 437	406	20 188
Agriculture	136	137			11	83.5	367
Total	7 680	32 640	1 088	4 081	4 983	9 616	60 088

Source: processing of Eurostat data

Natural gas is the energy source contributing the most to consumption in the subgroup relevant to this report (see table above); it contributes 54% of the total, 59% in the residential sector alone and 51% in services and industry. Most of the petroleum products (65%) are used in industry, while coal is used solely in industry. Renewable energy sources (predominantly biomass and heat pumps) cover 25% of analysed consumption by the residential sector while derived heat is mainly used in industry. Regarding electrical energy, considering the civil sector alone, where this energy carrier has been taken into account for heating purposes, it is clear that there has been greater electrification of thermal consumption in the service sector than in the residential sector.

Figure 13: 2018 consumption for heating and cooling purposes, relevant to this study, broken down by sector and energy source (in ktoe)



Residenziale	Residential
Servizi	Services
Industria	Industry
Agricoltura	Agriculture
prodotti petroliferi	Petroleum products
Gas naturale	Natural gas

carbone	Coal
energia elettrica	Electricity
calore derivato	Derived heat
fonti rinnovabili e rifiuti	Renewable sources and waste

2 Demand for heating and cooling

This chapter describes the energy demand for heating purposes of Italian households and businesses in the year 2018, in the context of the national energy system.

Heat demand is defined here as the demand for useful energy needed to meet space heating, domestic hot water production and, in industry, process requirements. It represents the demand that households and businesses have to meet through consumption of different energy carriers. Quantitatively, heat demand is thus calculated on the basis of consumption of individual sources, applying specific energy conversion efficiencies; the difference between consumption and demand thus represents energy conversion losses.

For space cooling only, this requires the removal of heat from an enclosed space, and the correct way to measure this negative demand is currently under discussion at European level; it is therefore represented here in the tables below in terms of the energy consumption (mostly electricity) needed to remove heat.

In the context of the study, the assessment of heat demand is the main database for developing evolution scenarios for the 'heating and cooling' sector and for assessing the development potential of efficient heating; it seems appropriate that the analysis of the potential to improve the efficiency of the heating and cooling sector is based on a characterisation of demand, because this is independent of the plant technology used to satisfy it.

2.1 Residential sector

2.1.1 Regional distribution

The heat demand of dwellings is calculated on the basis of the consumption for heating and domestic hot water production established for each Region or Autonomous Province and for each energy source as described in Section 1.2 (reported below for convenience), applying specific energy conversion efficiencies.

As mentioned above, only electricity consumption is considered for cooling due to the uncertainty about demand statistics.

Table 20: Consumption and demand (2018) for space heating and cooling, hot water production and cooling in the residential sector, broken down by Region and Autonomous Province (ktoe)

	Consumption			Demand	
	Heating	DHW	Cooling	Heating	DHW
Piedmont	2 423.8	324.4	5.2	1 964.8	277.5
Valle d'Aosta	78.0	8.2	0.0	59.0	7.0
Lombardy	4 264.6	688.0	34.1	3 523.1	591.9
Bolzano	288.5	54.2	0.1	228.3	45.0
Trento	316.7	44.6	0.1	243.3	38.4
Veneto	2 290.9	338.4	30.2	1 829.3	289.3
Friuli-Venezia Giulia	650.4	81.0	4.4	512.1	69.0
Liguria	577.1	112.5	2.7	461.9	96.7
Emilia-Romagna	2 103.6	313.8	29.1	1 730.2	269.2
Tuscany	1 364.5	241.6	7.6	1 073.4	207.0
Umbria	412.5	59.8	0.9	308.2	49.4
Marche	545.4	101.6	2.6	427.4	85.7
Lazio	1 521.7	378.8	15.5	1 207.5	325.3
Abruzzo	625.8	96.6	2.2	470.2	80.2
Molise	141.7	20.1	0.4	105.8	16.4
Campania	897.9	333.7	17.4	665.8	283.0
Apulia	838.0	238.3	15.9	667.3	205.0
Basilicata	234.9	43.7	1.0	172.4	36.0
Calabria	617.2	107.9	6.8	445.4	89.3
Sicily	570.2	263.1	29.1	462.4	235.9
Sardinia	428.3	92.5	8.7	309.8	83.2
Italy	**21 191.5**	**3 942.7**	**214.0**	**16 867.8**	**3 380.4**

2.1.2 Geographical breakdown

Regional heat demand (heating and domestic hot water production) was distributed among more than 400 000 census zones to enable a precise analysis of the territory, identifying areas with the highest levels of heat demand and checking opportunities for recovering waste heat.

The breakdown of domestic hot water demand was calculated by assuming a constant demand pro capita for each Region and applying this specific demand to the resident population data for each census zone (source: ISTAT Census of Population and Housing, 2011). The work required for the winter heating demand is more complex; in this case, specific demand values (kWh/m^2) produced by RSE[8] for each climate zone and building type (size and period of construction) are used. For each census zone, information on the following was collected and appropriately processed:

- Climate zone
- National housing stock occupied by residents, taken from the ISTAT Census of Population and Housing (2011).

Regional heat demand was then divided between the m^2 of occupied dwellings on the basis of climate and building type, using the specific demand parameters produced by RSE as a proxy.

2.1.2.1 Housing stock

The national housing stock of dwellings occupied by residents, broken down by the period of construction of the building and the number of dwellings in the building, is shown in the table below.

Table 21: Dwellings occupied by residents, broken down by the period of construction of the building and the number of dwellings in the building

	Building size class							
	1 dwelling	2 dwellings	3-4 dwellings	5-8 dwellings	9-15 dwellings	16 or more dwellings	Total	
1918 or earlier	676 748	463 745	445 449	406 805	237 275	223 015	**2 453 037**	10%
1919-1945	530 469	357 542	315 554	277 393	216 314	336 166	**2 033 438**	8%
1946-1960	685 258	550 095	465 330	444 864	430 077	806 514	**3 382 138**	14%
1961-1970	765 952	782 817	639 949	588 106	618 540	1 434 559	**4 829 923**	20%
1971-1980	776 695	810 959	671 934	604 941	550 654	1 079 074	**4 494 257**	19%
1981-1990	562 861	511 079	447 723	429 889	381 673	711 649	**3 044 874**	13%
1991-2000	356 827	288 912	271 774	311 397	267 286	374 465	**1 870 661**	8%
2001-2005	190 446	137 127	148 706	208 302	188 201	226 550	**1 099 332**	5%
2006 or later	143 716	92 805	111 695	171 433	154 075	183 910	**857 634**	4%
Total	**4 688 972**	**3 995 081**	**3 518 114**	**3 443 130**	**3 044 095**	**5 375 902**	**24 065 294**	**100%**

[8] 'Winter and summer climate control in residential and services buildings'. RSE 2018.

	19%	17%	15%	14%	13%	22%	100%

Source: GSE processing of ISTAT data - 2011 census.

The next map shows the density of inhabited floor area, characterised by means of the plot ratio, calculated on the basis of 2011 ISTAT census data using the following formula:

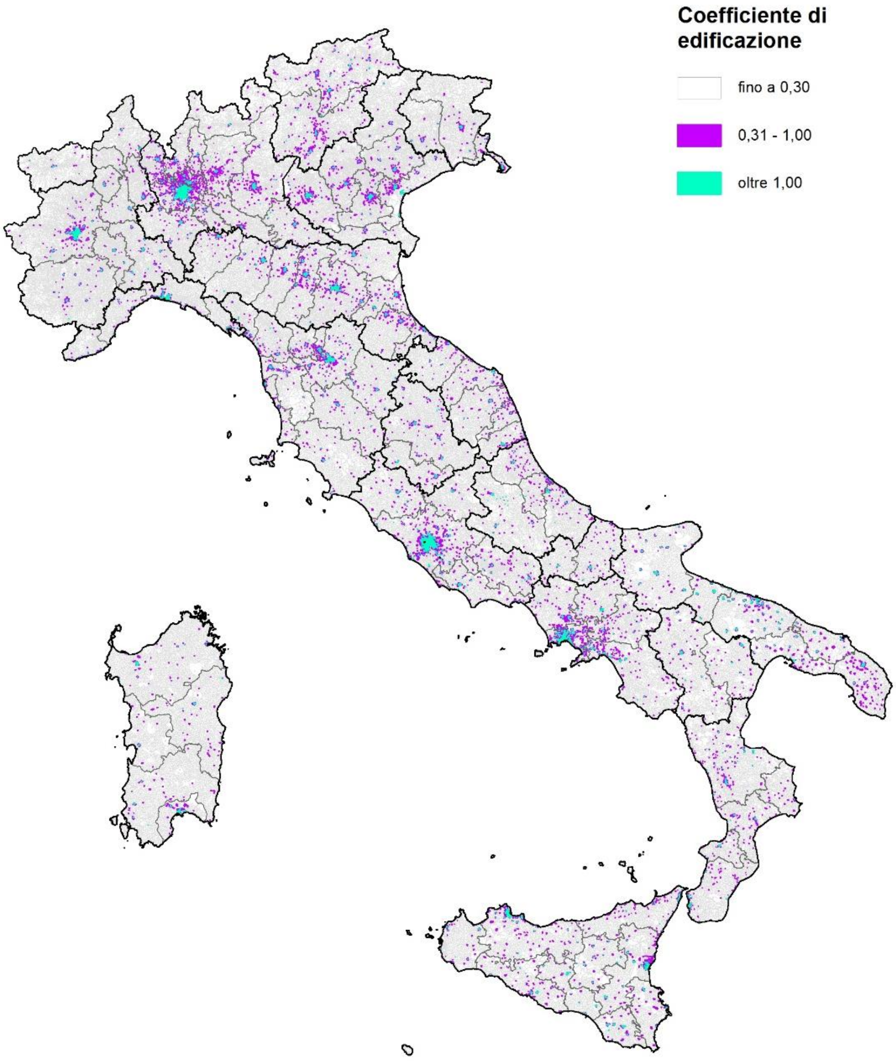
$$PR_i\ (\%) = \frac{Su_i}{A_i}$$

where:

- PR_i: Plot ratio of the nth area surveyed [%]
- Su_i: inhabited usable floor areas surveyed by the 2011 ISTAT Census [m^2]
- A_i: nth area of the 2011 ISTAT census zone [m^2]

The geographical resolution at which the plot ratio was calculated is very detailed, since the areas surveyed for the census (from which the aggregate value Su_i can be determined) have an average size of 0.6 km^2. The parameter used to assign a colour to the survey areas (census zones) shows whether the area has low construction density (plot ratio < 0.3), medium density (plot ratio 0.30-1) or high density (plot ratio > 1). The plot ratio is considered by many studies in the technical literature to be a proxy of heat demand; however, in Italy it should be considered with care because it needs to be assessed alongside specific requirements for units of usable floor area that vary widely across the country depending on latitude and terrain.

Figure 14: Map of the plot ratio



Coefficiente di edificazione	Plot ratio
fino a 0,30	up to 0.30
oltre 1,00	over 1.00

Generally speaking, the areas with high plot ratios are those of the country's large urban centres, where they cover an area of several square kilometres (Rome, Milan, Naples, Turin, Palermo, Genoa, Bologna, Florence, etc.). High ratios are also found in many small and medium-sized municipalities in the Po Valley and along much of Italy's coast.

2.1.2.2 Heat demand by census zone

As shown in the table below, more than 60% of domestic heating demand and 49% of domestic hot water demand occurs in climate zone E, which is broadly comparable to northern Italy. More than 38% of heat demand is concentrated in areas with density values above 30 kWh/m^2.

Table 22: Breakdown of relevant residential consumption, and the corresponding density, by climate zone

Climate zone	Demand for heating (GWh)	Demand for DHW (GWh)	Average density* of consumption (kWh/m^2)	Demand from zones with density* between 30 and 100 kWh/m^2 (GWh)	Demand from zones with density* above 100 kWh/m^2 (GWh)
A	12	13	0.49	2	-
B	2 028	1 742	0.58	465	21
C	17 050	7 407	0.69	4 961	412
D	43 676	9 515	0.86	16 699	4 278
E	122 895	19 221	1.33	35 240	11 408
F	10 512	1 415	0.44	1 946	204
Total	**196 172**	**39 314**	**0.99**	**59 311**	**16 321**

* density is calculated as the ratio of the consumption for winter heating and domestic hot water production associated with each individual census zone to the land area of the census zone.

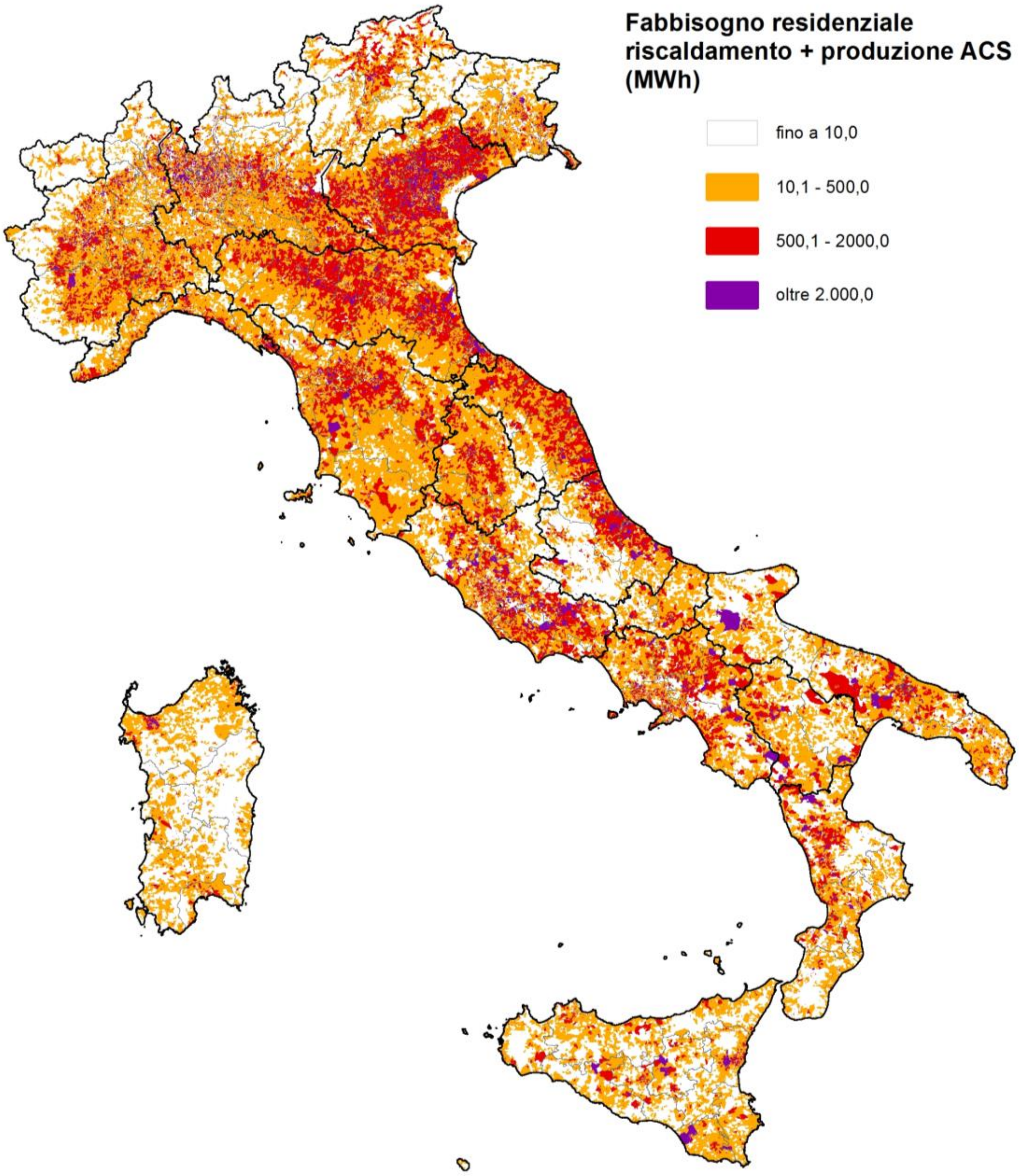
Analysing the demand of census zones on the basis of the plot ratio, it can be noted that, overall, areas with a plot ratio > 0.3 account for 31% of demand, compared to 0.6% of the total area of the country and 35% of its population. Considering only census zones in climate zones E-F, it can be noted that the demand from census zones with plot ratio > 0.3 in these zones is 25% of the total (in zones E and F).

Table 23: Characteristics of areas with a residential plot ratio > 0.3.

Climate zone	Number of municipal ity*	Residential demand** (MWh)	Land area** (m^2)	Occupied residential floor area** (m^2)	Population**
A	2	11 352	757 489	383 554	10 361
B	104	1 979 754	107 673 736	65 722 163	1 706 679
C	542	10 660 212	370 563 321	204 282 709	5 696 009
D	709	21 988 234	420 395 790	245 150 711	6 147 753
E	1 153	37 086 226	561 356 636	303 686 083	7 333 900
F	97	784 945	11 075 099	5 150 770	125 134
Total (PR > 0.3)	**2 607**	**72 510 723**	**1 471 822 070**	**824 375 990**	**21 019 836**
% of whole country	**32%**	**31%**	**0.6%**	**34%**	**35%**

* figure refers to the number of municipalities with at least one census zone with plot ratio > 0.3
** figure refers only to census zones with plot ratio > 0.3.

Figure 15: Residential demand for winter heating and domestic hot water production. 2018



Fabbisogno residenziale riscaldamento + produzione ACS (MWh)	Residential demand for heating and DHW production (MWh)
fino a 10,0	up to 10.0
oltre 2.000,0	over 2 000.0

2.1.2.3 Type of system by census zone

The processing of data from the census zones[9] has also made it possible to collect information about the types of heating systems used. In particular, reference is made to the following categories:

- Centralised air-conditioning and heating system,
- Stand-alone system in an apartment block,
- Stand-alone system in a single-family home.

These data have been used for subsequent analyses relating to the possibility of expanding district heating systems in each census zone (see section 7.2 in this regard) and to illustrate the number and heat demand of the following standard user types in order to evaluate the potential for expanding high-efficiency CHP. These standard user types have been derived from an analysis of data relating to HE CHP plants currently in operation.

Table 24: Characteristics of residential buildings identified as standard user types for high-efficiency CHP.

Building type*	Plant	Zone	Building data			Total demand			Demand of standard user type**		
			No Thousands	Total floor area Mm^2	Average floor area m^2	Heating GWh	DHW *** GWh	Electricity GWh	Heating kWh/m^2	DHW kWh/ed	Electricity kWh/ed
Single-family home	stand-alone	D	1 232	130	106	10 949	1 990	3 696	84	1 615	3 000
Medium apartment block	centralised	D	38	28	752	2 282		340	80		9 000
Large apartment block	centralised	D	20	51	2 635	3 140		293	61		15 000
Single-family home	stand-alone	E	2 416	272	112	32 784	4 195	7 247	121	1 736	3 000
Medium apartment block	centralised	E	104	77	744	8 756		933	114		9 000
Large apartment block	centralised	E	37	93	2 543	8 032		550	86		15 000
Single-family home	stand-alone	F	233	24	101	3 661	433	700	155	1 855	3 000
Medium apartment block	centralised	F	6	4	701	630		58	140		9 000
Large apartment block	centralised	F	1	1	2 356	137		9	99		15 000

*Medium-sized apartment blocks are defined as buildings with 5-8 and 9-15 dwellings. Large apartment blocks therefore have 16 dwellings or more. Since the aim of the analysis is to

[9]Some data, for example relating to the type of heating system used in dwellings in each census zone, have been made available by ISTAT to the Polytechnic University of Milan and subsequently shared with GSE.

evaluate the potential for expanding high-efficiency cogeneration systems, only apartment blocks with a high rate of occupancy have been considered, i.e. with at least the minimum number of dwellings occupied for the relevant category (5 or 9 for medium-sized apartment blocks and 16 for large apartment blocks).
** the values given for electricity consumption by users are estimates to be understood as indicative for standard user types and relate, for apartment blocks, only to common electrical utilities.
***the energy demand for domestic hot water production has only been assessed for single-family homes, because only in this type of building is it considered to be relevant for domestic cogeneration plants in this analysis.

2.2 Service sector

Heat demand in the service sector is calculated on the basis of the consumption for heating and domestic hot water production established for each Region or Autonomous Province and for each energy source as described in Section 1.3, applying specific energy conversion efficiencies.

2.2.1 Distribution by sector and by Region

The service sector is highly diverse in terms of structure, consumption profile and demand. The following table shows heat demand and consumption for cooling purposes by subsectors, calculated by GSE on the basis of the detailed evaluations set out in the section below, carried out on the basis of land registry and census data and with the help of RSE, making use of the extensive literature on the subject[10]. The breakdown of demand by subsector was necessary in order to start the analysis of the HE CHP potential in which various standard user types in the service sector are evaluated (see Section 8.6) and to accurately distribute heating and DHW demand between the census zones, as described in the following paragraph, used to analyse DH potential (see Section 7.2). In addition, as already mentioned, the analysis of individual sectors allowed consumption for cooling purposes to be estimated using the parameters provided by RSE.

[10] RSE, Madonna et al. 'Studio sulla domanda di climatizzazione: influenza del comportamento dell'utenza sui consumi ed effetto rebound nel caso di riqualificazioni energetiche' [Study on the demand for heating and air conditioning: influence of user behaviour on consumption and rebound effect in energy retrofitting]. RSE report 16002288, 2016.

RSE, Lorenzo Croci et al. 'Fabbisogno di climatizzazione invernale ed estiva degli edifici residenziali e del terziario' [Winter and summer climate control in residential and services buildings], RdS Report No 18007687, December 2018.

RSE, 'La pompa di calore. Una soluzione efficiente e sostenibile' [Heat pumps: an efficient and sustainable solution]. RSEView, editrice ALKES, December 2018.

RSE, F. Carrara 'I consumi energetici della Pubblica Amministrazione Stima dei consumi e scenari di riqualificazione energetica, Rapporto RSE GSE' [Energy consumption by public bodies: estimated consumption and energy retrofitting scenarios, RSE and GSE report], December 2014.

Table 25: Regional demand for heating and DHW by the service sector in Italy, broken down by subsector (figures in ktoe)

	Commercial	Education	Offices*	Health	Government	Hotels	Sports and sports complexes	Leisure activities	Other	Total
Piedmont	534	76	64	135	60	37	81	29	98	**1 112**
Valle d'Aosta	6	2	1	1	2	4	1	0	2	**20**
Lombardy	1 644	212	311	232	115	65	174	74	190	**3 018**
Autonomous Province of Bolzano	88	14	10	7	8	30	10	11	14	**192**
Autonomous Province of Trento	78	13	8	9	10	16	9	8	11	**162**
Veneto	1 100	103	140	76	65	105	102	50	106	**1 847**
Friuli-Venezia Giulia	171	25	22	36	24	14	20	10	32	**354**
Liguria	54	8	8	31	6	10	14	3	10	**144**
Emilia-Romagna	955	66	117	112	50	157	113	40	95	**1 704**
Tuscany	235	33	41	64	25	33	63	19	33	**545**
Umbria	78	7	12	16	6	13	29	5	13	**179**
Marche	176	15	18	22	14	17	25	8	19	**315**
Lazio	234	21	28	56	35	20	28	7	35	**465**
Abruzzo	96	12	10	22	10	8	21	2	11	**192**
Molise	8	1	1	4	2	2	2	0	1	**20**
Campania	160	13	15	66	12	14	24	2	17	**322**
Apulia	104	10	8	32	7	8	15	0	9	**194**
Basilicata	11	1	1	4	2	1	2	0	1	**25**
Calabria	39	3	3	18	4	6	7	1	3	**83**
Sicily	109	8	10	52	11	12	14	2	11	**229**
Sardinia	47	4	4	16	8	7	8	1	4	**97**
Italy	**5 926**	**646**	**832**	**1 011**	**478**	**579**	**760**	**272**	**716**	**11 221**

* includes building units in land registry category A10.

Table 26: Electricity consumption per Region/Autonomous Province for cooling purposes in the service sector in Italy, broken down by subsector (figures in ktoe)

	Commercia l	Health	Offices*	Hotels	Other sectors	Total
Piedmont	66	10	5	4	8	**93**
Valle d'Aosta	2	0	0	0	0	**2**
Lombardy	191	21	25	9	14	**260**
Autonomous Province of Bolzano	11	0	1	1	1	**14**
Autonomous Province of Trento	10	0	1	0	1	**12**
Veneto	92	11	12	9	8	**133**
Friuli-Venezia Giulia	19	3	2	1	3	**28**
Liguria	26	5	2	3	2	**38**
Emilia-Romagna	84	14	11	14	8	**130**
Tuscany	73	7	7	8	6	**102**
Umbria	14	2	2	2	2	**21**
Marche	27	3	3	3	3	**39**
Lazio	131	13	9	10	14	**178**
Abruzzo	24	3	2	2	2	**33**
Molise	5	1	0	1	1	**8**
Campania	109	22	7	9	7	**155**
Apulia	87	16	6	7	6	**122**
Basilicata	9	1	1	1	1	**13**
Calabria	34	8	3	4	4	**53**
Sicily	91	20	6	9	8	**135**
Sardinia	42	7	3	5	6	**63**
Italy	**1 148**	**169**	**106**	**103**	**107**	**1 631**

* Includes building units in land registry category A10.

2.2.2 Geographical breakdown

Demand for heating and DHW were distributed among the census zones in each Region or Autonomous Province following the steps below:

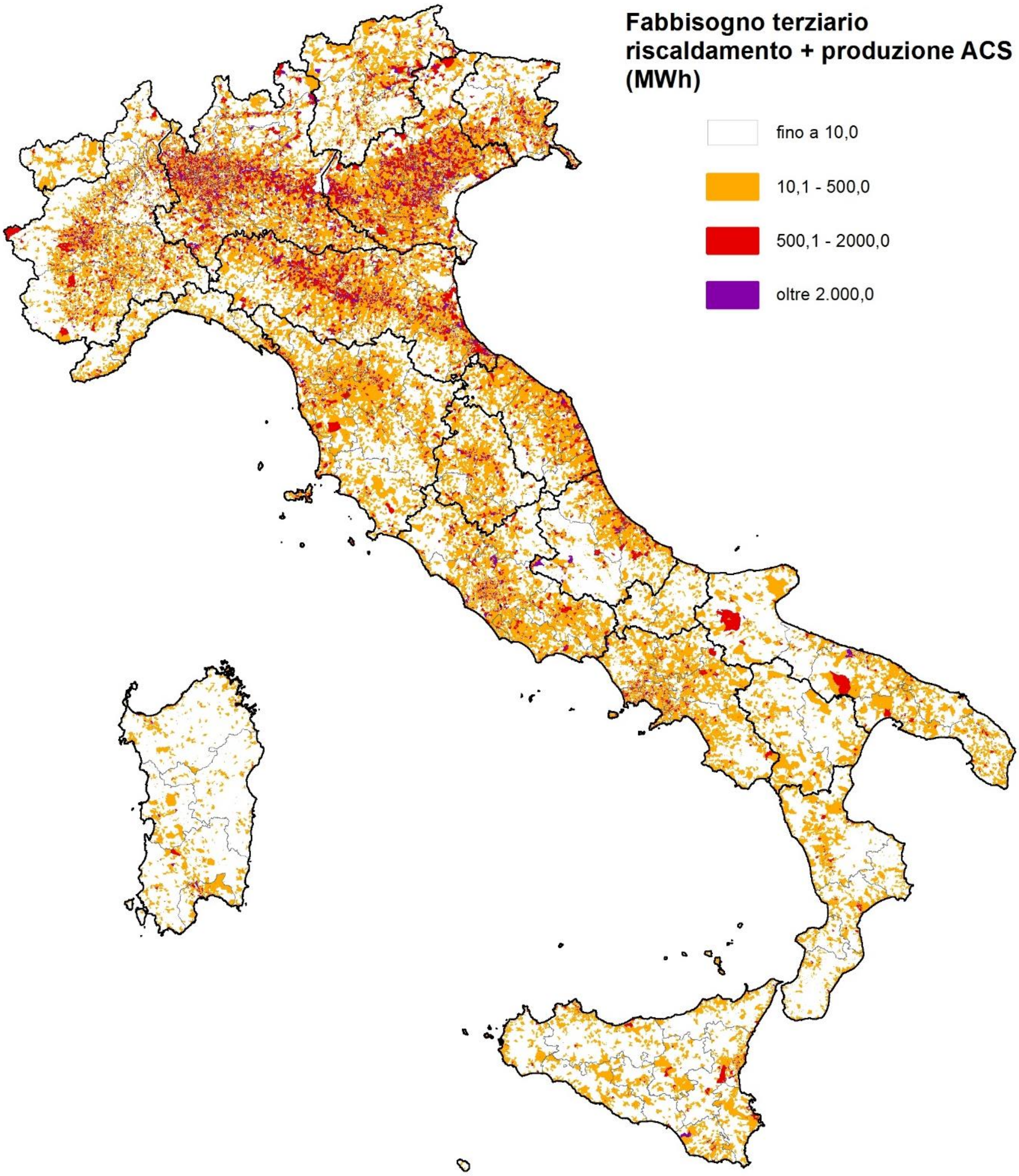
- processing of the information published by the Real Estate Market Observatory, managed by the Land Registry/Revenue Agency, relating to the property assets in each subsector (the data are available for each province and, separately, for each capital city);
- collection of data on the number of employees in each subsector, taken from the 2011 Census of Industry and Services, for each census zone;
- division of the floor area and volume of each subsector between the census zones of provinces, excluding capital cities and, separately, the zones of capital cities, on the basis of the number of employees recorded in each zone;
- distribution of the total regional demand between the census zones using specific demand data for each subsector as a proxy, developed in collaboration with RSE. In particular, the heating and cooling demand was estimated using the calculation programme developed by RSE (CARAPACE) which is based on the UNI-EN-ISO 13790 and UNI/TS 11300-1 and related annexes, and the reference standards.

Table 27: Breakdown of relevant consumption in the service sector, and the corresponding density, by climate zone

Climate zone	Heating and DHW demand in the service sector (GWh)	Average density* of consumption (kWh/m²)	Civil sector demand in census zones with density* between 30 and 100 kWh/m² (GWh)	Civil sector demand in census zones with density* over 100 kWh/m² (GWh)
A	11	0.22	2	-
B	1 829	0.28	538	189
C	8 538	0.24	2 474	1 061
D	18 072	0.29	5 763	4 195
E	94 907	0.89	30 078	27 691
F	7 140	0.26	2 365	1 267
Total	**130 497**	**0.55**	**41 220**	**34 402**

(*) Density is calculated as the ratio of the consumption for winter heating and domestic hot water production associated with each individual census zone to the land area of the census zone.

Figure 16: Demand for winter heating and domestic hot water production in the service sector. 2018



Fabbisogno terziario riscaldamento + produzione ACS (MWh)	Demand for heating and DHW production in the service sector (MWh)
fino a 10.0	up to 10.0
oltre 2.000,0	over 2 000.0

2.3 Industry

Heat demand in industry is calculated on the basis of the consumption for heating established for each industrial sector and for each energy source as described in Section 1.4, applying specific energy conversion efficiencies.

Table 28: Demand for heating in the industrial sector, including the energy industry, in Italy, broken down by subsector, for the year 2018 (figures in ktoe)

	Heat demand
Iron & steel	1 809
Chemical & petrochemical	1 894
Non-ferrous metals	447
Non-metallic minerals	3 193
Transport equipment	103
Machinery	1 496
Mining & quarrying	60
Food, beverages & tobacco	1 589
Paper, pulp & printing	1 265
Wood & wood products	217
Construction	213
Textile & leather	622
Other industries	206
Own use in electricity, CHP and heat plants	2
Oil and natural gas extraction plants	1 041
Oil refineries (Petroleum Refineries)	3 565
Other energy (coke ovens, coal mines, etc.)	792
Total	**18 513**

*Source: GSE processing of Eurostat data

2.4 Agriculture and fishery

It was not considered essential to analyse the demand from agriculture and fishery, given that the consumption for heating and cooling, set out in Section 1.5, is marginal compared to the total; that said consumption generally has unusual features in terms of time profile and geographical location, making it difficult to assimilate it to other heat demand; the centres of that agricultural heat consumption can rarely be linked to district heating networks, as shown by the current proportion of agricultural customers using district heating networks.

2.5Overview as of 2018

Focusing on the civil sector, for which specific geographical breakdown analyses have been carried out, a number of summary tables are provided below.

Table 29: Average heat demand in the civil sector per capita, broken down by Region/Autonomous Province and climate zone (MWh/inhabitant)

	Climate zone						Total
	A	B	C	D	E	F	
Abruzzo			4.4	6.2	8.6	11.3	7.6
Basilicata			2.8	4.4	5.9		5.0
Bolzano					10.1	10.5	10.5
Calabria		2.1	3.0	5.0	7.1	5.2	4.5
Campania			2.4	3.8	4.9	5.5	3.4
Emilia-Romagna				8.0	9.3	12.2	9.7
Friuli-Venezia Giulia					8.4	10.2	8.9
Lazio			3.0	4.3	6.1	8.0	5.0
Liguria			3.8	5.5	7.9	10.0	6.3
Lombardy					8.1	10.0	8.4
Marche				5.4	7.1		6.4
Molise			2.7	4.8	6.8	7.5	6.1
Piedmont					9.7	11.5	10.2
Apulia			2.9	4.0	5.6		3.4
Sardinia		2.1	3.3	5.5	6.5		4.1
Sicily	1.6	1.7	2.3	3.5	5.0	4.0	2.6
Tuscany			5.1	5.4	7.1	9.5	6.2
Trento					8.2	10.4	10.0
Umbria				6.1	7.4		6.9
Valle d’Aosta					7.6	8.4	8.2
Veneto				12.2	8.5	11.4	9.0
Overall total	**1.6**	**1.9**	**2.9**	**4.8**	**8.3**	**10.7**	**7.2**

Table 30: Absolute heat demand in the civil sector, broken down by Region/Autonomous Province and climate zone (GWh)

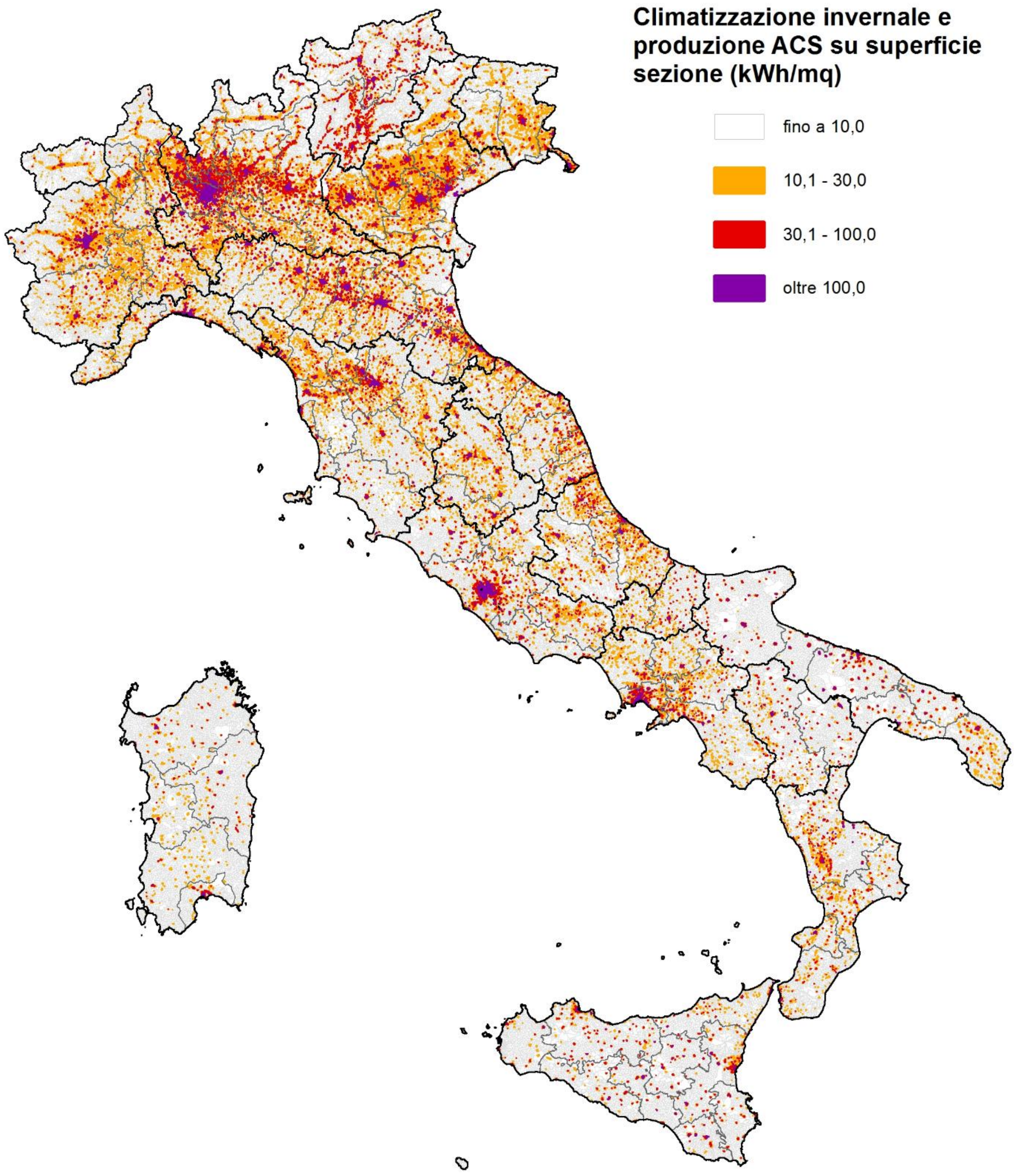
	Less than 10 000 inhabitants	Between 10 000 and 60 000 inhabitants	Between 60 000 and 250 000 inhabitants	More than 250 000 inhabitants	TOTAL
Abruzzo	3 758	3 531	1 341	0	8 630
Basilicata	1 532	822	358	0	2 712
Bolzano	3 056	1 265	996	0	5 317
Calabria	4 254	1 847	1 088	0	7 189
Campania	4 418	6 459	1 726	2 174	14 777
Emilia-Romagna	10 185	14 895	14 384	3 582	43 046
Friuli-Venezia Giulia	4 827	3 236	2 793	0	10 856
Lazio	4 005	6 570	1 359	11 303	23 237
Liguria	2 433	1 915	794	3 022	8 165
Lombardy	32 717	27 734	10 720	11 669	82 841
Marche	3 479	4 421	1 730	0	9 631
Molise	1 125	535	0	0	1 659
Piedmont	16 619	12 825	2 498	7 256	39 197
Apulia	2 211	6 971	2 368	850	12 400
Sardinia	2 938	1 708	1 057	0	5 703
Sicily	2 801	4 832	1 549	1 601	10 783
Tuscany	4 977	8 392	5 628	2 221	21 218
Trento	3 187	873	1 199	0	5 259
Umbria	1 454	2 909	1 878	0	6 242
Valle d'Aosta	753	245	0	0	998
Veneto	15 518	20 620	4 626	5 361	46 124
Overall total	**126 247**	**132 604**	**58 092**	**49 039**	**365 983**

Table 31: Breakdown of relevant consumption in the civil sector, and the corresponding density, by climate zone

Climate zone	Residential demand for heating (GWh)	Residential demand for DHW (GWh)	Heating and DHW demand in the service sector (GWh)	Average density* of consumption (kWh/m^2)	Civil sector demand in census zones with density* between 30 and 100 kWh/m^2 (GWh)	Civil sector demand in census zones with density* over 100 kWh/m^2 (GWh)
A	12	13	11	0.71	6	-
B	2 028	1 742	1 829	0.86	1 314	236
C	17 050	7 407	8 538	0.93	8 699	1 995
D	43 676	9 515	18 072	1.15	23 283	10 792

E	122 895	19 221	94 907	2.22	73 534	47 473
F	10 512	1 415	7 140	0.70	5 167	1 801
Total	**196 172**	**39 314**	**130 497**	**1.54**	**112 002**	**62 297**

Figure 17: Density of consumption in the civil sector for heating and for domestic hot water production. 2018



Climatizzazione invernale e produzione ACS su superficie sezione (kWh/mq)	Winter heating and domestic hot water (DHW) production by land area of census zone (kWh/m^2)
fino a 10,0	up to 10.0

oltre 100,0	over 100.0

Table 32: Electricity consumption for space cooling by Region/Autonomous Province. 2018 (GWh)

	Electricity consumption for space cooling
Abruzzo	410
Basilicata	160
Bolzano	155
Calabria	694
Campania	2 000
Emilia-Romagna	1 850
Friuli-Venezia Giulia	379
Lazio	2 245
Liguria	477
Lombardy	3 419
Marche	482
Molise	97
Piedmont	1 145
Apulia	1 599
Sardinia	839
Sicily	1 911
Tuscany	1 277
Trento	151
Umbria	253
Valle d'Aosta	28
Veneto	1 893
Overall total	**21 463**

3 Derived heat and district heating

This chapter illustrates the trends in derived heat production in Italy over the years and focuses in particular on a subset thereof, namely district heating systems[11]. The main information sources referred to are:

- Eurostat for official data on derived heat;
- AIRU, the Italian Urban Heating Association, collects and publishes detailed information in its yearbook on the main district heating systems in operation in Italian territory;
- GSE, which carries out surveys of several categories of plants and operators, complementing those carried out by AIRU and in collaboration with the latter; in particular, the GSE surveys mainly consider district heating systems using biomass, which are generally small in size;
- the administrative archives of various Regions and Autonomous Provinces.

The data presented were obtained by collating three information sources; more generally, the layout and some of the contents of this chapter are taken from the annual GSE publication 'District heating and cooling - deployment of networks and energy supplied in Italy - 2018'[12].

[11] Reference is made here to the definition included in Article 2 of Italian Legislative Decree No 28/2011, according to which district heating means the distribution of thermal energy from one or more sources of production through a network to multiple buildings or sites, to be used for space heating, manufacturing processes and domestic hot water supply. 'Derived heat' includes other forms of heat production for transfer/sale to third parties (for example distribution of thermal energy to a single building or site).
[12] https://www.gse.it/dati-e-scenari/statistiche

3.1Derived heat

The total consumption of derived heat[13] recorded in Italy between 2009 and 2018 in the different sectors is set out in the following table.

Table 33: Consumption of derived heat in Italy between 2009 and 2018 (figures in ktoe)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Consumption in energy sector	**1 225**	**1 573**	**2 021**	**1 490**	**1 448**	**1 154**	**1 309**	**1 373**	**1 403**	**1 203**
Own use in electricity, CHP and heat plants	-	-	1	1	1	2	0	0	0	*2*
Consumption in oil and gas extraction	20	56	17	19	18	21	22	15	16	*21*
Consumption in petroleum refineries	1 066	953	1 105	968	1 078	747	912	961	959	*549*
Consumption in coal mines	-	-	-	2	2	0	-	-	-	-
Consumption in coke ovens	2	2	3	2	4	5	7	7	8	*8*
Consumption in non-specified (energy)	138	563	895	498	345	379	368	390	420	*624*
Distribution losses	**-**	**-**	**17**	**21**	**19**	**18**	**21**	**24**	**58**	**58**
Final energy consumption	**3 094**	**3 332**	**3 195**	**3 433**	**3 702**	**3 747**	**3 851**	**3 950**	**4 114**	**4 221**
Industry	2 938	3 129	2 445	2 583	2 560	2 629	2 696	2 736	2 874	2 234
Iron and steel	267	38	43	125	87	94	160	188	162	*90*
Non-ferrous metals	0	0	1	1	1	1	0	0	0	*0*
Chemicals and petrochemicals	1 086	1 048	1 132	909	1 243	902	811	875	1 033	*633*
Non-metallic minerals	74	78	84	100	108	130	166	134	126	*147*
Mining and quarrying	0	0	0	0	0	5	1	1	1	*1*
Food and tobacco	177	159	241	278	266	378	320	351	379	*382*
Textile and leather	29	43	45	42	40	44	35	36	40	*39*
Paper, pulp and print	543	515	589	844	564	837	940	874	833	*666*
Transport equipment	97	171	101	90	79	87	96	109	111	*103*
Machinery	18	20	24	23	15	15	25	30	29	*28*
Wood and wood products	33	29	32	32	27	36	31	33	36	*33*
Construction	0	0	0	0	0	1	0	0	0	*0*
Non-specified (industry)	612	1 027	152	138	129	99	110	105	122	*111*
Residential	52	123	568	694	931	818	908	947	905	1 242
Agriculture/forestry	13	1	9	15	20	22	9	11	10	11
Services	62	49	139	105	154	266	221	245	308	714

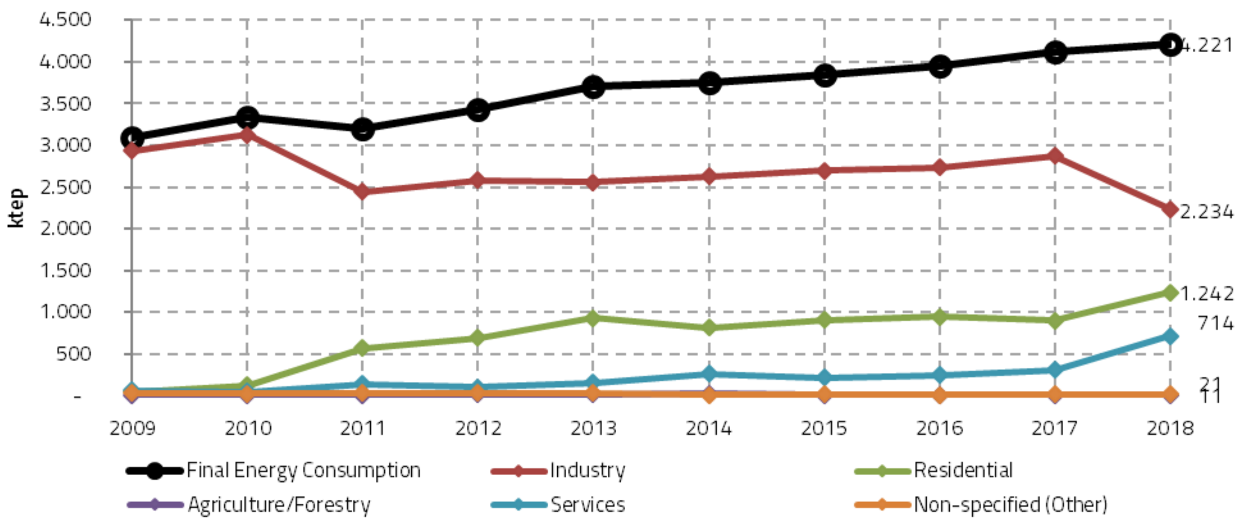
[13] Derived heat is defined as heat produced in renewable and non-renewable energy plants and transferred/sold to third parties, either through district heating (DH) networks or through direct sales - without links to district heating networks - to a single user or to a small group of users (such as hospitals, shopping centres, etc.).

Non-specified (other)	31	29	34	35	37	11	17	11	16	21

Source: processing of Eurostat data

Final consumption of derived heat has increased by 36% over the past 10 years. The largest increases were recorded in the residential and service sectors; while consumption in the energy sector remained more or less constant and the industrial sector saw a decline (variation of -24%).

Figure 18: Trends in derived heat consumption over the 2009-2018 period, broken down by consumption sectors (ktoe)



The following table illustrates changes in the mix of energy sources used to produce derived heat. Natural gas consistently accounts for 60% of production, followed by renewables (around 17% in 2018); petroleum products – mostly used by autoproducers – are in sharp decline: their share of the total has fallen from 35% in 2009 to 14% in 2018.

Lastly, cogeneration plants produced 94% of the derived heat consumed in 2018.

Table 34: Production of derived heat in Italy between 2009 and 2018 (figures in ktoe)

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Heat only plants	**Main activity**	**-**	**68**	**78**	**89**	**90**	**84**	**89**	**98**	**323**	**356**
	Gas oil/diesel oil	-	-	-	-	-	-	-	-	2	3
	Residual fuel oil	-	-	-	-	-	-	-	-	-	1
	Natural gas	-	-	-	-	-	-	-	-	223	250
	Solid biofuels (excluding charcoal)	-	53	64	74	74	65	70	78	78	80
	Biogases	-	0	0	0	0	0	0	0	0	0
	Other liquid biofuels	-	-	-	-	-	0	0	0	1	1
	Geothermal	-	14	14	16	16	18	19	19	19	21
	Solar thermal	-	-	0	0	0	0	0	0	0	0
CHP plants	**Main activity**	**1 837**	**2 212**	**2 604**	**2 681**	**3 080**	**3 085**	**3 303**	**3 712**	**3 625**	**3 356**
	Other bituminous coal	-	18	30	29	30	26	36	37	37	37
	Coke oven gas	12	11	16	32	30	24	7	25	8	8
	Blast furnace gas	6	12	15	53	34	36	-	27	-	-
	Other recovered gases	-	-	-	1	0	0	-	-	-	-
	Refinery gas	51	72	76	34	43	14	55	249	239	248
	Liquefied petroleum gases (LPG)	-	-	-	-	-	-	-	3	2	2
	Gas oil/diesel oil	2	1	3	1	1	2	1	0	2	1
	Residual fuel oil	26	24	14	27	48	15	71	63	59	46
	Other oil products	180	186	148	151	252	281	270	308	301	307
	Natural gas	1 384	1 656	1 639	1 801	1 828	1 736	1 959	2 068	2 025	1 769
	Industrial waste	-	-	-	1	0	1	5	7	7	4
	Municipal waste (renewable)	48	55	83	70	83	84	106	117	124	124
	Municipal waste (non-renewable)	48	55	83	70	83	84	106	117	124	124
	Solid biofuels (excluding charcoal)	42	78	153	260	432	521	455	455	441	439
	Biogases	14	19	322	132	195	229	192	195	212	200
	Other liquid biofuels	23	24	22	20	20	31	39	40	43	48
	Autoproducers	**2 482**	**2 625**	**2 551**	**2 173**	**2 000**	**1 751**	**1 790**	**1 537**	**1 627**	**1 771**
	Other bituminous coal	5	12	9	3	5	10	9	8	9	9
	Coke oven gas	-	-	-	-	-	-	17	13	28	21
	Blast furnace gas	-	-	-	-	-	-	65	64	65	30
	Other recovered gases	-	-	-	-	-	-	11	0	2	0
	Refinery gas	289	341	389	406	386	301	311	141	140	119
	Liquefied petroleum gases (LPG)	12	9	7	9	5	3	3	1	1	1
	Naphtha	59	43	41	26	25	6	-	-	-	-
	Other kerosene	0	1	0	0	1	1	0	0	0	0
	Gas oil/diesel oil	0	0	0	0	1	2	1	0	0	1
	Residual fuel oil	695	520	426	259	224	143	49	13	11	14
	Petroleum coke	153	142	170	74	77	34	13	-	-	-
	Other oil products	25	99	109	97	10	11	8	28	14	19
	Natural gas	1 195	1 421	1 361	1 276	1 243	1 217	1 276	1 244	1 315	1 512
	Industrial waste	3	-	-	-	2	1	1	0	1	4
	Municipal waste (renewable)	8	7	3	1	1	1	2	0	-	3
	Municipal waste (non-renewable)	8	7	3	1	1	1	2	0	-	3

	Solid biofuels (excluding charcoal)	*19*	*16*	*29*	*12*	*12*	*7*	*5*	*9*	*24*	*19*
	Biogases	*5*	*5*	*5*	*6*	*6*	*9*	*13*	*12*	*14*	*14*
	Other liquid biofuels	*5*	*0*	*0*	*2*	*3*	*2*	*3*	*2*	*2*	*3*
Total gross production		**4 319**	**4 904**	**5 233**	**4 944**	**5 169**	**4 919**	**5 182**	**5 347**	**5 575**	**5 483**

Source: processing of Eurostat data

3.2District heating

In Italy, district heating is today a widespread and established reality, with more than 300 networks covering a total of 4 800 km and 9.3 GW of installed thermal capacity. More than 250 municipalities are served by at least one network, mostly concentrated in the northern regions of the country. Looking at the residential sector, these networks meet about 2% of the total national demand for energy products for heating and domestic hot water production. In 2018, the thermal energy fed into the grid by plants serving district heating networks amounted to 1 014 ktoe (11 798 GWh) while the thermal energy supplied to users amounted to 842 ktoe (9 787 GWh). Losses during heat distribution amounted to 17% of feed-in energy (173 ktoe, 2 010 GWh).

In more recent years, a parallel district cooling service has gradually become more widespread, supplied by a dedicated distribution network (with refrigerated water) or via absorption units installed at the users' premises and fed by the district heating network. In 2018, a total of 11.2 ktoe (129.8 GWh) of refrigerated energy was supplied to users.

The leading role to be played by district heating and cooling systems in Italy is also confirmed by the Integrated National Energy and Climate Plan (INECP), submitted to the European Commission in January 2020, which makes these systems key to achieving the sustainable development and energy savings targets, anticipating an additional extension of the networks and emphasising the distribution of efficient systems.

Table 35: Overview of district heating networks in Italy as of 2018

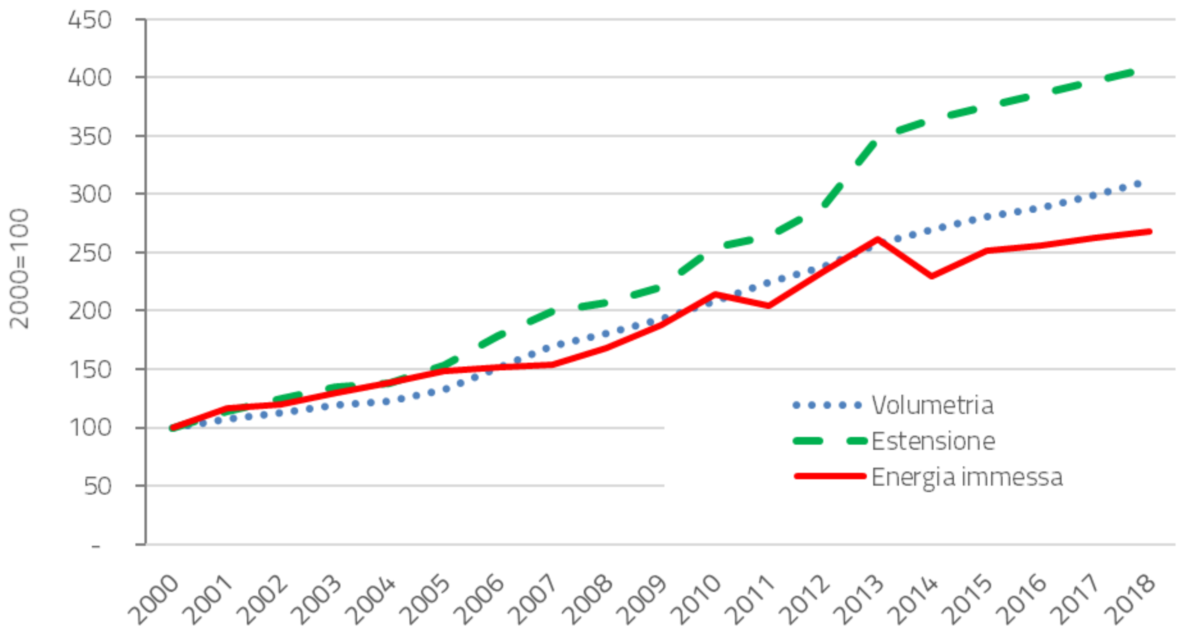
Municipalities with district heating	**No**	**255**		
Total heated volume	**Mm³**	**364**		
Length of distribution networks	**km**	**4 835**		
Thermal energy supplied	**MWht**	**9 787 498**		
Residential	"	6 240 509	*% of total*	64%
Services	"	3 286 955	"	34%
Industrial	"	260 034	"	3%
Losses	**MWht**	**2 010 482**	**% of feed-in energy**	**17%**
Feed-in thermal energy	**MWht**	**11 797 980**		
Gas CHP	"	4 701 463	% of total	40%
Non-renewable waste CHP	"	918 635	"	8%
Other fossil fuels CHP	"	330 182	"	3%
Bioenergy CHP*	"	1 716 996	"	15%
Gas HO	"	2 858 172	"	24%
Other fossil fuels HO	"	64 628	"	1%
Bioenergy HO	"	866 156	"	7%
Geothermal HO	"	253 131	"	2%
Heat pumps HO	"	19 541	"	0%
Solar power HO	"	983	"	0%
Energy recovery	"	68 093	"	1%
Refrigerated energy supplied	**MWht**	**129 790**		
Services	"	127 550	*% of total*	98%
Residential	"	1 626	"	1%
Industrial	"	614	"	0%
Losses	**MWht**	**3 710**	**% of feed-in energy**	**3%**
Feed-in refrigerated energy	**MWht**	**133 500**		
Efficient plants (feed-in thermal energy)	**No**	**226**	**MWht**	**8 877 186**
Renewables ≥ 50%	"	158	"	1 576 522
CHP ≥ 75%	"	28	"	4 987 760
EITHER CHP ≥ 75% OR RENEWABLES ≥ 50%	"	31	"	486 150
COMBINATION ≥ 50%	"	9	"	1 826 754
Non-efficient plants	**No**	**88**	**MWht**	**2 920 794**

*Includes the biodegradable fraction of waste

3.2.1 Growth of district heating in Italy

District heating has developed steadily in Italy over the past 20 years. As shown in the graph below, between 2000 and 2018 the space heated has increased by 211% overall, while the length of the networks has increased by 308% and the feed-in energy by 168%.

Figure 19: Trends in space heated, size and feed-in energy over time (2000=100)



Volumetria	Space heated
Estensione	Size
Energia immessa	Feed-in energy

Source: GSE processing of AIRU data

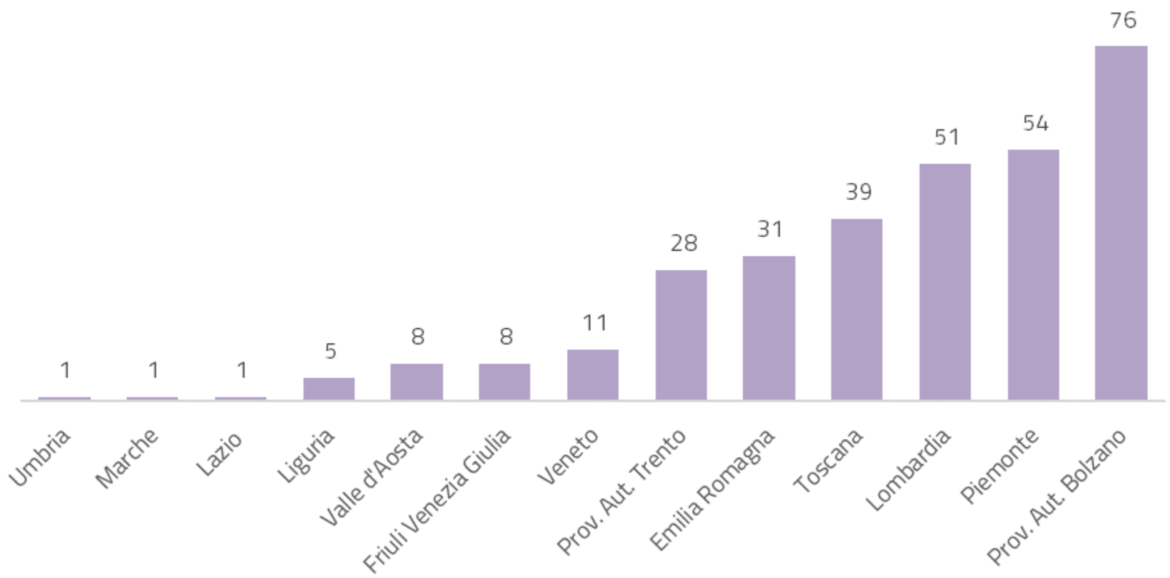
The development of district heating in Italy started later than in other European countries, both as a result of the climate conditions, which are on average less cold than other countries, and of strategic alternatives (for example the natural gas distribution programme launched in northern Italy in the 1950s).

The first projects date back to the 1970s, with networks in Modena (Quartiere Giardino, 1971), Brescia (1972), Mantua (1972), Verona (Forte Procolo, 1973), Reggio Emilia (Rete 1 and Pappagnocca, 1979). Of these, Brescia's network grew the fastest, reaching 20 million m^3 of heated space by 1990, or half of the volume heated by district heating in Italy at that time. In the 1980s and 1990s, many Italian cities launched their own networks. Some of these were relatively small and linked to specific residential initiatives (Rome), while others were part of an organic project to supply district heating to large areas (Alba, Cuneo, Cremona, Vicenza, Ferrara, Turin). Since the 1990s, a number of small mountain towns have also developed district heating networks using biomass-fuelled systems.

3.2.2 Distribution and characteristics of district heating networks in 2018

At the end of 2018, there were 314 district heating networks in operation in Italy, concentrated in the northern and central regions of the country. There are 255 municipalities served by at least one network, spread across 13 Regions and 2 Autonomous Provinces.

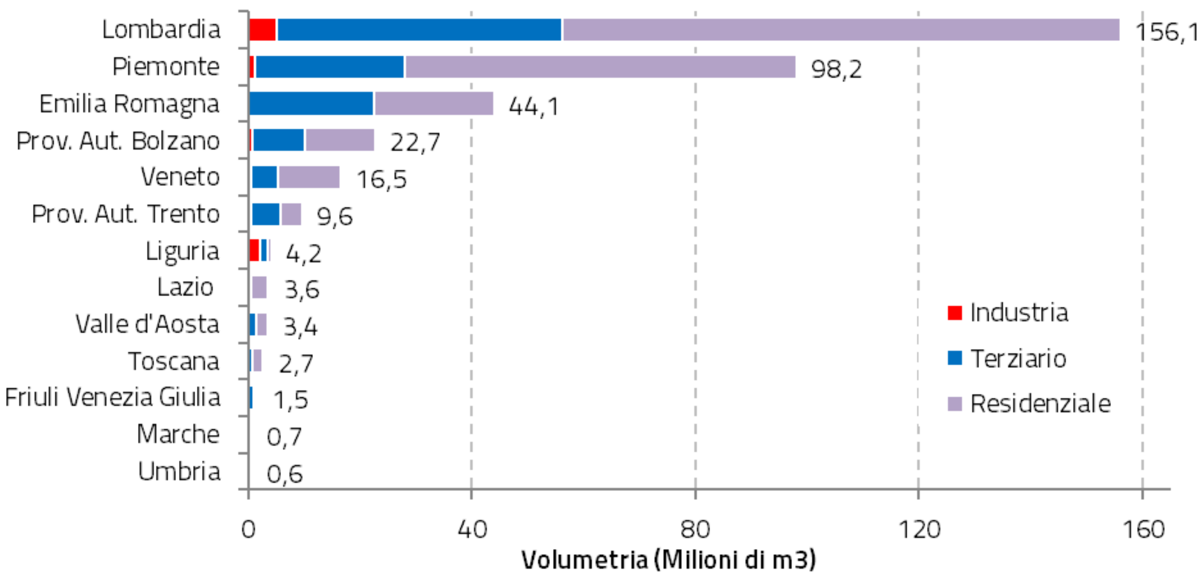
Figure 20: Number of district heating networks per Region/Autonomous Province in 2018



Umbria	Umbria
Marche	Marche
Lazio	Lazio
Liguria	Liguria
Valle d'Aosta	Valle d'Aosta
Friuli Venezia Giulia	Friuli-Venezia Giulia
Veneto	Veneto
Prov. Aut. Trento	Autonomous Province of Trento
Emilia Romagna	Emilia-Romagna
Toscana	Tuscany
Lombardia	Lombardy
Piemonte	Piedmont
Prov. Aut. Bolzano	Autonomous Province of Bolzano

The district heating networks extend across a distance of just over 4 800 km, around 50% of which is accounted for by the 105 district heating systems in Lombardy and Piedmont. These networks serve over 90 000 utility substations (i.e. the exchange facilities between the district heating network and the user distribution circuit); in this case, too, the largest share can be found in Lombardy (39% of the total), followed by the Province of Bolzano (22%) and Piedmont (14%).

Figure 21: Built stock volumes connected to the district heating network in 2018

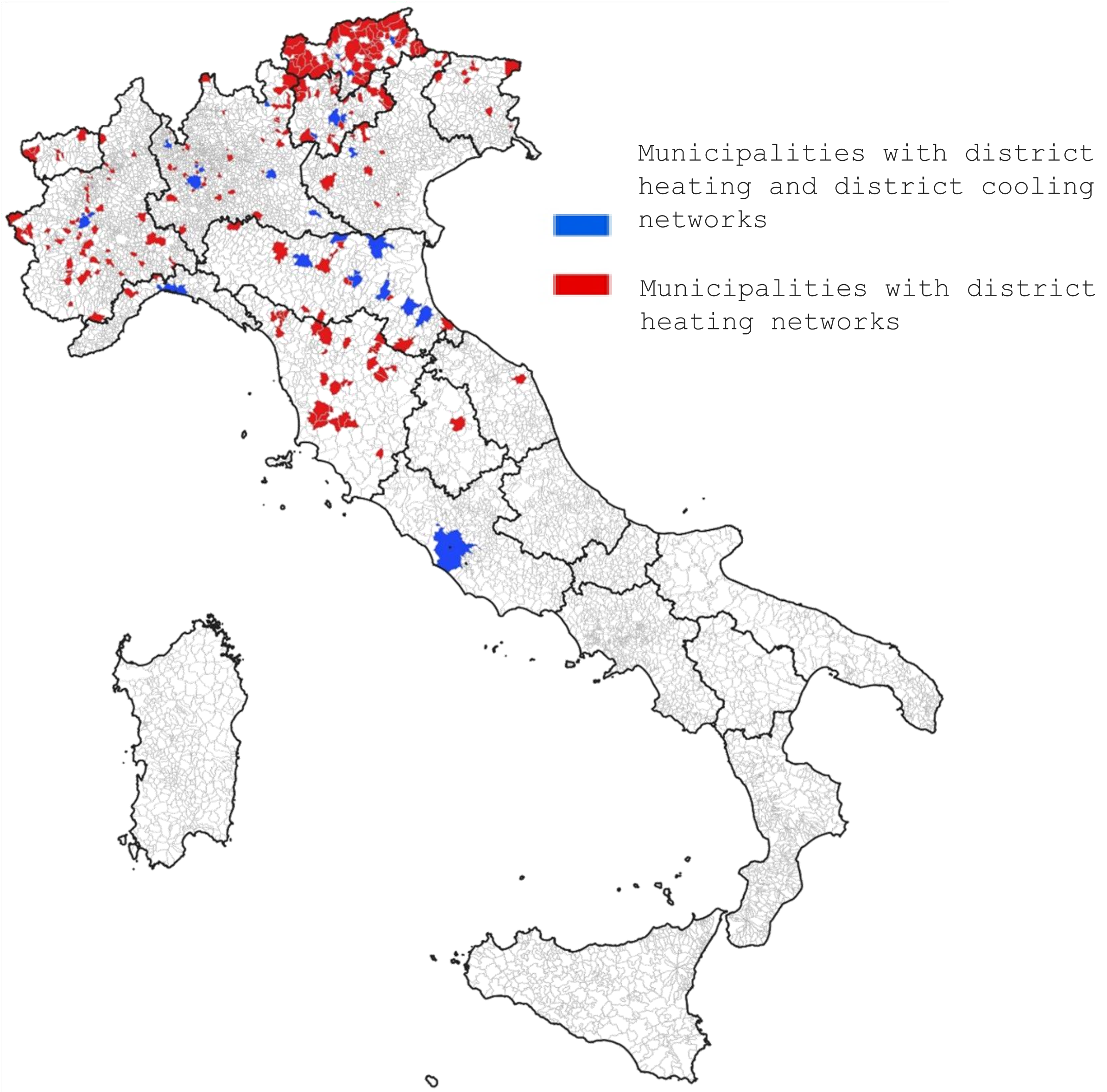


Lombardia	Lombardy
Piemonte	Piedmont
Emilia Romagna	Emilia-Romagna
Prov. Aut. Bolzano	Autonomous Province of Bolzano
Veneto	Veneto
Prov. Aut. Trento	Autonomous Province of Trento
Liguria	Liguria
Lazio	Lazio
Valle d'Aosta	Valle d'Aosta
Toscana	Tuscany
Friuli Venezia Giulia	Friuli-Venezia Giulia
Marche	Marche
Umbria	Umbria
Industria	Industry
Terziario	Services
Residenziale	Residential
Volumetria (Milioni di m3)	**Built stock volumes (million m^3)**

The total built stock volume heated in Italy is 364 million m^3. Residential users account for 63% of the space heated by DH networks, followed by the service sector (35%) and industrial users (3%). About 43% of the total heated space is in the Region of Lombardy (156 million m^3); followed by Piedmont (98 million m^3, 27% of the total), Emilia-Romagna (44 million m^3, 12% of the total) and the Autonomous Province of Bolzano (23 million m^3, 6% of the total).

District heating networks are predominant; however, over the years associated district cooling networks have also been gaining ground.

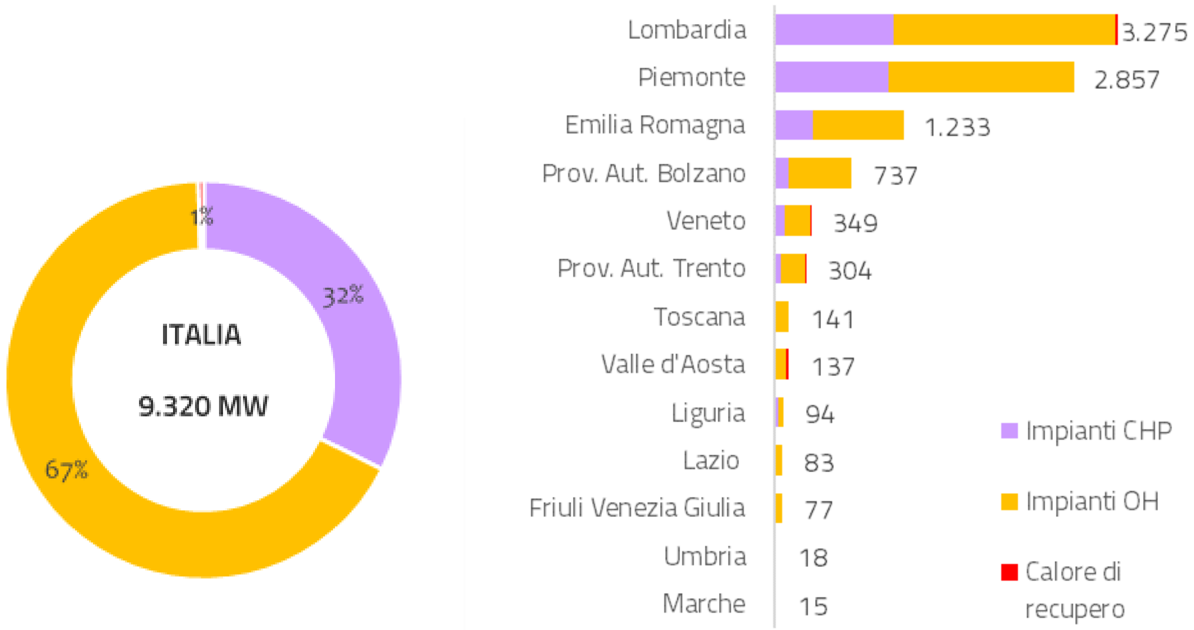
Figure 22: Geographical distribution of district heating and district cooling networks (2018)



It is important to clarify that the size of each coloured area represents the administrative area of the municipality served by a network and not the extent of the district heating or cooling networks.

At the end of 2018, the thermal capacity of generators serving district heating networks was 9.3 GW. About 67% of installed capacity is heat-only plants, the remaining 32% is plants which produce energy in CHP mode. Fossil fuels (mainly natural gas) account for a total of 84% of the installed capacity; renewable sources are mainly used in heat-only plants (solid biomass, geothermal).

Figure 23: Thermal capacity of generators serving district heating networks in 2018



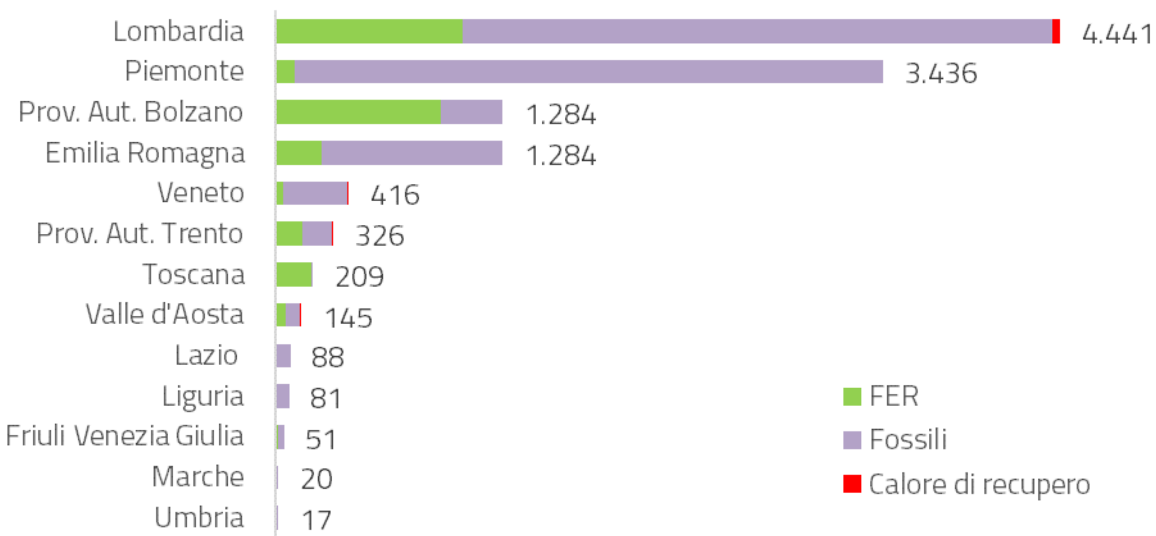
ITALIA	ITALY
Lombardia	Lombardy
Piemonte	Piedmont
Emilia Romagna	Emilia-Romagna
Prov. Aut. Bolzano	Autonomous Province of Bolzano
Veneto	Veneto
Prov. Aut. Trento	Autonomous Province of Trento
Toscana	Tuscany
Valle d'Aosta	Valle d’Aosta
Liguria	Liguria
Lazio	Lazio
Friuli Venezia Giulia	Friuli-Venezia Giulia
Umbria	Umbria
Marche	Marche
Impianti CHP	CHP plants
Impianti OH	HO (heat only) plants
Calore di recupero	Recovered heat

Lombardy, with around 3.3 GW installed, accounts for 35% of the total thermal capacity, thanks in particular to more than 2 GW of heat-only plants powered by natural gas. Renewable energy sources are particularly widespread in the Autonomous Province of Bolzano, where there is a high level of biomass utilisation in heat-only plants.

3.2.3 Energy fed into district heating networks

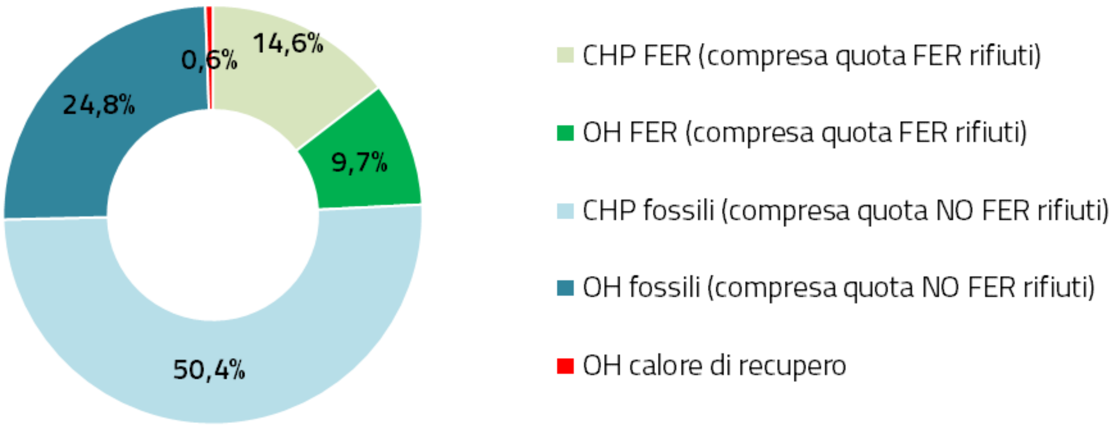
In 2018, the thermal energy fed into district heating networks in Italy amounted to 11.8 TWh (equivalent to more than 1 000 ktoe or 42 500 TJ), of which 65% came from plants producing energy in CHP mode. With about 8.9 TWh (763 ktoe), fossil-fired plants account for about 75% of the energy released for consumption; these are mainly natural gas plants. The remaining 24% of energy from district heating networks (2.9 TWh/246 ktoe) fed into the grid comes from renewable energy plants. The main Regions in terms of feed-in energy are Lombardy and Piedmont, which are home to, among others, the large plants in Milan, Brescia and Turin.

Figure 24: Energy fed into the grid by Region/Autonomous Province in 2018



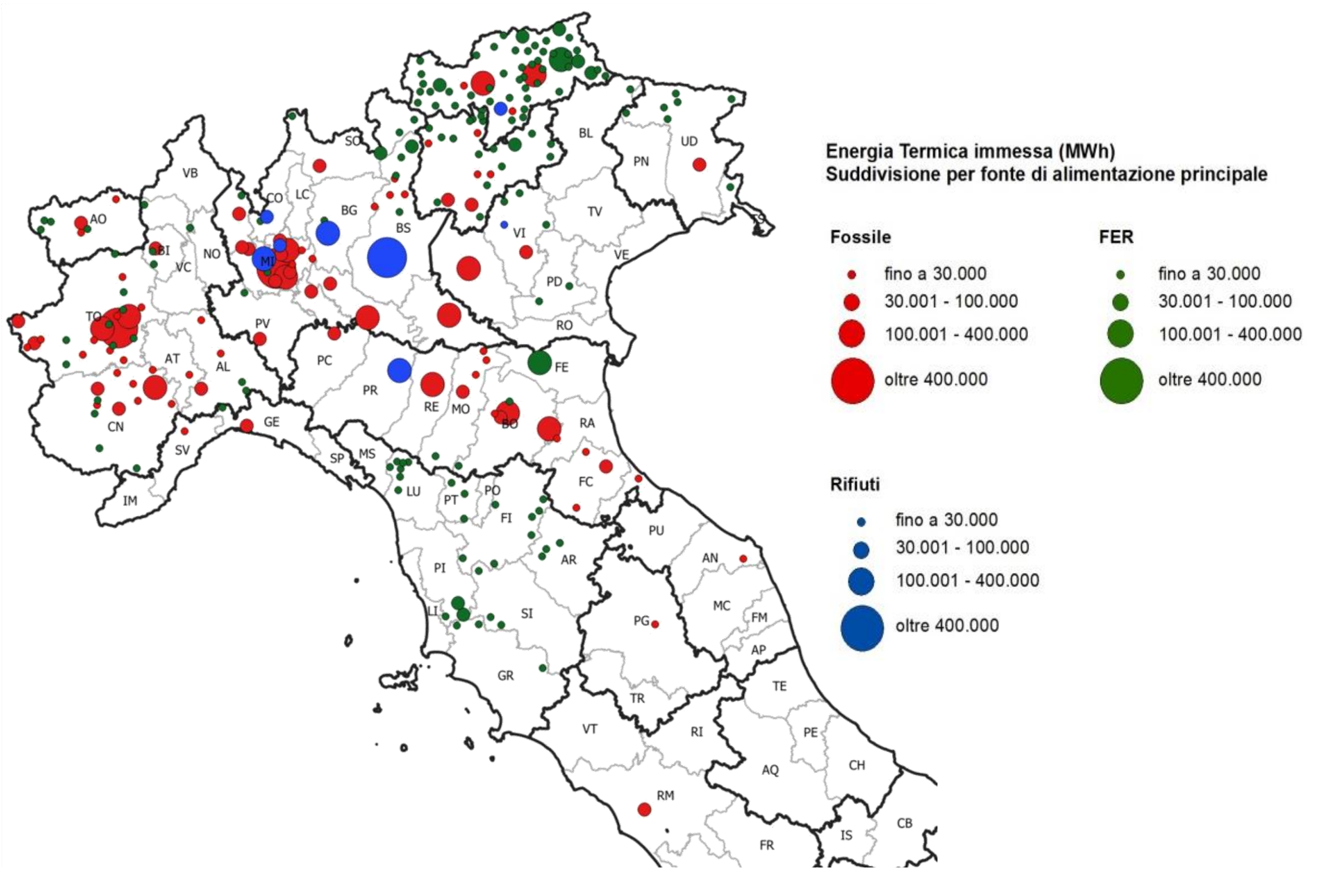
Lombardia	Lombardy
Piemonte	Piedmont
Emilia Romagna	Emilia-Romagna
Prov. Aut. Bolzano	Autonomous Province of Bolzano
Veneto	Veneto
Prov. Aut. Trento	Autonomous Province of Trento
Toscana	Tuscany
Valle d'Aosta	Valle d'Aosta
Lazio	Lazio
Liguria	Liguria
Friuli Venezia Giulia	Friuli-Venezia Giulia
Umbria	Umbria
Marche	Marche
FER	Renewables
Fossili	Fossil fuels
Calore di recupero	Recovered heat

Figure 25: Energy fed into the grid by source and technology in 2018



CHP FER (compresa quota FER rifiuti)	Renewables CHP (including share of renewable waste)
OH FER (compresa quota FER rifiuti)	Renewables HO (including share of renewable waste)
CHP fossili (compresa quota NO FER rifiuti)	Fossil fuels CHP (including share of non-renewable waste)
OH fossili (compresa quota NO FER rifiuti)	Fossil fuels HO (including share of non-renewable waste)
OH calore di recupero	HO recovered heat

Figure 26: Map of district heating municipalities by main energy source (> 50%)



Energia Termica immessa (MWh)	Feed-in thermal energy (MWh)
Suddivisione per fonte di alimentazione principale	Breakdown by primary power source
Fossile	Fossil fuels
fino a 30.000	up to 30 000
oltre 400.000	over 400 000
FER	Renewables
fino a 30.000	up to 30 000
oltre 400.000	over 400 000
Rifiuti	Waste
fino a 30.000	up to 30 000
oltre 400.000	over 400 000

The figure represents Italian municipalities with district heating broken down by the primary energy source used in the individual municipality; a sole source of supply has thus been assigned to each municipality, even in cases where the district heating is also supplied from other sources. The primary energy source is defined as the source from which at least 50% of the heat fed into the district heating networks of the municipality is generated; the renewable share and non-renewable share of waste has been combined under the heading 'Waste'. The size of the circle on the map represents the amount of thermal energy fed in by district heating systems.

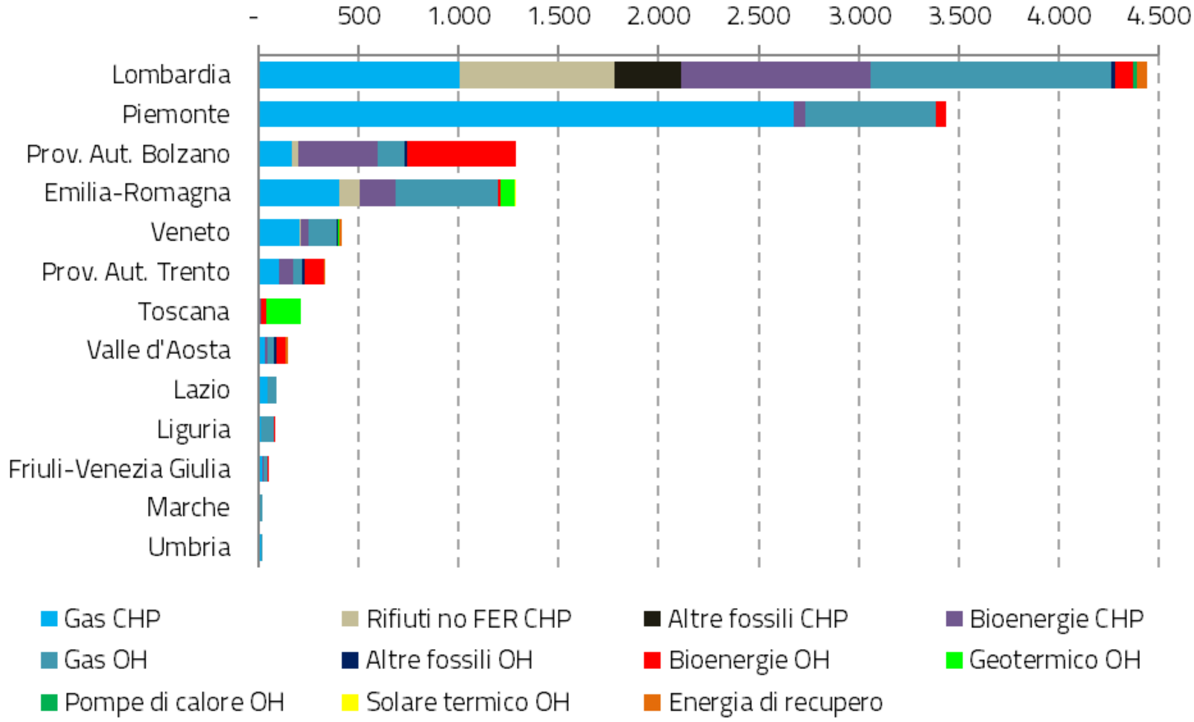
The district heating systems in the municipalities located in Piedmont, Lombardy, Veneto and Emilia-Romagna are powered mainly by fossil fuels (red bubbles); whereas in the municipalities of Trentino Alto Adige and Tuscany there is more evidence of systems with a renewable primary energy source (solid biomass or a geothermal resource).

Table 36: Energy fed into the grid broken down by Region/Autonomous Province and source in 2018

Region	Energy fed into the grid (GWh/year)										
	Gas CHP	Non-renewable waste CHP	Other fossil fuels CHP	Bioenergy CHP	Gas HO	Other fossil fuels HO	Bioenergy HO	Geothermal HO	Heat pumps HO	Solar power HO	Energy recovery
Piedmont	2 677	-	-	57	649	0	53	-	-	-	-
Valle d'Aosta	30	-	-	16	31	16	43	-	-	-	9
Lombardy	1 008	772	330	948	1 204	21	89	-	20	1	48
Autonomous Province of Bolzano	165	35	0	399	132	12	541	-	-	-	-
Autonomous Province of Trento	105	-	0	66	50	11	92	-	-	-	1
Veneto	203	9	-	35	145	3	5	6	-	-	10
Friuli-Venezia Giulia	18	-	-	10	15	0	8	-	-	-	-
Liguria	16	-	-	-	63	-	2	-	-	-	-
Emilia-Romagna	404	103	-	179	511	0	10	76	-	0	-
Tuscany	4	-	-	8	3	-	23	171	-	-	-
Umbria	17	-	-	-	1	-	-	-	-	-	-
Marche	6	-	-	-	14	-	-	-	-	-	-
Lazio	47	-	-	-	40	-	-	-	-	-	-
Italy	**4 701**	**919**	**330**	**1 717**	**2 858**	**65**	**866**	**253**	**20**	**1**	**68**

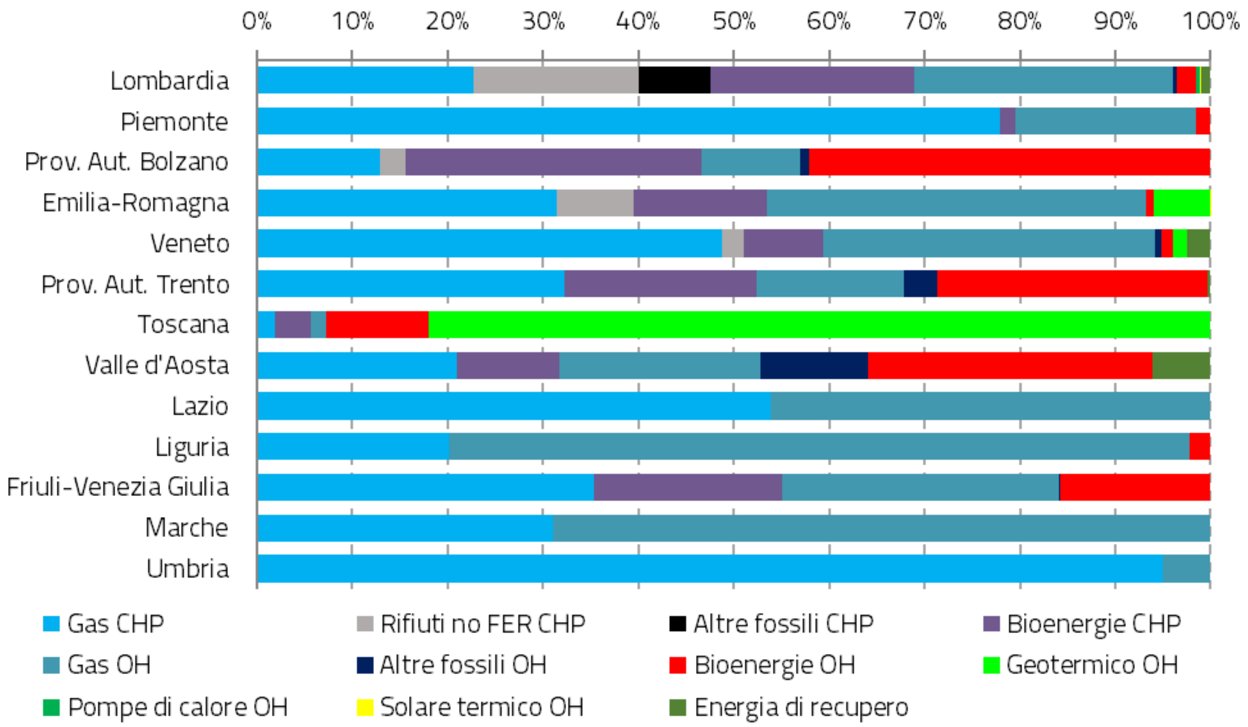
Significantly larger quantities of thermal energy are fed into district heating networks in Lombardy, Piedmont and Emilia-Romagna and in the Autonomous Province of Bolzano than in the other Regions; with the exception of Bolzano, these systems are mainly powered by natural gas. Overall, 64% of the energy fed into the grid in Italy comes from natural gas, followed at some distance by solid biomass (13%).

Figure 27: Absolute composition of feed-in thermal energy broken down by Region/Autonomous Province – 2018



Lombardia	Lombardy
Piemonte	Piedmont
Emilia-Romagna	Emilia-Romagna
Prov. Aut. Bolzano	Autonomous Province of Bolzano
Veneto	Veneto
Prov. Aut. Trento	Autonomous Province of Trento
Toscana	Tuscany
Valle d'Aosta	Valle d'Aosta
Lazio	Lazio
Liguria	Liguria
Friuli Venezia Giulia	Friuli-Venezia Giulia
Marche	Marche
Umbria	Umbria
Gas CHP	Gas CHP
Gas OH	Gas HO
Pompe di calore OH	Heat pumps HO
Rifiuti no FER CHP	Non-renewable waste CHP
Altre fossili OH	Other fossil fuels HO
Solare termico OH	Solar power HO
Altre fossili CHP	Other fossil fuels CHP
Bioenergie OH	Bioenergy HO
Energia di recupero	Energy recovery
Bioenergie CHP	Bioenergy CHP
Geotermico OH	Geothermal HO

Figure 28: Percentage composition of sources used to produce feed-in thermal energy broken down by Region/Autonomous Province – 2018



Lombardia	Lombardy
Piemonte	Piedmont
Prov. Aut. Bolzano	Autonomous Province of Bolzano
Emilia-Romagna	Emilia-Romagna
Veneto	Veneto
Prov. Aut. Trento	Autonomous Province of Trento
Toscana	Tuscany
Valle d'Aosta	Valle d'Aosta
Lazio	Lazio
Liguria	Liguria
Friuli Venezia Giulia	Friuli-Venezia Giulia
Marche	Marche
Umbria	Umbria
Gas CHP	Gas CHP
Gas OH	Gas HO
Pompe di calore OH	Heat pumps HO
Rifiuti no FER CHP	Non-renewable waste CHP
Altre fossili OH	Other fossil fuels HO
Solare termico OH	Solar power HO
Altre fossili CHP	Other fossil fuels CHP
Bioenergie OH	Bioenergy HO
Energia di recupero	Energy recovery
Bioenergie CHP	Bioenergy CHP
Geotermico OH	Geothermal HO

The energy source used in Piedmont, Liguria, Umbria, Marche and Lazio is almost exclusively natural gas, while in Friuli-Venezia Giulia, Valle d'Aosta, Trento and Bolzano there is widespread use of solid biomass. Tuscany differs from the other Regions in that it makes greater use of geothermal sources to supply district heating networks; by contrast, the proportion of waste as a percentage of the energy mix feeding the district heating networks is relatively high in Lombardy and Emilia-Romagna.

3.2.4 Energy supplied to users

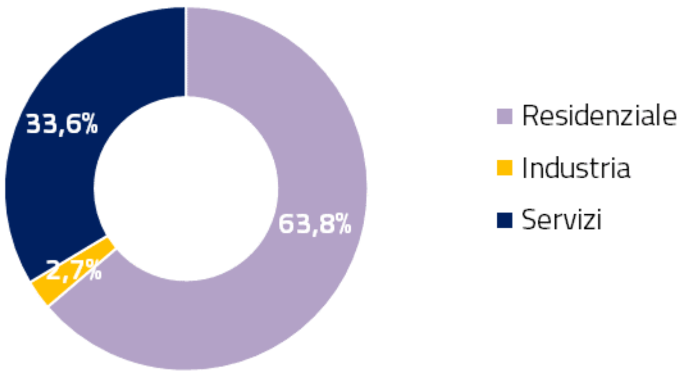
In 2018, a total of 9.8 TWh of energy was supplied to users. The network distribution losses in the network are around 17% of the feed-in energy (2 TWh).

Table 37: Energy fed into the grid, losses and energy supplied, broken down by Region/Autonomous Province in 2018 (GWh)

Region	Feed-in thermal energy	Losses	Thermal energy supplied
Piedmont	3 436	561	2 875
Valle d'Aosta	145	27	118
Lombardy	4 441	734	3 706
Autonomous Province of Bolzano	1 284	292	992
Autonomous Province of Trento	326	69	257
Veneto	416	64	352
Friuli-Venezia Giulia	51	9	42
Liguria	81	4	76
Emilia-Romagna	1 284	182	1 101
Tuscany	209	43	166
Umbria	17	5	12
Marche	20	6	14
Lazio	88	13	74
Italy	**11 798**	**2 010**	**9 787**

Liguria has the smallest percentage of losses (5%) and Umbria has the greatest (31%). Focusing the analysis on the Regions where the use of district heating is most widespread (total feed-in energy greater than 100 GWh/8.6 ktoe), there is far less variation, with values ranging from 14% (Emilia-Romagna) to 23% (Autonomous Province of Bolzano).

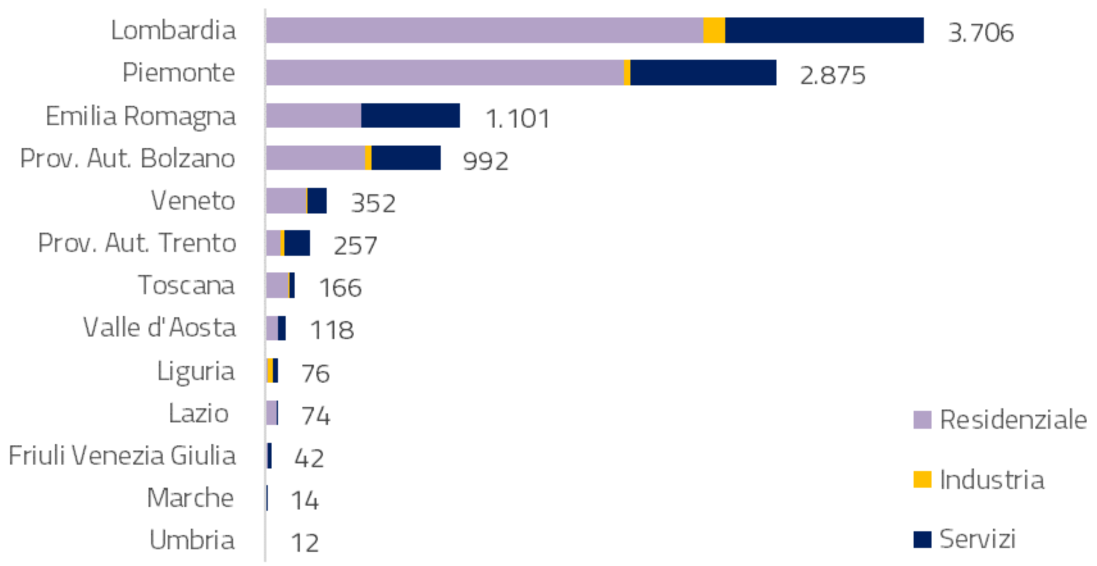
Figure 29: Breakdown of energy supplied by sector in 2018



Residenziale	Residential
Industria	Industry
Servizi	Services

In Italy in 2018, 64% of energy was supplied to residential users, 34% to services and the remaining approximately 3% to industry; with the exception of Liguria, where energy supplied for industrial use rose to 41% of the total. The largest share of energy delivered to the service sector can be found in the Autonomous Province of Trento (around 57%).

Figure 30: Energy supplied by sector and Region/Autonomous Province in 2018 (GWh)



Lombardia	Lombardy
Piemonte	Piedmont
Emilia Romagna	Emilia-Romagna
Prov. Aut. Bolzano	Autonomous Province of Bolzano
Veneto	Veneto
Prov. Aut. Trento	Autonomous Province of Trento
Toscana	Tuscany
Valle d'Aosta	Valle d'Aosta
Lazio	Lazio

Liguria	Liguria
Friuli Venezia Giulia	Friuli-Venezia Giulia
Marche	Marche
Umbria	Umbria
Residenziale	Residential
Industria	Industry
Servizi	Services

34% of the energy delivered both by the most developed networks (Turin, Brescia, Milan and Reggio Emilia) and by some of the many small networks in the Province of Bolzano goes to the service sector; however, the significant demand for heat from the residential sector remains the prerequisite for the development of district heating, since it is extremely rare to find networks that mainly supply customers in the service sector (20 networks).

3.2.5 Efficient district heating systems

The concept of efficient district heating systems, introduced by Directive 2012/27/EC, is also a key part of the 'Clean Energy for all Europeans' package, which defines European energy and climate policy up to 2030. The definitions setting out the quantitative requirements for classifying a district heating system as efficient are given below (Article 2 of Legislative Decree No 102/2014):

'efficient district heating and cooling' means a district heating or cooling system that uses, alternatively, at least

(a) 50 per cent of energy from renewable sources;

(b) 50 per cent of waste heat;

(c) 75 per cent of cogenerated heat;

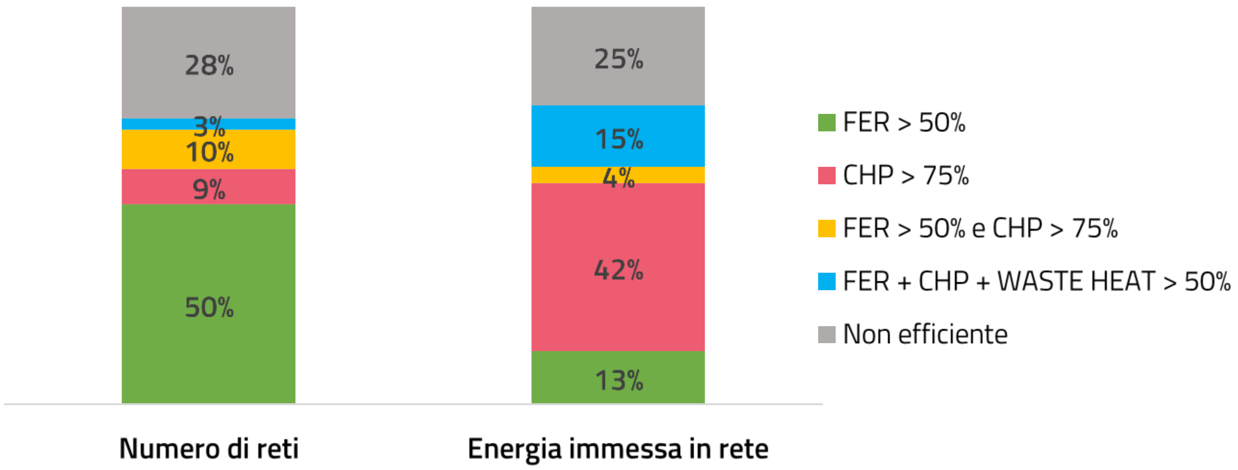
(d) 50 per cent of energy from a combination of the above.

The values in the following paragraphs provide an overview of the existing district heating networks in Italy at the end of 2018. For the purposes of this data, the following types of efficient network were included:

- Renewables ≥ 50%: DH systems that used at least 50% renewable energy in 2018
- CHP ≥ 75%: DH systems that used at least 75% CHP in 2018
- Renewables ≥ 50% and CHP ≥ 75%: DH systems that met both of the above requirements in 2018
- Renewables + CHP + waste heat ≥ 50%: DH systems that used a combination of renewables and CHP heat of 50% or more in 2018.

The type of plant that uses more than 50% of waste heat is not included in the above list since no such plants currently exist in Italy. It should be noted, however, that the analysis has been conducted on heat production as recorded in 2018: changes to the production mix in the years to come may therefore change the classifications indicated here.

Figure 31: District heating networks by type of efficiency (2018)



Numero di reti	**Number of networks**
Energia immessa in rete	**Energy fed into the grid**
FER > 50%	Renewables > 50%
CHP > 75%	CHP > 75%
FER > 50% e CHP > 75%	Renewables > 50% and CHP > 75%
FER + CHP + WASTE HEAT > 50%	Renewables + CHP + WASTE HEAT > 50%
Non efficiente	Non-efficient

According to the definitions given, 226 (72% of the total 314) of the district heating systems in operation in Italy are efficient; these systems account for more than 73% of the installed power, 75% of the energy fed into the grid (8.9 TWh) and 82% of users.

Table 38: Thermal energy fed into district heating networks, broken down by efficiency requirement met in 2018 (GWh)

Region	Energy fed into the grid (GWh/year)				
	Renewables > 50%	CHP > 75%	RENEWABLES > 50% and CHP > 75%	Renewables + CHP + WASTE HEAT > 50%	Non-efficient
Piedmont	50	2 650	29	-	707
Valle d'Aosta	60	-	-	66	20
Lombardy	155	2 034	132	1 287	832
Autonomous Province of Bolzano	785	76	149	154	119
Autonomous Province of Trento	126	71	40	4	85
Veneto	5	10	44	309	48

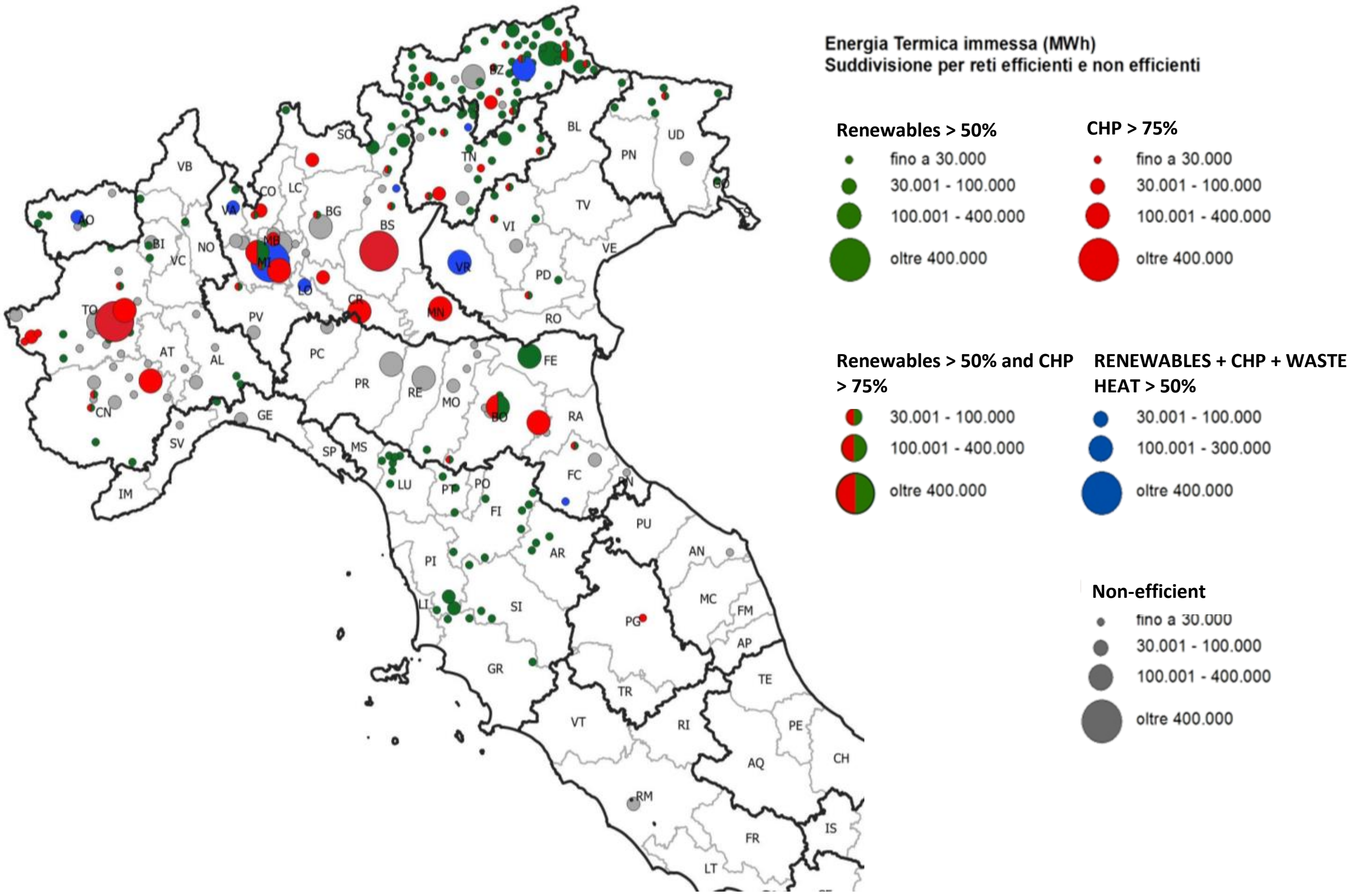
Friuli-Venezia Giulia	8	-	12	-	31
Liguria	2	0	-	-	79
Emilia-Romagna	180	124	80	7	892
Tuscany	205	4	-	-	-
Umbria	-	17	-	-	-
Marche	-	-	-	-	20
Lazio	-	-	-	-	88
Italy	**1 577**	**4 988**	**486**	**1 827**	**2 921**

Breaking down the energy fed into the grid by the four efficiency requirements listed above reveals that the most common networks in terms of feed-in energy, with around 5 million MWh, are those that meet the condition to produce at least 75% of their total energy in CHP mode ('CHP > 75%'). Looking at the number of networks, on the other hand, there is a clear predominance of networks with more than 50% of energy generated by renewables (158 of 226 efficient networks). It can thus be concluded that there are numerous small networks, mainly powered by renewables, which make a relatively small contribution in terms of feed-in energy but are very widespread across Italy.

As regards waste heat, it should be noted that the seven networks that recover waste heat are all efficient. In three cases, the recovery of waste heat is sufficient to meet the efficiency requirement.

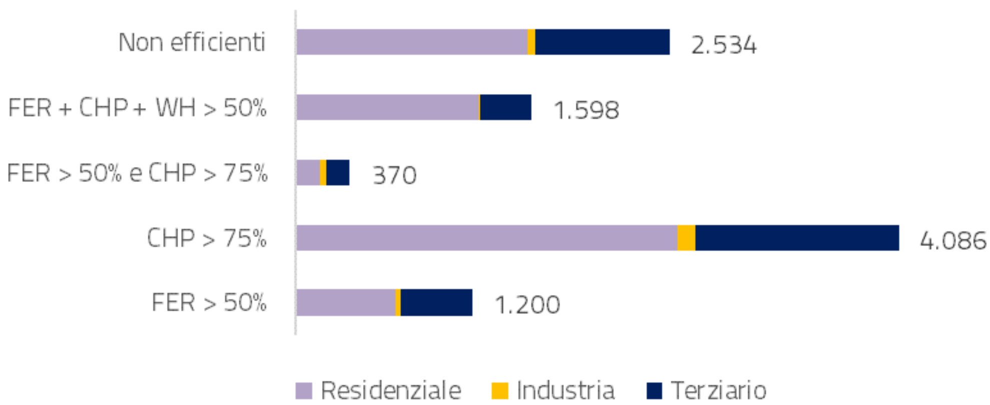
On a regional level, the small-scale networks located in Trentino Alto Adige and Tuscany are almost exclusively powered by renewables and are therefore efficient as they meet the renewables > 50% efficiency criterion. Among the larger city networks, Brescia and Turin are efficient due to meeting the CHP > 75% criterion, and Milan due to a combination of the above criteria.

Figure 32: Geographical distribution of efficient district heating systems (2018)



Energia Termico immeso (Mwh) suddivisione per reti efficiente e non efficiente	Feed-in thermal energy (MWh) broken down by efficient and non-efficient networks
fino a 30.000	up to 30 000
oltre 400 000	over 400 000

Figure 33: Thermal energy supplied by efficiency criterion and sector – 2018 (GWh)



Non efficienti	Non-efficient
FER + CHP+ WH >50%	RENEWABLES + CHP + WASTE HEAT > 50%
FER > 50% e CHP > 75%	Renewables > 50% and CHP > 75%

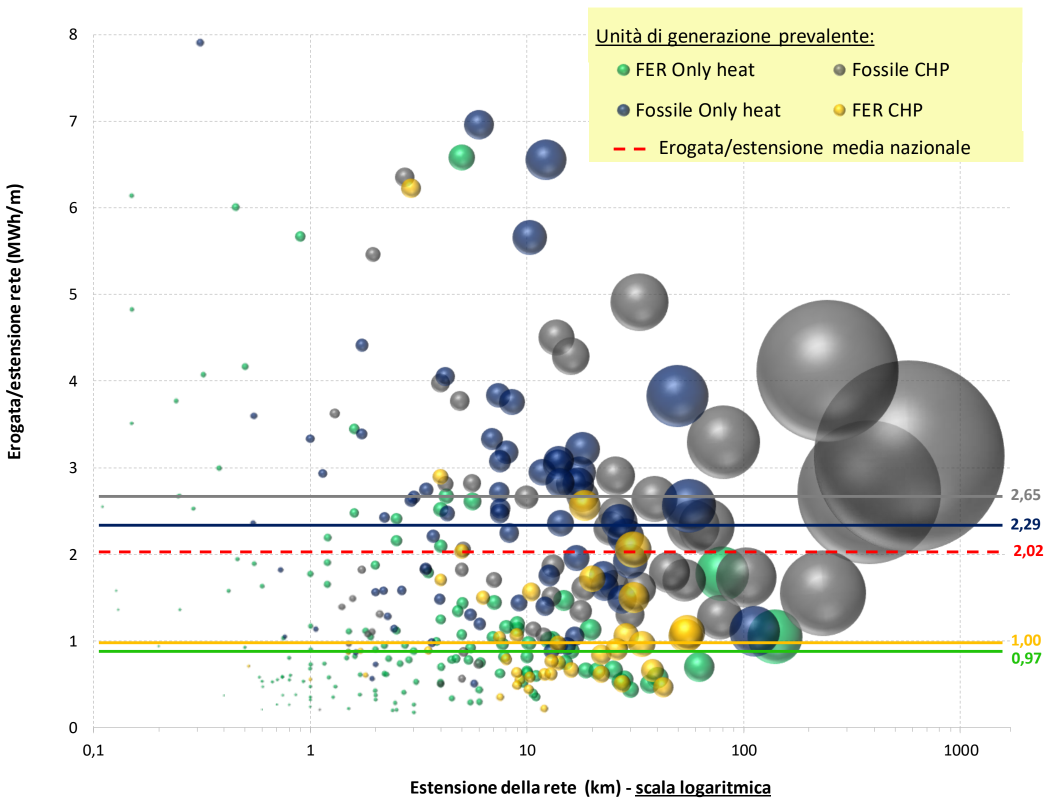
CHP > 75%	CHP > 75%
FER > 50%	Renewables > 50%
Residenziale	Residential
Industria	Industry
Terziario	Services

Breaking down the energy delivered by efficiency requirement and by sector of use, it can be noted that networks that are efficient due to a combination of the criteria relating to renewables, waste heat and CHP heat 'RENEWABLES + CHP + WH > 50%' supply a greater share of energy to the residential sector (78% of the total energy supplied by these networks), offset by a lower share delivered to the service sector (22%). By contrast, systems classed as efficient under both criteria (RENEWABLES > 50% and CHP > 75%) supply a smaller share of energy to the residential sector (46%) and a larger share to the service sector (44%).

3.2.6 Linear heat density of district heating networks

The linear heat density of a district heating network is an indicator composed of the ratio between the energy supplied and the size of the network, which can be used to assess the economic sustainability of a district heating network: the parameter depends both on the urban characteristics of the built-up area served and on its specific demand for district heating, and varies over the years as the size of the network and the users connected to the network vary.

Figure 34: Linear heat density of existing networks



Unità di generazione prevalente:	Principal generation unit:
FER Only heat	Renewables Heat only
Fossile Only heat	Fossil fuels Heat only
Fossile CHP	Fossil fuels CHP
FER CHP	Renewables CHP
Erogata/estensione media nazionale	National average supply/size
Erogata/estensione rete (MWh/m)	**Network supply/size (MWh/m)**
Estensione della rete (km) - scala logaritmica	**Length of network (km) – logarithmic scale**

The figure represents the linear thermal density value calculated for each network analysed for the year 2018, varying the length of the network (represented on a logarithmic scale to better highlight the differences between small networks). The colours of the bubbles represent the energy source and the principal form of generation, while the size of the area is proportional to the energy supplied.

District heating systems delivering small quantities of energy are mainly powered by renewable sources in simple boilers. District heating networks supplying high volumes of energy, which are generally larger in size, are mostly powered by fossil fuels and produce energy in cogenerative mode. Small networks have a high variability of linear thermal density, which decreases as network size increases.

The continuous horizontal lines drawn on the graph represent the average linear density values calculated for four different district heating systems grouped according to principal supply type, while the dashed line shows the average value for all networks. Linear density values are around 1 MWh/m for DH networks powered by renewables, which are often located in small mountain municipalities where the volume of heat supplied is often low and networks are not always short in length; by contrast, networks powered by fossil fuels, generally located in medium to large urban centres, show values of around 2.5 MWh/m. On average, the linear density of district heating networks in Italy in 2018 is around 2 MWh per metre.

3.2.7 District cooling networks

At the end of 2018, there were 32 district cooling networks in operation in Italy; 28 municipalities were served by at least one system, distributed across 8 Regions and 2 Autonomous Provinces in central and northern Italy. In total, district heating networks cover 35.2 km, with a cooled volume of 8.8 million cubic metres.

Table 39: Distribution of district cooling broken down by Region/Autonomous Province – 2018

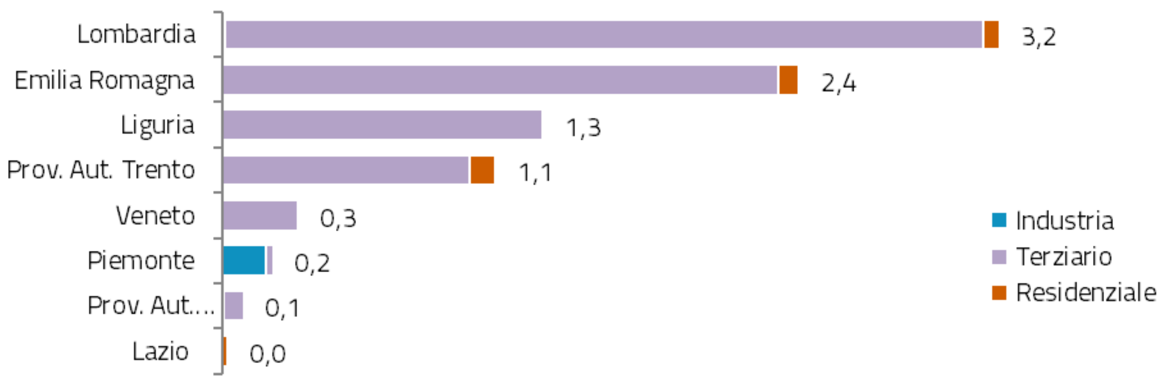
Region	Number of municipalities with district cooling	Number of district cooling networks	Total length of networks* (km)	Cooled volume
Piedmont	3	3	0.3	0.2
Lombardy	8	9	22.2	3.2
Autonomous Province of Bolzano	3	3	0.0	0.1
Autonomous Province of Trento	3	3	2.4	1.1
Veneto	1	1	-	0.3
Liguria	1	2	-	1.3
Emilia-Romagna	8	10	10.4	2.4
Lazio	1	1	-	0.0
Italy	**28**	**32**	**35.2**	**8.8**

Only the cold water network is taken into account; district cooling can also be provided through the district heating network, these networks are not included here.

District cooling systems are developed by exploiting both system efficiency and the possibility of implementation using existing infrastructure: currently all existing systems have been implemented in municipalities which already had district heating networks.

The total space cooled by means of district cooling is just under 9 million m^3, mostly in the service sector (95%). There are four regions where the volume exceeds 1 million m^3, distribution in other Regions remains limited.

Figure 35: Cooled volume by sector in 2018 (million m^3)



Lombardia	Lombardy
Emilia Romagna	Emilia-Romagna
Liguria	Liguria
Prov. Aut. Trento	Autonomous Province of Trento

Veneto	Veneto
Piemonte	Piedmont
Prov. Aut....	Autonomous Province of
Lazio	Lazio
Industria	Industry
Terziario	Services
Residenziale	Residential

District cooling can be supplied using various technical solutions:

- central cooling: the cooling systems are centralised and a cold water network is installed, separate from the hot water network (for district heating), to connect the systems to users;
- cooling at users' premises: there is no dedicated district cooling network, and the district heating network is used instead; the systems are located at the users' premises and are powered by the thermal energy distributed by the network.

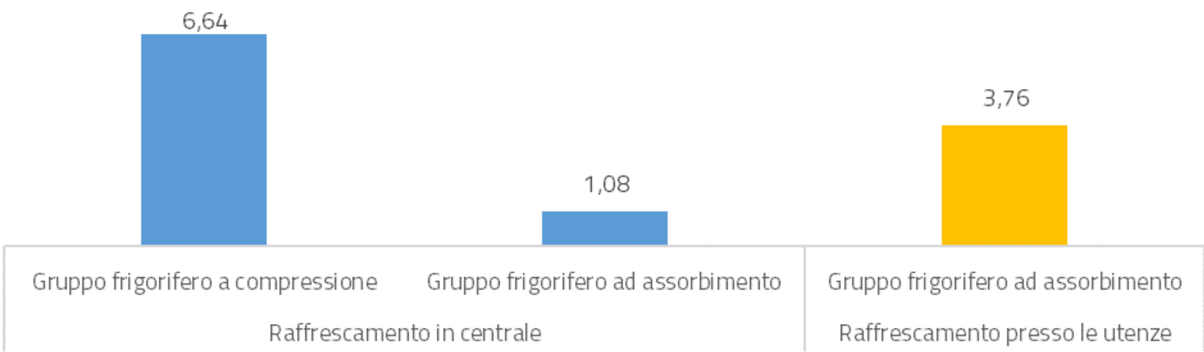
District cooling can be provided by machines powered by electricity (compression chillers) or heat (absorption chillers). District cooling at the users' premises can only be provided by absorption chillers, as cooling at the users' premises by means of compression chillers falls within the definition of individual heating.

Table 40: Chiller units serving district cooling systems – capacity by type of installed machine (MW) – 2018

Region	Central cooling		Cooling at users' premises
	Compression chiller	Absorption chiller	Absorption chiller
Piedmont	-	0.2	1.5
Lombardy	34.6	11.8	54.6
Autonomous Province of Bolzano	0.6	0.5	0.0
Autonomous Province of Trento	7.2	2.7	6.7
Veneto	-	-	3.0
Liguria	7.0	-	6.1
Emilia-Romagna	20.0	11.4	31.9
Lazio	-	-	0.4
Italy	**69**	**26**	**104**

The capacity of chillers serving district cooling systems is about 200 MW, equally divided between district cooling systems located at users' premises (52%) and centrally (48%); the latter type of district cooling has installed capacity of 69 MW in compression chillers and 26 MW in absorption chillers.

Figure 36: Thermal energy extracted from district cooling networks (ktoe) – 2018

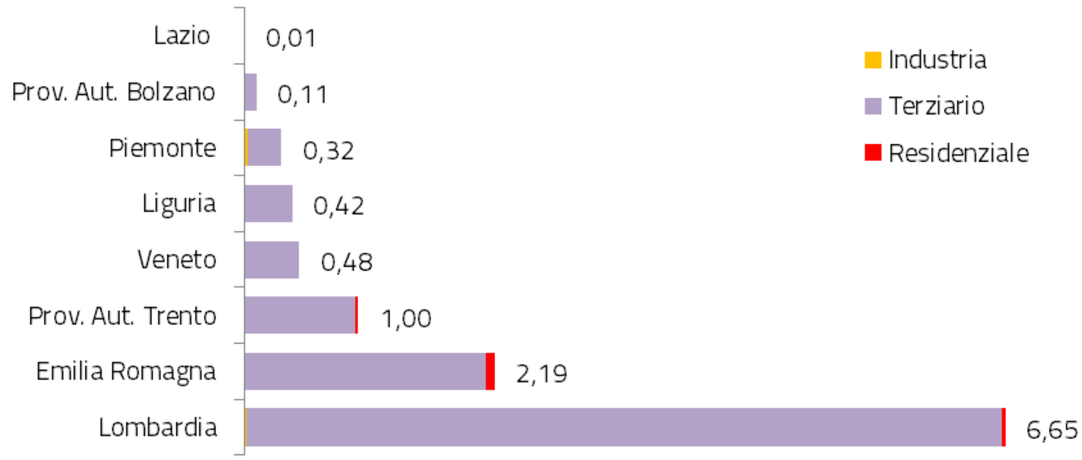


Gruppo frigorifero a compressione	Compression chiller
Gruppo frigorifero ad assorbimento	Absorption chiller
Raffrescamento in centrale	Central cooling
Gruppo frigorifero ad assorbimento	Absorption chiller
Raffrescamento presso le utenze	Cooling at users' premises

The thermal energy extracted in 2018 amounted to around 11.5 ktoe (133.5 GWh), with 67% coming from central cooling and 33% from cooling at users' premises; Lombardy and Emilia-Romagna accounted for almost 80% of the total energy extracted from the country's networks.

The thermal energy extracted by users, on the other hand, totalled around 11.2 ktoe (129.8 GWh), almost entirely by the service sector (98%).

Figure 37: Thermal energy extracted by users, broken down by sector (ktoe) – 2018



Lazio	Lazio
Prov. Aut. Bolzano	Autonomous Province of Bolzano
Piemonte	Piedmont
Liguria	Liguria
Veneto	Veneto
Prov. Aut. Trento	Autonomous Province of Trento
Emilia Romagna	Emilia-Romagna
Lombardia	Lombardy

Industria	Industry
Terziario	Services
Residenziale	Residential

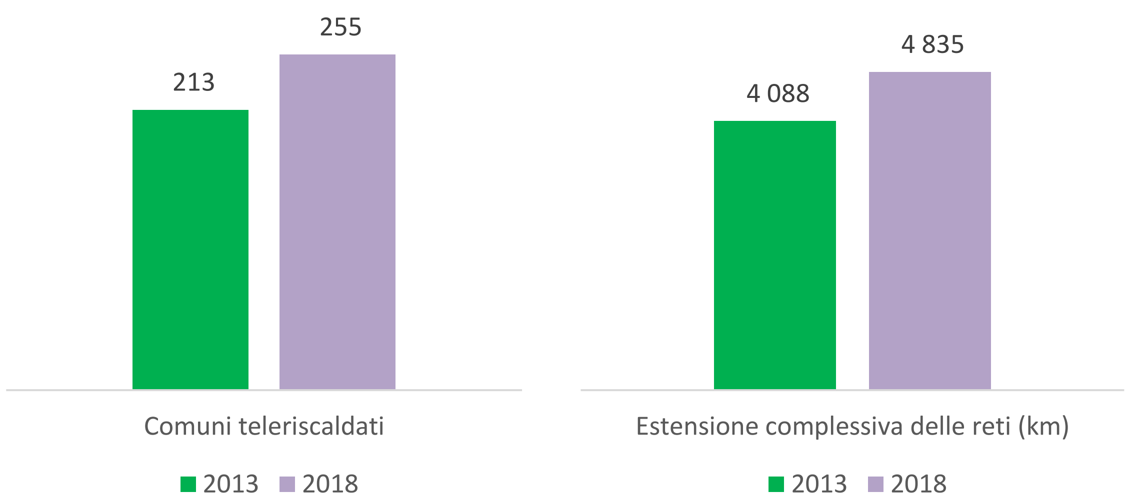
Out of a total of 32 district cooling systems in operation in Italy, 20 fall under the definition of efficient systems; the total installed capacity in these systems is 64% of the total capacity, energy extracted by users is 58% of the total.

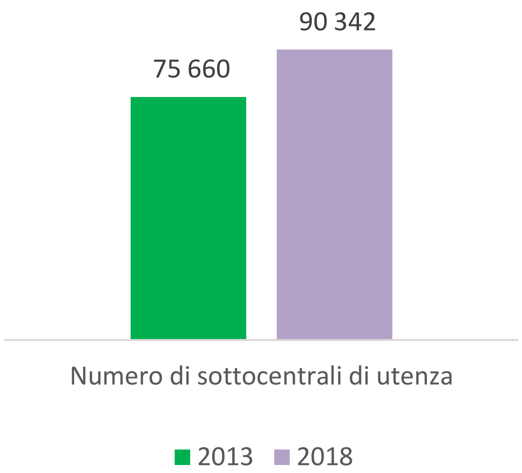
3.2.8 Comparison with 2013 figures

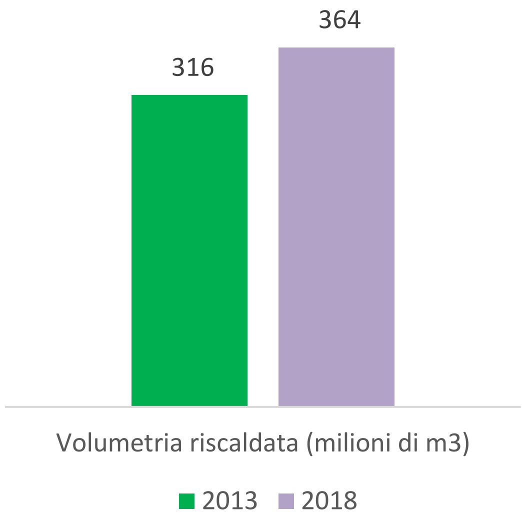
For the study 'Assessment of the national and regional potential for the application of high-efficiency cogeneration and efficient district heating', prepared by GSE in 2015 (with 2013 data), there was less data and information available in comparison to 2018; in some cases, therefore, the figures were estimated parametrically.

Between 2013 and 2018, there was an increase in the number of district heating systems in operation in Italy. Compared to 2013, in particular, at the end of 2018, 42 new municipalities were served by a district heating network (+20%), with an increase in network length of 750 km; utility substations increased by almost 14 700 units (+19%), and heated space by 48 million m^3 (+15%).

Figure 38: Distribution of district heating systems in 2013 and 2018



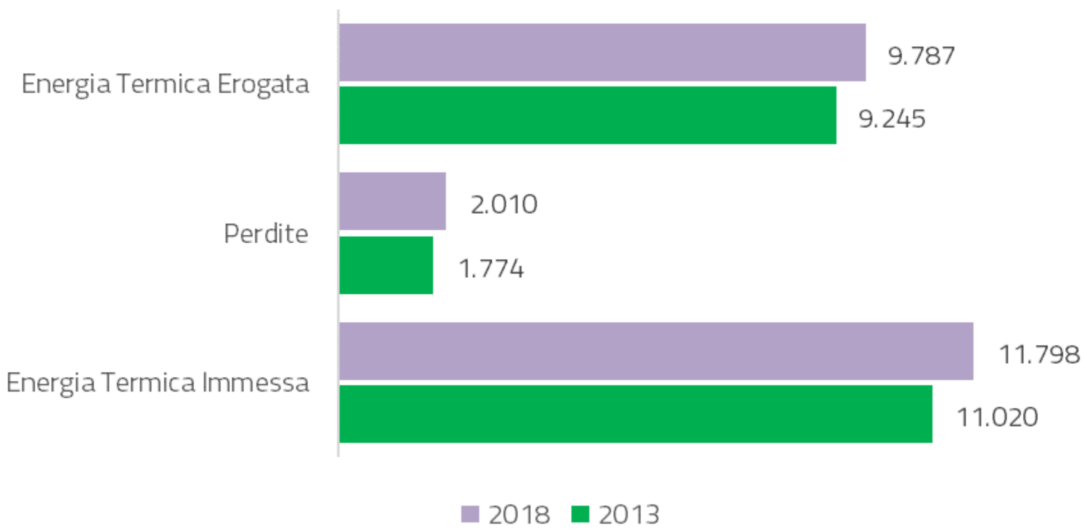




Comuni teleriscaldati	Municipalities with district heating
Estensione complessiva delle reti (km)	Total length of networks (km)
Numero di sottocentrali di utenza	Number of utility substations
Volumetria riscaldata (milioni di m3)	Heated space (million m^3)

The increase in the number of networks between 2013 and 2018 resulted in an increase in total energy delivered (from 9.25 TWh to 9.79 TWh), feed-in energy (from 11.0 GWh to 11.8 GWh) and losses (from 1.77 TWh to 2.01 TWh).

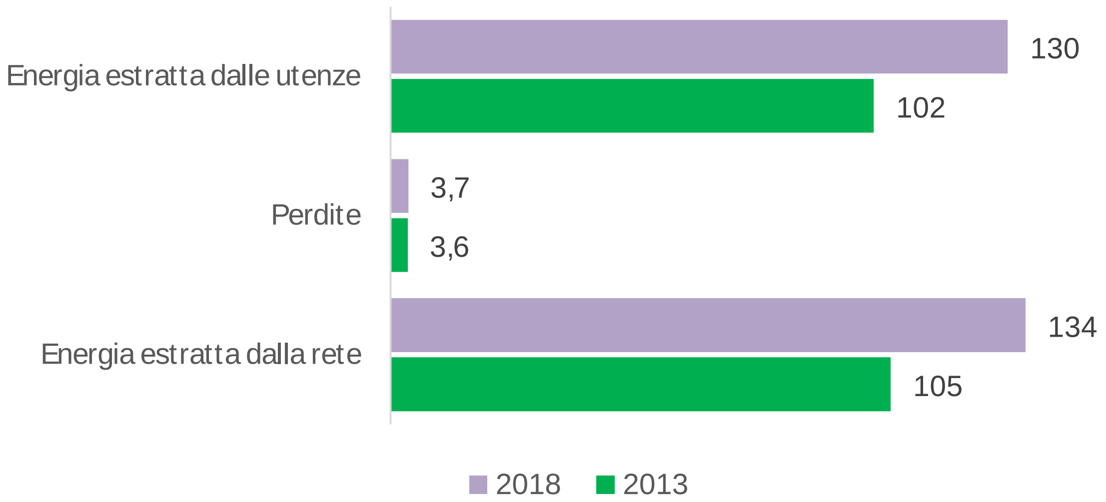
Figure 39: Energy fed into the network, energy supplied and losses in 2013 and 2018 in the district heating network (GWh)



Energia Termica Erogata	Thermal energy supplied
Perdite	Losses
Energia Termica Immessa	Feed-in thermal energy

With regard to district cooling, however, over the 2013-2018 period, systems increased significantly both in absolute terms and – proportions obviously notwithstanding – in comparison to district heating systems. Compared to 2013, there were 7 new networks (+33%) at the end of 2018, with an increase in network length of 2.5 km; whereas cooled space increased by 1.2 million m^3 (+15%). In terms of energy extracted, the change between 2013 and 2018 is significant (an increase of just over 28 GWh/2.4 ktoe, or 27%); the change in energy extracted by users is very similar (+28%).

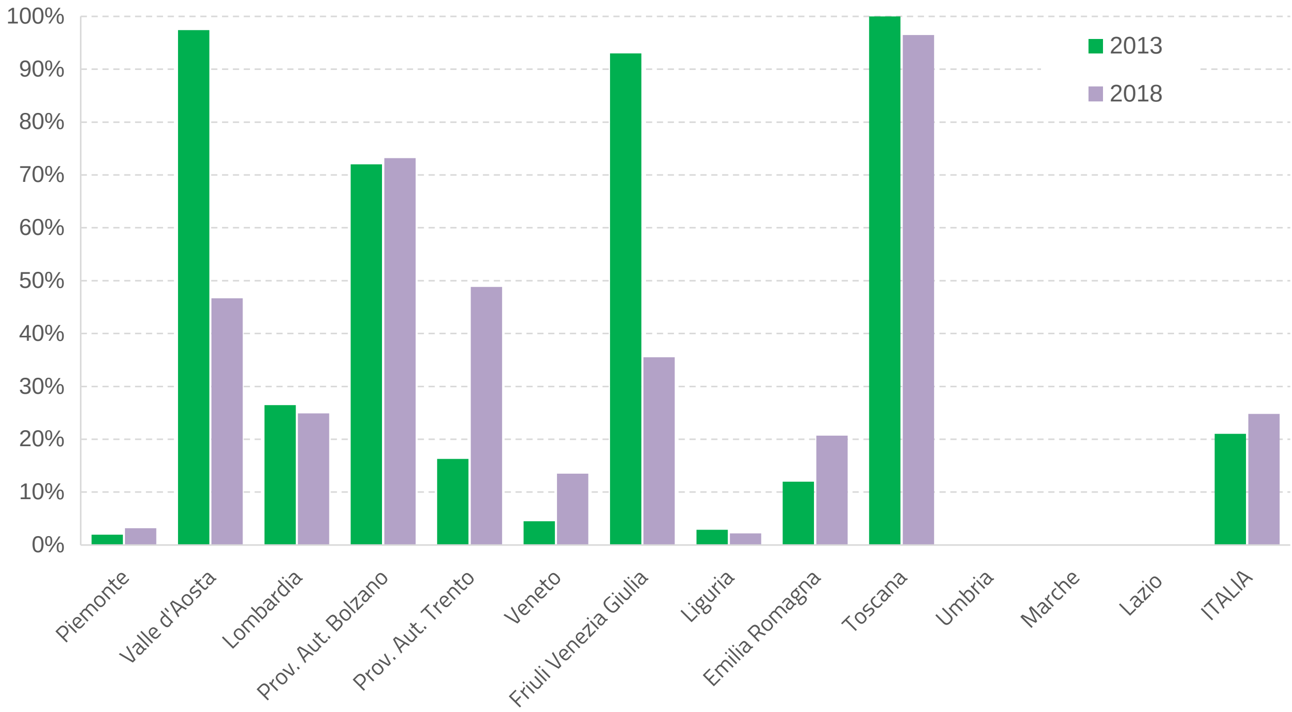
Figure 40: Energy extracted by users, from the network and losses in 2013 and 2018 in district cooling networks (GWh)



Energia estratta dalle utenze	Energy extracted by users
Perdite	Losses
Energia estratta dalla rete	Energy extracted from the network

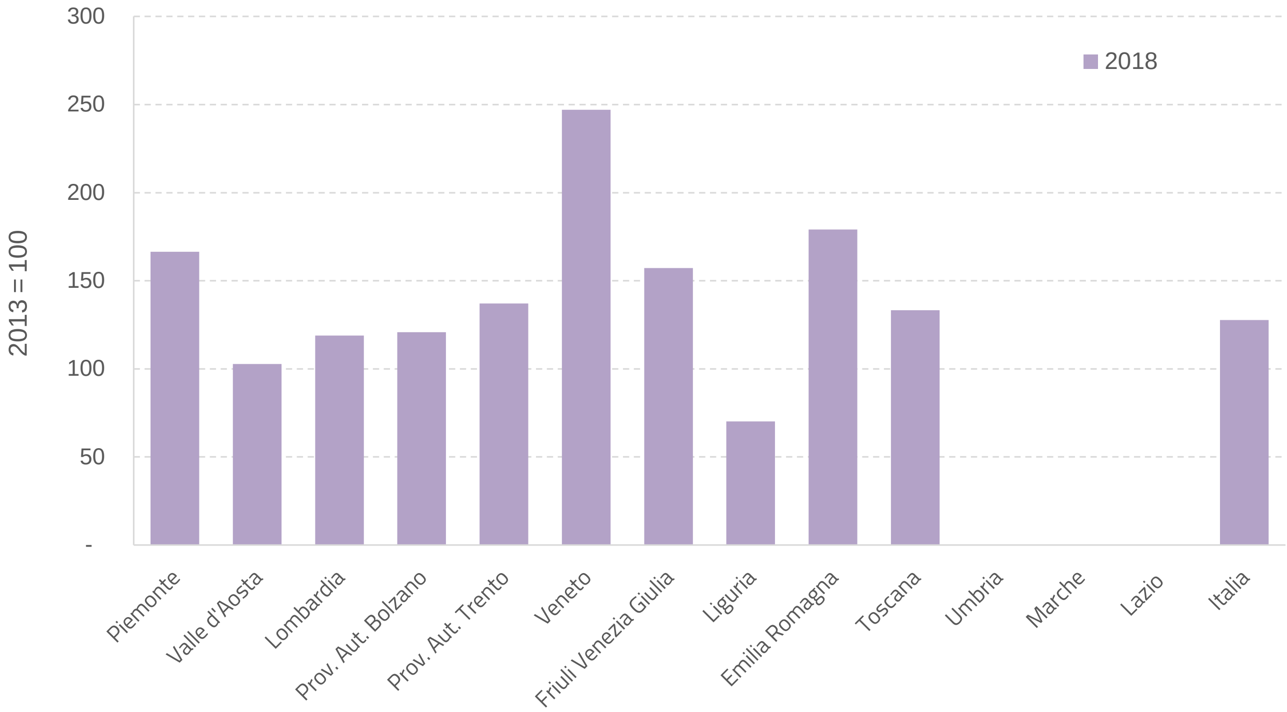
The use of renewables in district heating systems has increased slightly over the last 5 years. In 2013, feed-in thermal energy from renewable sources accounted for 21% of total feed-in energy. This value reached 25% in 2018. In absolute terms, the highest growth in renewables feed-in energy was recorded in Lombardy, Emilia-Romagna and the Autonomous Province of Bolzano.

Figure 41: Share of feed-in energy produced from renewables in 2013 and 2018, broken down by Region/Autonomous Province (%)



Piemonte	Piedmont
Valle d'Aosta	Valle d'Aosta
Lombardia	Lombardy
Prov. Aut. Bolzano	Autonomous Province of Bolzano
Prov. Aut. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli Venezia Giulia	Friuli-Venezia Giulia
Liguria	Liguria
Emilia Romagna	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria
Marche	Marche
Lazio	Lazio
ITALIA	ITALY

Figure 42: Regional increase of feed-in energy from renewables in 2018 compared to 2013 (2013=100)



Piemonte	Piedmont
Valle d’Aosta	Valle d’Aosta
Lombardia	Lombardy
Prov. Aut. Bolzano	Autonomous Province of Bolzano
Prov. Aut. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli Venezia Giulia	Friuli-Venezia Giulia
Liguria	Liguria
Emilia Romagna	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria
Marche	Marche
Lazio	Lazio
Italia	Italy

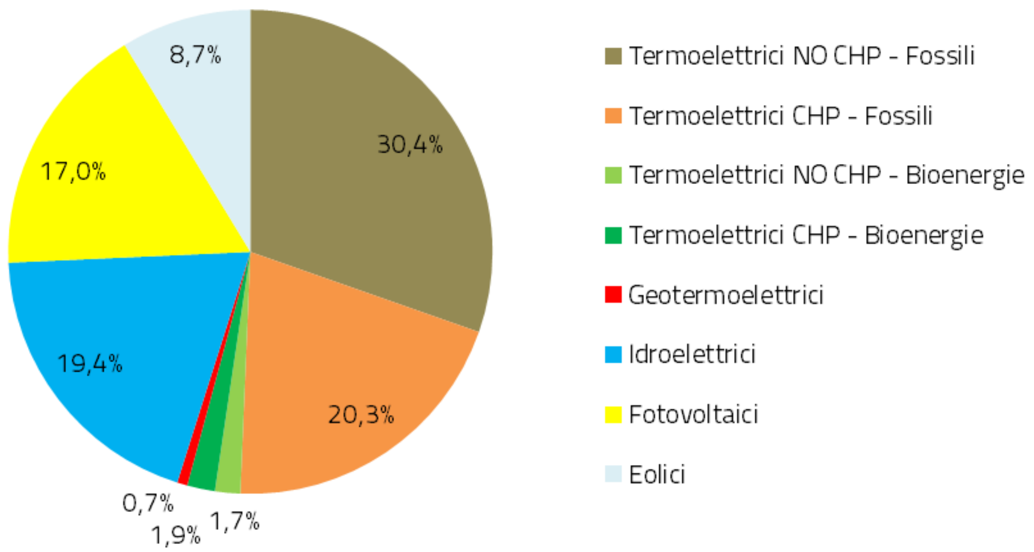
4 Cogeneration in Italy's power plants

4.1 Thermal power plants

At the end of 2018, Italy had a total installed electric capacity of 118.1 GW, of which 64.8 GW (55%) comprised thermal power plants[14]. The remainder consisted of 19% hydroelectric plants and 26% plants powered by other renewable energy sources (solar, wind, etc.). 40% of the capacity of thermal power plants, or 26.2 GW (22% of the total installed capacity), is from CHP plants[15].

On the basis of Terna's statistical data, the gross output of electricity by the total stock of Italian power stations in 2018 amounted to 290 TWh, including 199 TWh output by thermal power stations. CHP plants produced a total of 105 TWh of electricity.

Figure 43: Breakdown of output of electrical power stations in 2018 – Total 118.1 GW



Termoelettrici NO CHP - Fossili	Non-CHP thermal power plants – Fossil fuels
Termoelettrici CHP - Fossili	CHP thermal power plants – Fossil fuels

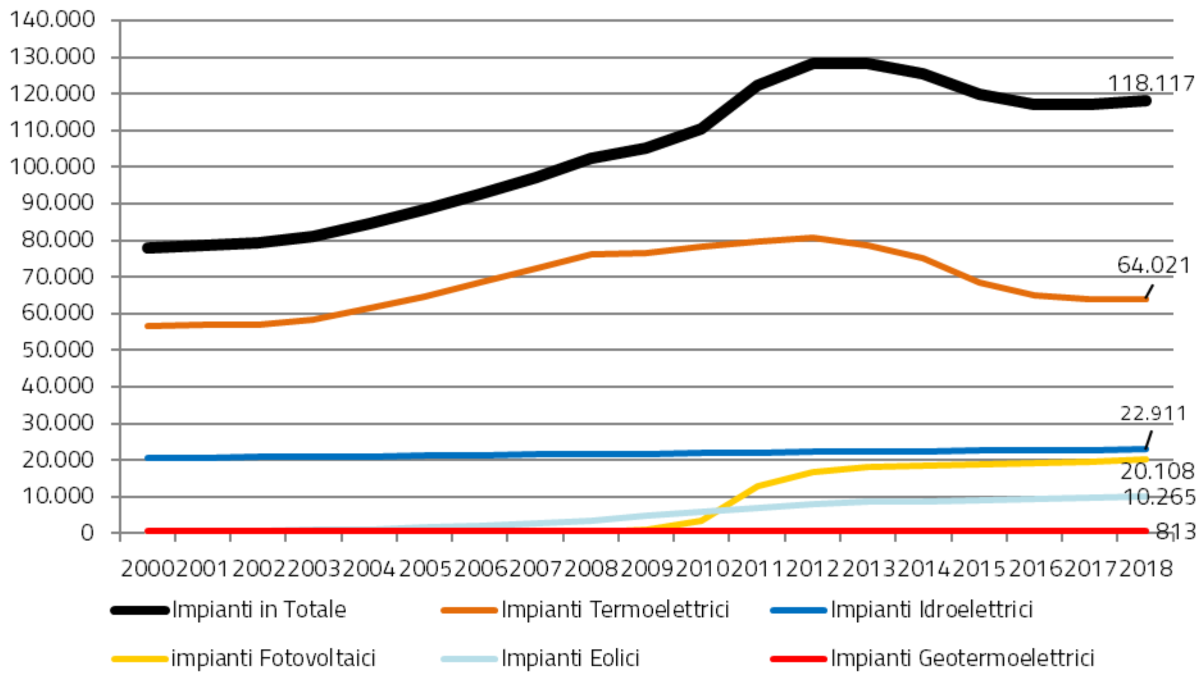
[14] This group includes plants using the following sources: fossil fuels, geothermal energy, bioenergy and waste.

[15] The capacity refers to the overall capacity of plants, including units which produced energy in CHP mode in 2013.

Termoelettrici NO CHP- Bioenergie	Non-CHP thermal power plants – Bioenergy
Termoelettrici CHP - Bioenergie	CHP thermal power plants – Bioenergy
Geotermoelettrici	Geothermal
Idroelettrici	Hydroelectric
Fotovoltaici	Photovoltaics
Eolici	Wind power

An analysis of the time series of installed capacity shows significant, steady growth up to 2013; from that year onwards, the trend reversed due to the decommissioning of several thermoelectric power plants. The largest contributions in this respect come in particular from renewable sources such as solar and wind power, although not enough to compensate for the decline in overall output.

Figure 44: Time series of output of electric power plants (MW)

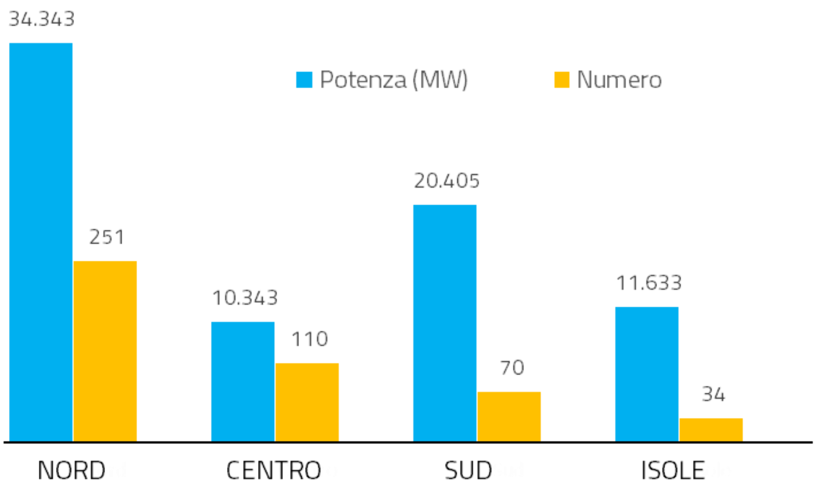


Impianti in Totale	Total plants
Impianti Termoelettrici	Thermal power plants
Impianti Idroelettrici	Hydroelectric plants
Impianti Fotovoltaici	Photovoltaic plants
Impianti Eolici	Wind power plants
Impianti Geotermoelettrici	Geothermal plants

Attention has been focused on those plants which, on account of their size, are expected to offer more significant heat recovery, i.e. thermal power stations with a capacity of more than 5 MWe. The installed capacity of this size class is 76.7 GW (65% of the total).

Thermal power stations with a capacity of more than 5 MW are mostly located in the north (54%); their total installed capacity is 34.3 GW. Central Italy has 24% of these plants, and the south and Islands have 22%.

Figure 45: Geographical distribution of thermal power stations with a capacity of more than 5 MW. Capacity and number



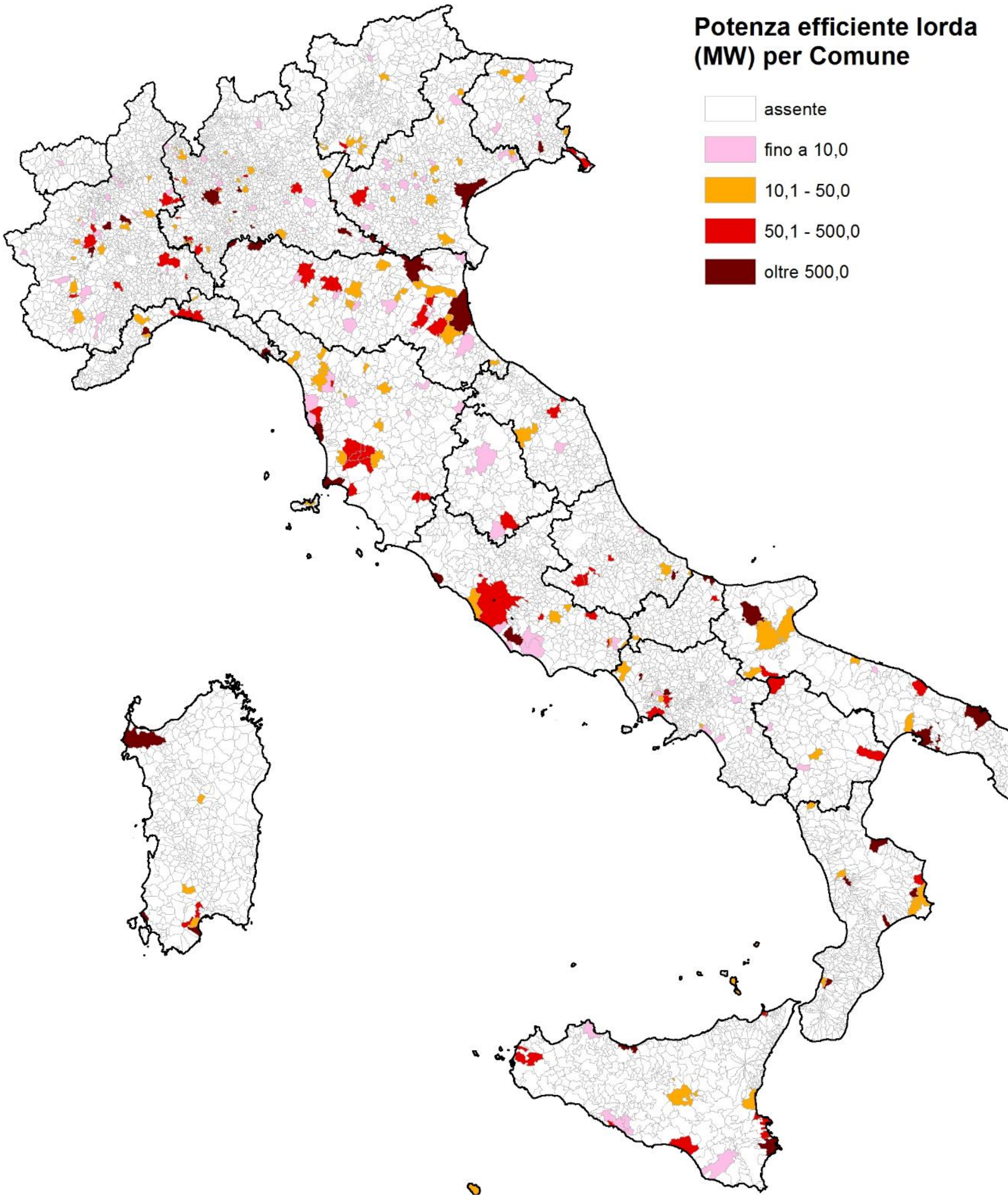
Potenza (MW)	Capacity (MW)
Numero	Number
NORD	NORTH
CENTRO	CENTRE
SUD	SOUTH
ISOLE	ISLANDS

The following map shows the geographical distribution of medium-large installed thermoelectric capacity in Italy.

The identification details of the thermal power stations have been taken from the Gaudi database of electrical power stations managed by Terna. The capacity used is gross electric output.

Capacities were cumulated by municipality, excluding non-thermal stations using renewables (photovoltaic, wind, hydroelectric) and all electricity generation plants below 5 MWe, which on initial assessment are considered to be less relevant for potential centralised heat production systems. Consequently, the mapped municipal electrical capacities do not match the sum total of the electrical capacities installed in each municipality.

Figure 46: Geographical distribution of plants with thermoelectric capacity exceeding 5 MW



Potenza efficiente lorda (MW) per Comune	Gross electric output (MW) per municipality
assente	none
fino a 10,0	up to 10.0
oltre 500,0	over 500.0

A look at the map shows that the highest thermoelectric capacity is located in the north of the country, in absolute terms and in terms of geographical concentration. This is mainly due to both the greater demand for electricity in northern Italy[16] and the more evenly distributed presence of industrial

[16] Electricity consumption in Northern Italy is double that of the whole of southern Italy and the islands combined.

plants in that area, compared with the south which, by contrast, has large, more isolated industrial centres.

For the purpose of the assessments made in this study, the plants have been categorised in terms of type and fuel by collating and harmonising identification and operating data from the databases managed by Terna (which holds and handles the electricity data and identification details of all the national plants) and by GSE (which certifies, monitors and provides incentives to produce energy from renewable sources).

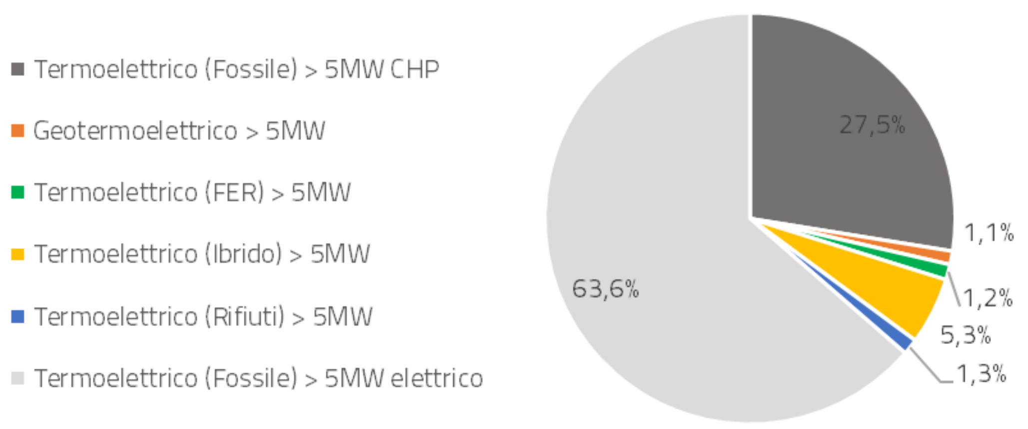
The plants included in the map have a capacity of > 5 MWe and use a thermal fuel.

The plants have been classified according to type of fuel as follows:

- thermoelectric (fossil): plants using fossil fuels such as coal, petroleum products, natural gas, other derived gases;
- thermoelectric (renewables): plants using bioenergies such as solid biomass, bioliquids and biogases;
- thermoelectric (waste): plants powered by waste;
- thermoelectric (hybrid): plants using a combination of the previous sources;
- geothermal power: plants using endogenous fluids from the ground.

The electrical capacity installed in Italy at the end of 2018 was 118.1 GW but, as stated earlier, this study has only analysed those thermal power stations with a capacity of more than 5 MWe in order to assess their heat recovery potential. The installed capacity of these plants can be measured as 76.7 GW.

Figure 47: Thermoelectric generation mix > 5 MW – Total 76.7 GW



Termoelettrico (Fossile) > 5MW CHP	Thermoelectric (fossil) > 5 MW CHP
Geotermoelettrico > 5MW	Geothermal electric > 5 MW
Termoelettrico (FER) > 5MW	Thermoelectric (renewables) > 5 MW
Termoelettrico (Ibrido) > 5MW	Thermoelectric (hybrid) > 5 MW
Termoelettrico (Rifiuti) > 5MW	Thermoelectric (waste) > 5 MW

Termoelettrico (Fossile) > 5MW elettrico	Thermoelectric (fossil) > 5 MW electrical

Looking at the energy sources of thermal power stations having a capacity exceeding 5 MW, we can see that the vast majority (91% of the sample) uses fossil fuels; a share (28% of total installed capacity) of those plants are used for cogeneration. Just 1.1% of the thermoelectric capacity mix is made up of geothermal electrical plants, 1.2% of plants powered by bioenergy[17] and waste-to-energy plants and hybrid plants account for around 7%.

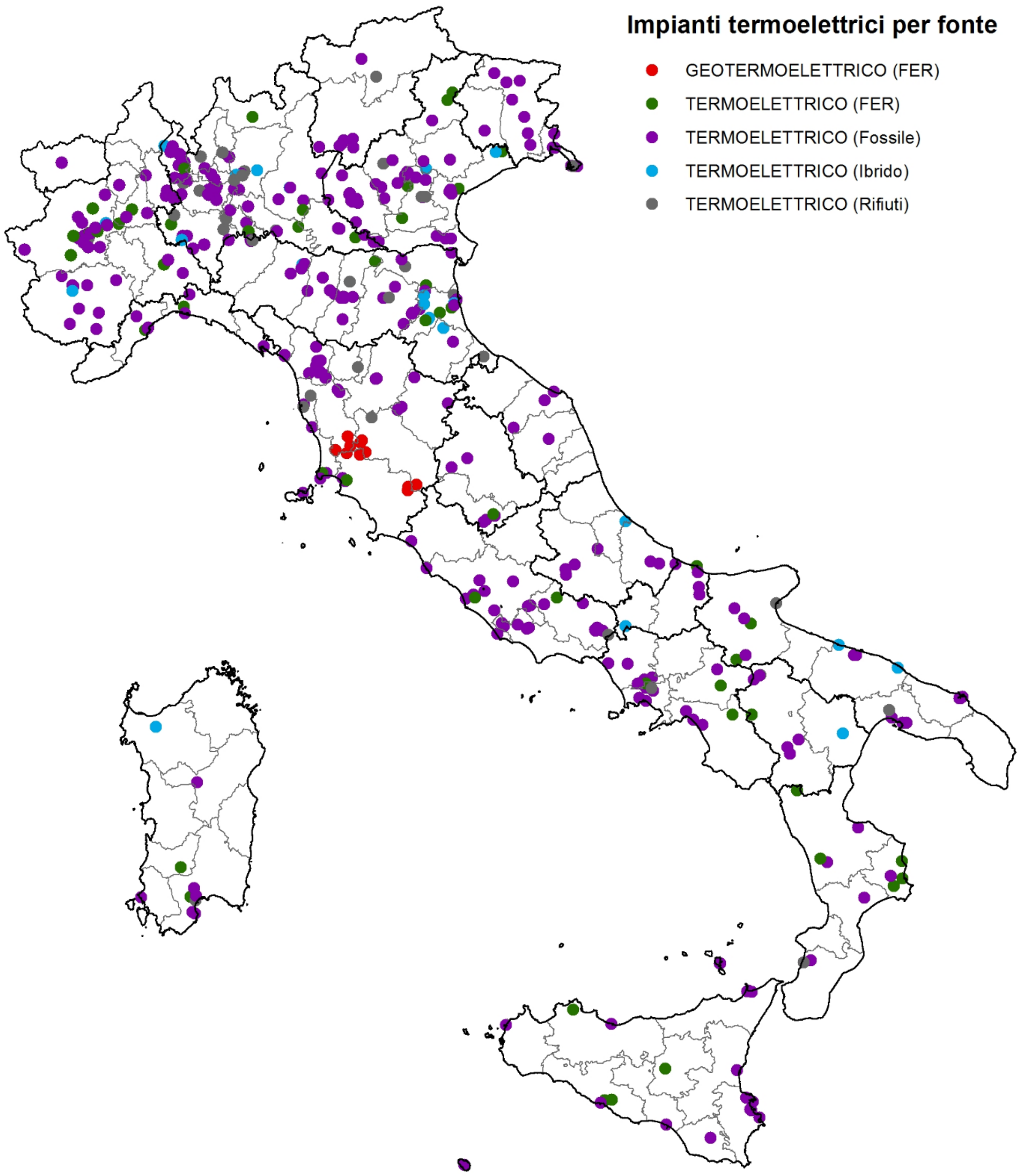
The following map shows the geographical distribution of thermal power stations with a capacity greater than 5 MWe, with an indication of the type of plants and power sources. The plants have been categorised by collating and harmonising the data from several databases managed by various organisations with different roles in the energy sector (Terna, GSE, AIRU, Utilities).

Thermal power plants were categorised in terms of:

- geographical location
- capacity
- heat recovery and compliance with high-efficiency cogeneration requirements
- power source.

[17] This share is significantly lower than the share of total national production, because most of the capacity from bioenergies is below the capacity threshold considered here.

Figure 48: Geographical distribution of thermal power stations with a capacity of more than 5 MW.



Impianti termoelettrici per fonte	Thermal power plants by source
GEOTERMOELETTRICO (FER)	GEOTHERMAL (renewables)
TERMOELETTRICO (FER)	THERMOELECTRIC (renewables)
TERMOELETTRICO (Fossile)	THERMOELECTRIC (Fossil)
TERMOELETTRICO (Ibrido)	THERMOELECTRIC (hybrid)
TERMOELETTRICO (Rifiuti)	THERMOELECTRIC (waste)

Within the selected class of thermal power stations having a capacity of more than 5 MW, the Region of Lombardy has the greatest number of hybrid plants (9) and waste-fuelled plants (8). Piedmont has a higher than average share of plants using renewable energy sources (20% of its plants use renewables), while Tuscany stands out as the only region with geothermal electricity plants. In the centre and south, the concentration of renewable thermal power plants is lower but more evenly distributed.

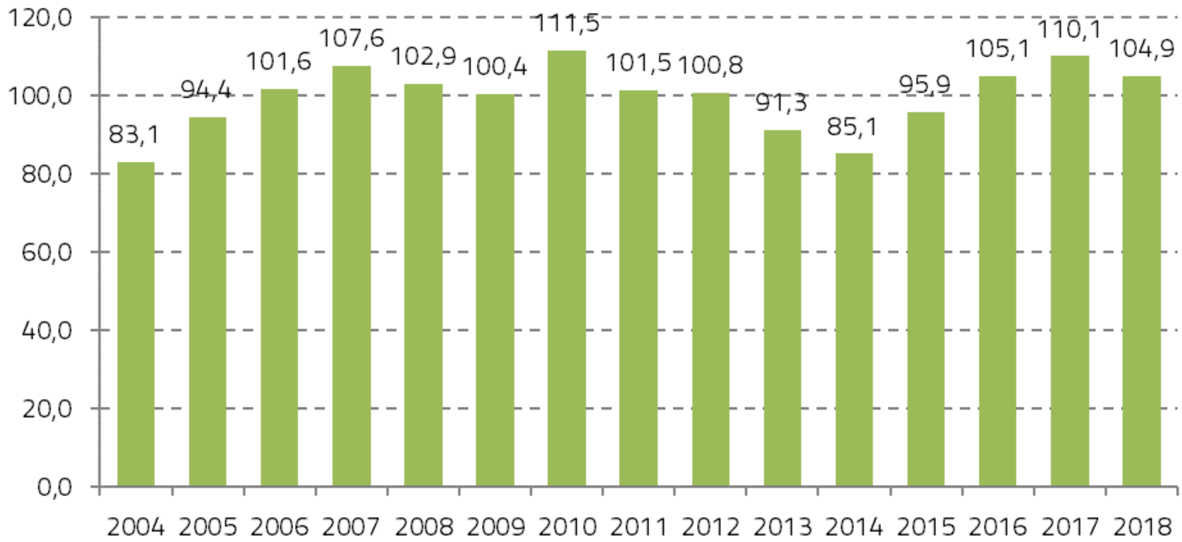
4.2 Cogeneration (CHP) plants

As of 2018, 22% of the national generation capacity, or 26 GW, consisted of cogeneration plants.

According to Eurostat data, supplied by Terna under Regulation (EC) No 1099/2008, CHP power generation in Italy rose steadily over the period from 1990 to 2007, going from 16.6 TWh to 107.6 TWh. In recent years, the trend has been up and down, peaking in 2010 and reaching a low of 85.1 TWh in 2014.

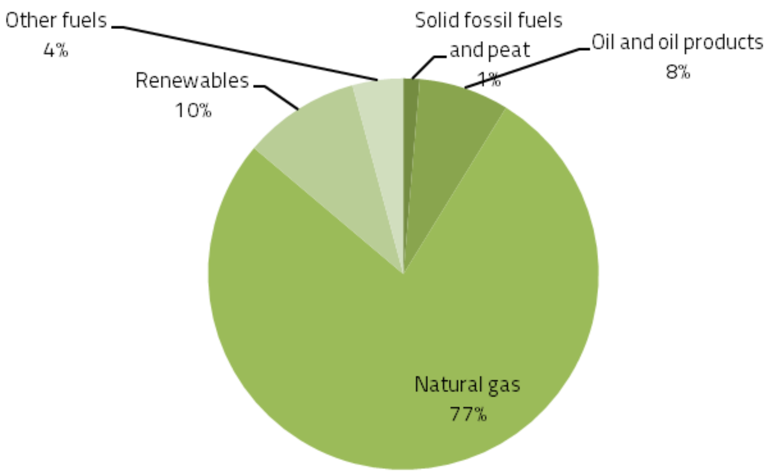
In 2018, electricity production in CHP plants totalled 104.9 TWh, based on installed capacity of 26 GW.

Figure 49: Time series of electricity generation by CHP plants (TWhe)



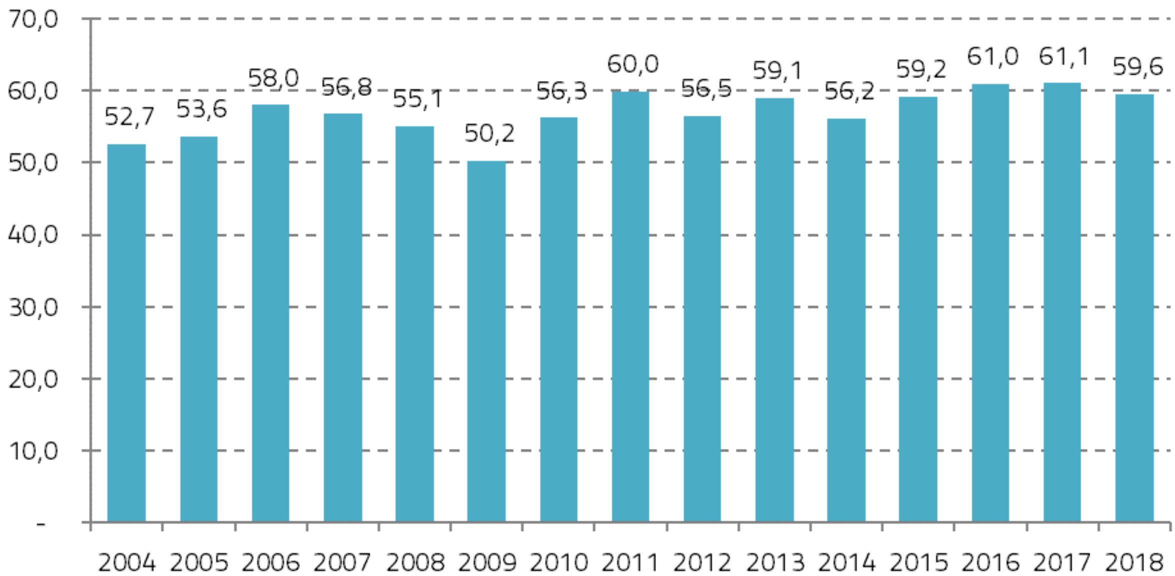
Focusing on 2018, it can be noted that the fuel most used in these plants is natural gas, which alone accounts for 77% of gross power generation from CHP.

Figure 50: Electricity generation from CHP plants in 2018 by source – Total 104.9 TWhe



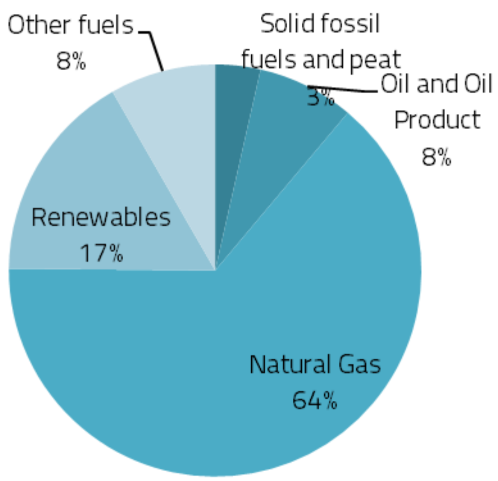
The useful heat from CHP plants in 2018 stood at 59.6 TWht, up from previous years. The trend observed in individual years is slightly different from that of electricity, but it reflects the same fluctuations.

Figure 51: Time series of the useful heat produced by CHP plants (TWht)



More than 60% of the useful heat is produced by natural gas.

Figure 52: Useful heat produced by CHP plants in 2018, broken down by source - Total 59.6 TWht



It is important to highlight that the data presented so far (consistent with Eurostat's compilation rules) always refers to all the energy produced in plants that operate, even if only partially, in cogeneration mode. For this purpose, Directive 2008/4/EC (updated by Annex I to Directive 2012/27/EU), aiming to promote cogeneration, introduced the concept of 'electricity from cogeneration', defined as electricity generated in a process linked to the production of useful heat. The Directive then defined the method for calculating electricity from cogeneration, based on minimum values of overall efficiency.

The production of electricity from cogeneration is considered equal to total annual electricity production in cogeneration units with an annual overall efficiency of at least 75% or 80% according to plant type (overall efficiency, defined as the annual sum of electricity and useful heat output divided by the fuel input, is higher the more the plant operates in cogeneration mode). In units not meeting this efficiency requirement, the quantity of electricity from cogeneration is recalculated, according to the technology, based on the ratio of electricity to heat produced, using the method set out in Annex I to Directive 2012/27/EU.

Applying this method, 39.7 TWh of electricity was produced from cogeneration in 2018 (source: Eurostat), well below the 104.9 TWh which takes into account all cogenerated electricity produced, including by plants that operate only partially in cogeneration mode. Natural gas contributes 66% of the total.

Figure 53: Time series of 'electricity from cogeneration' as defined in Annex 1 to Directive 2012/27/EU (TWh)

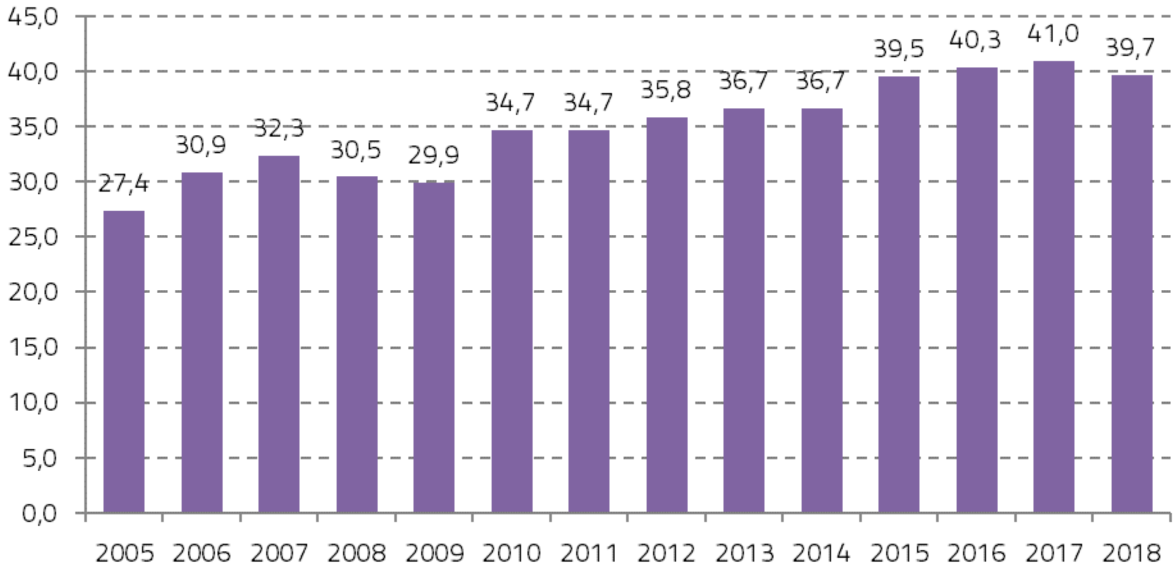
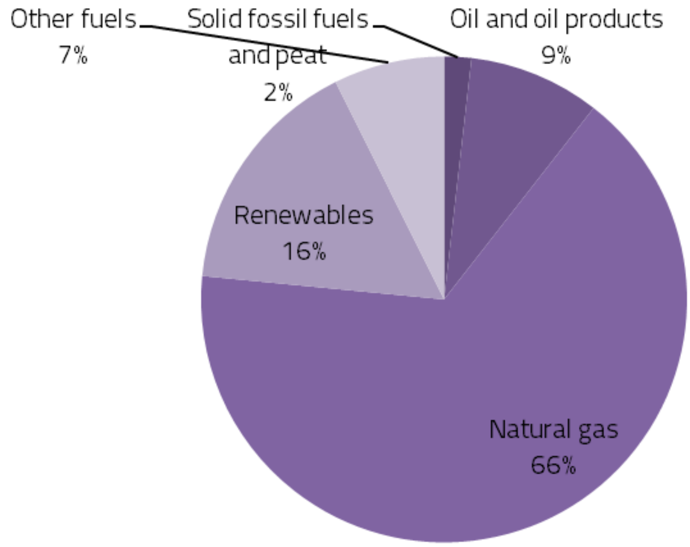


Figure 54: Electricity produced from cogeneration in 2018, broken down by source – Total 39.7 TWhe



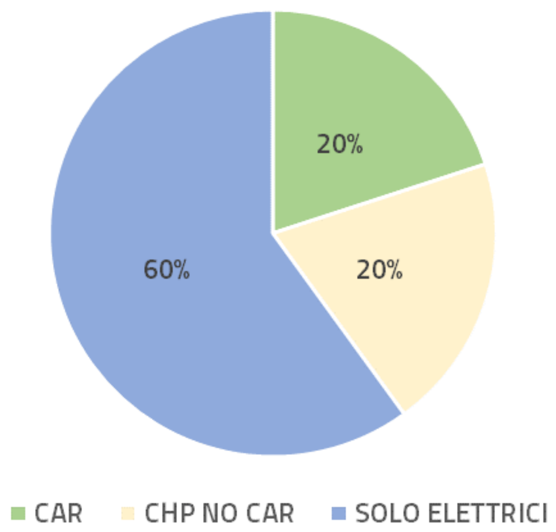
4.3High-efficiency cogeneration (HE CHP) plants

The analyses in this section derive partly from calculations carried out on the basis of all the data contained in applications submitted to GSE regarding output in 2018. These applications were for the recognition of high-efficiency cogeneration pursuant to the Ministerial Decree of 4 August 2011, and for the recognition of cogeneration pursuant to Decision AEEG 42/02, for cogeneration units associated with a district heating network and classified pursuant to the Ministerial Decree of 24 October 2005 as amended.

Values used to calculate efficiency of cogeneration and primary energy savings shall be determined on the basis of the operation of the unit under normal conditions of use. According to Annex 2 to the Ministerial Decree of 4 August 2011, cogeneration is defined as high efficiency if the output from the cogeneration units provides primary energy savings (PES) of at least 10% compared with the references for separate production of heat and electricity. Cogeneration can also be defined as being high-efficiency for small and micro-cogeneration units having PES greater than zero.

As stated earlier, at the end of 2018, 40% of installed thermoelectric capacity was categorised as cogeneration, and around half of this satisfied the definition of high-efficiency cogeneration.

Figure 55: Breakdown of thermoelectric capacity by cogeneration level



20%	20%
60%	60%
20%	20%
CAR	HIGH-EFFICIENCY COGENERATION
CHP NO CAR	NON HIGH-EFFICIENCY COGENERATION
SOLO ELETTRICI	ELECTRICITY ONLY

The thermal power stations producing electricity only are spread quite evenly across the country. By contrast, high-efficiency CHP plants tend to be more concentrated in the north, demonstrating the link between the development of high-efficiency CHP and the presence of industrial sites.

The following map provides a snapshot of the current spread of cogeneration in Italy. The plants considered have an electrical capacity of more than 5 MWe[18] and the operating data for assessing their compliance with high-efficiency cogeneration requirements relate to the year 2018.

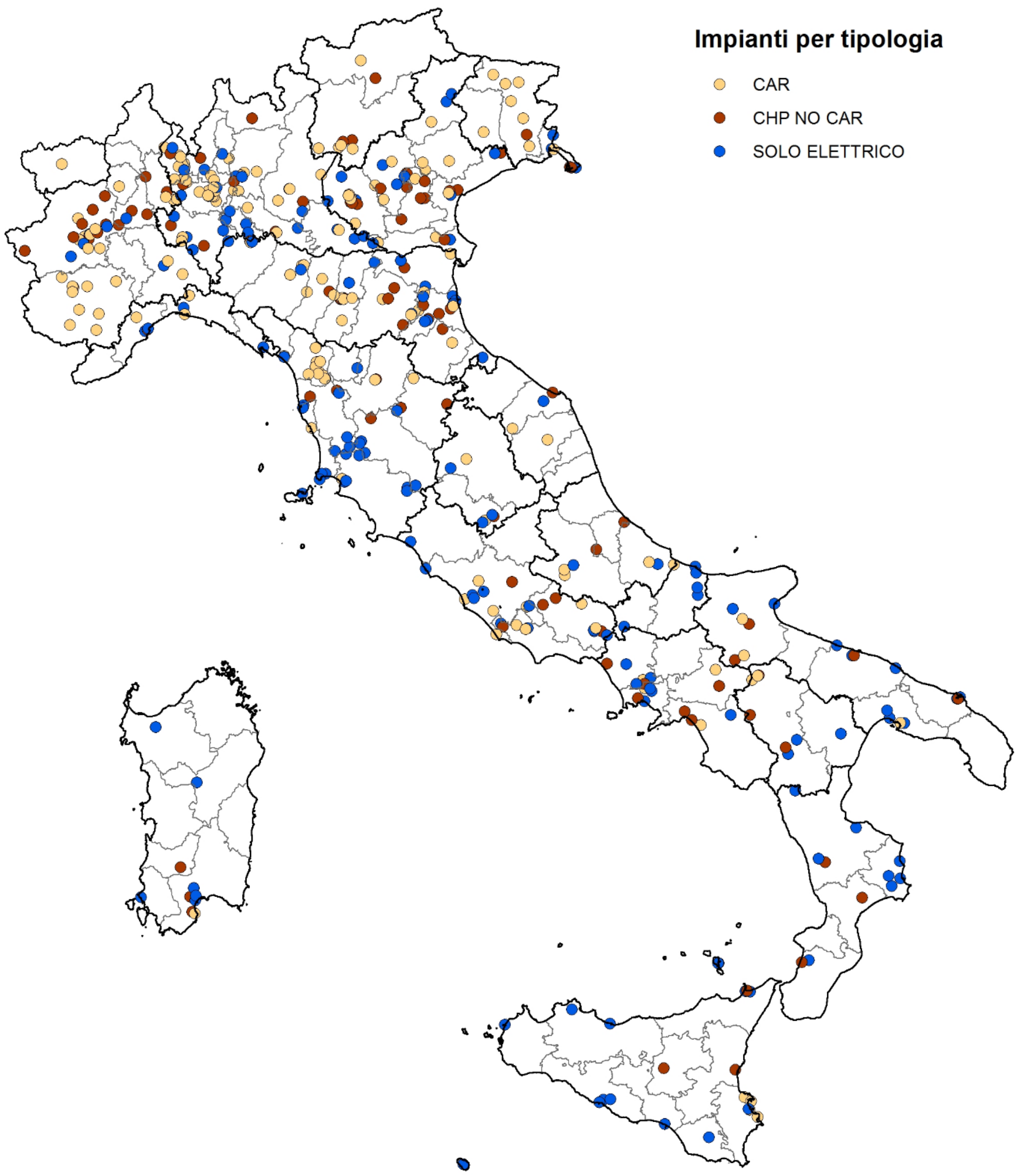
The plants have been classified in relation to cogeneration as follows:

- electricity only: producing only electricity
- Non-HE CHP: plants producing both electricity and heat but which in 2018 did not meet the requirements for classification as high-efficiency CHP [19]
- High-efficiency CHP: plants which in 2018 produced electricity and heat in accordance with high-efficiency requirements.

[18] The map thus does not include about 5% of total high-efficiency CHP capacity in 2013. More than half of the 1 024 CHP plants have a capacity lower than 5 MW and a total nominal capacity of just over 500 MWe.

[19] This includes plants not classed as high-efficiency CHP for various reasons, including failing to apply for recognition, the operating mode used in 2018 and design requirements. It cannot be ruled out that plants giving the first two reasons may be reclassified as HE CHP at a later date.

Figure 56: Map of thermal power stations with a capacity of more than 5 MWe, categorised according to cogeneration type



Impianti per tipologia	Plants by type
CAR	HIGH-EFFICIENCY COGENERATION
CHP NO CAR	NON HIGH-EFFICIENCY COGENERATION
SOLO ELETTRICO	ELECTRICITY ONLY

4.3.1 HE CHP: production and plant technology

The analyses carried out in this section of the document are based largely on the applications for recognition as a high-efficiency CHP plant received by GSE for the year 2018, supplemented with other data available for statistical purposes. More precisely, the number of units, total generation capacity and gross electricity output set out below refer to the total number of units that applied to GSE for recognition as high-efficiency units. However, the electricity produced in high-efficiency cogeneration and cogenerated useful heat refer only to the units which met the requirements for high-efficiency CHP.

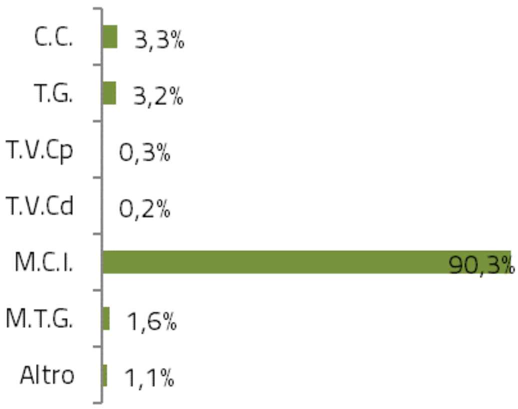
The scope of analysis covers 1 865 cogeneration units, with a total generation capacity of more than 13 GW.

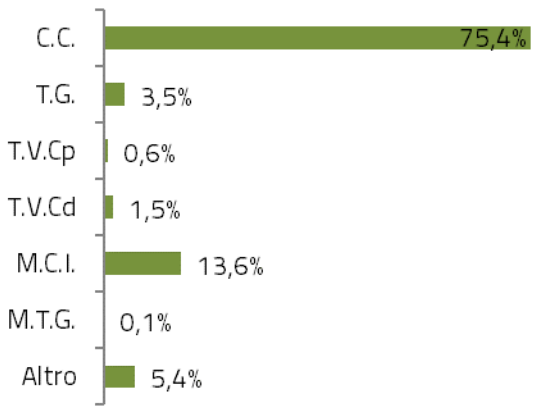
Cogeneration technologies are those defined in Part II of Annex I to Directive 2012/27/EU:

- combined cycle gas turbine with heat recovery (CC)
- gas turbine with heat recovery (GT)
- steam back pressure turbine (SBPT)
- steam-condensing extraction turbine (SCET)
- internal combustion engine (ICE)
- microturbines (MTG);
- Stirling engines, fuel cells, steam engines, organic Rankine cycles and any other type of technology or combination of technologies not falling within the above definitions (other).

As to the share of each cogeneration technology used, the greatest incidence in terms of number is that of internal combustion engines (ICE), making up 90% of the sample. Combined-cycle gas turbines with heat recovery (CC) and gas turbines with heat recovery (GT) make up 6.5% of the sample examined.

Figure 57: Number of units (100%=1 865 units) **Figure 58: Generation capacity (100%=13 442 MW)**





C.C.	CC
T.G.	GT
T.V.Cp	SBPT
T.V.Cd	SCET
M.C.I.	ICE
M.T.G.	MTG
Altro	Other
3,3%	3.3%
3,2%	3.2%
0,3%	0.3%
0,2%	0.2%
90,3%	90.3%
1,6%	1.6%

1,1%	1.1%
C.C.	CC
T.G.	GT
T.V.Cp	SBPT
T.V.Cd	SCET
M.C.I.	ICE
M.T.G.	MTG
Altro	Other
75,4%	75.4%
3,5%	3.5%
0,6%	0.6%
1,5%	1.5%
13,6%	13.6%
0,1%	0.1%
5,4%	5.4%

Out of the 13.4 GW of capacity, 13.6% is attributable to internal combustion engines, while combined cycle gas turbines with heat recovery are the technology with the largest amount of installed electricity generation capacity (75.4%) in the group considered.

The limited number (and capacity) of steam turbines (back-pressure or steam condensing) not coupled with gas turbines shows that sector operators have typically selected combined-cycle cogeneration units, including by modifying previous layouts of units consisting of steam turbines alone, by installing upstream one or more gas turbines with their heat recovery steam generators.

The largest contributions to the production of electricity and heat undoubtedly came from combined cycles, supported by internal combustion engines for both variables and by gas turbines for useful heat.

The total electricity produced in 2018 by the 1 865 units analysed by the GSE is 57 752 GWh, while the useful heat is 35 570 GWh.

Figure 59: 'Gross' electricity (100% = 57 752 GWhe)

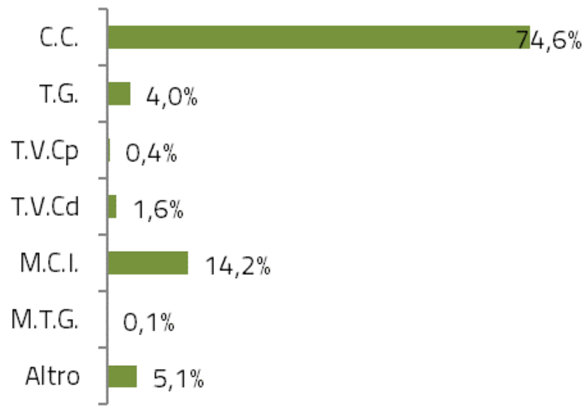
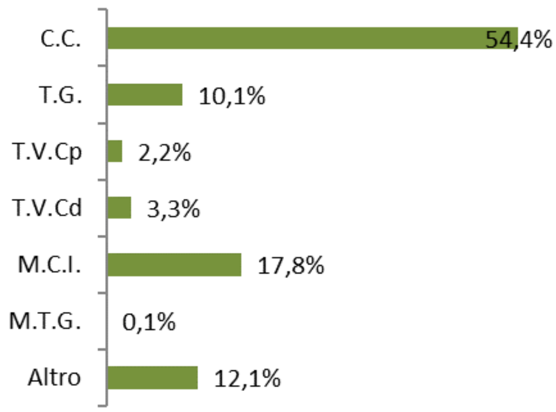


Figure 60: Useful heat (100% = 35 570 GWht)

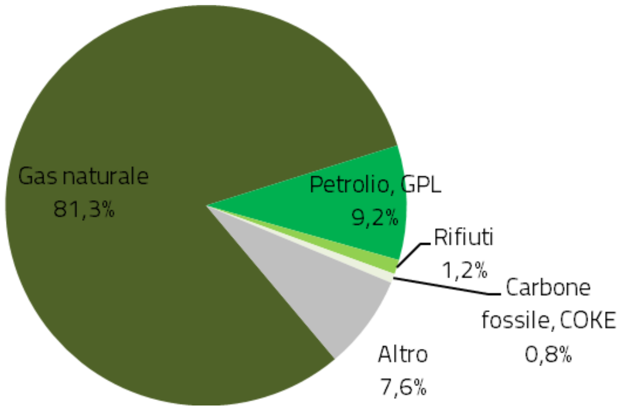


C.C.	CC
T.G.	GT
T.V.Cp	SBPT
T.V.Cd	SCET
M.C.I.	ICE
M.T.G.	MTG
Altro	Other
74,6%	74.6%
4,0%	4.0%
0,4%	0.4%
1,6%	1.6%
14,2%	14.2%
0,1%	0.1%
5,1%	5.1%
C.C.	CC
T.G.	GT
T.V.Cp	SBPT
T.V.Cd	SCET
M.C.I.	ICE
M.T.G.	MTG
Altro	Other
54,4%	54.4%
10,1%	10.1%
2,2%	2.2%
3,3%	3.3%
17,8%	17.8%
0,1%	0.1%
12,1%	12.1%

Natural gas is the main fuel and is practically the only fuel used for internal combustion engines and gas turbines, whether simple cycle or combined cycle.

Waste is used only by units with steam-condensing extraction turbines, while renewable sources, which include dry biomass, biogas and synthetic gas from gasification of dry biomass, are used by internal combustion engines, steam back pressure turbines and 'other' cogeneration technologies.

Figure 61: Fuels used by the plants that applied for classification as high-efficiency CHP in 2018



Gas naturale 81,3%	Natural gas 81.3%
Petrolio, GPL 9,2%	Petrol, LPG 9.2%
Rifiuti 1,2%	Waste 1.2%
Carbone fossile, COKE 0,8%	Hard coal, coke 0.8%
Altro 7,6%	Other 7.6%

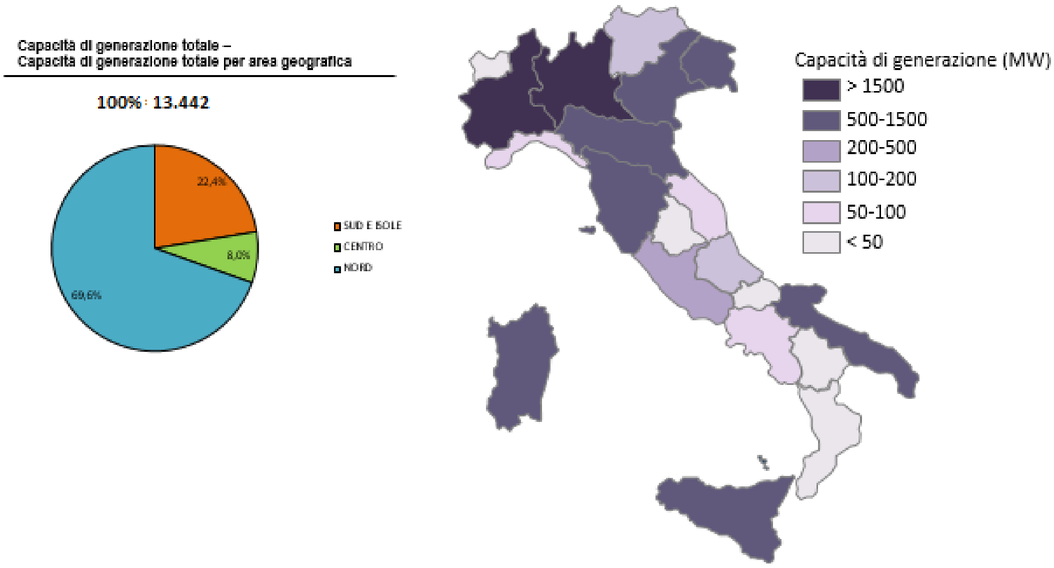
GSE processing of operational data for 2018 indicates that the high-efficiency electricity produced totals 28 627 GWh, about 50% of the total production of the units analysed. The useful heat produced in compliance with HE CHP requirements is 35 570 GWh.

4.3.2 HE CHP: geographical distribution

High-efficiency cogeneration is more widespread, both in terms of number of units and installed electricity generation capacity, in northern Italy, while higher average capacity values are recorded in southern Italy and on the islands.

Approximately 70% of generation capacity is located in the north, especially in Lombardy and Piedmont. In the south and on the islands, only Apulia and Sicily recorded significant results. Central Italy's contribution is modest, with only Tuscany and Emilia-Romagna recording significant values.

Figure 62: Geographical distribution of the plants that applied for recognition of high-efficiency CHP in 2018



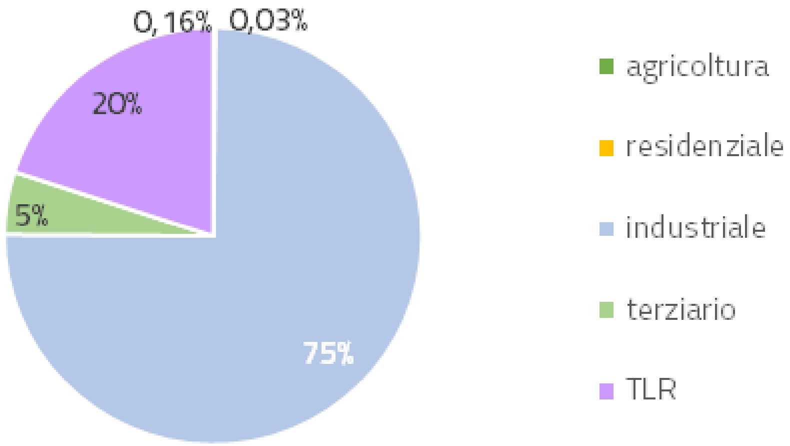
Capacità di generazione totale – Capacità di generazione totale per area geografica	Total generation capacity – Total generation capacity by geographical area
100% 13.442	100% 13 442
22,4%	22.4%
8,0%	8.0%
69,6%	69.6%
SUD E EOLE	SOUTH AND ISLANDS
CENTRO	CENTRE
NORD	NORTH
Capacità di generazione (MW)	Generation capacity (MW)
> 1500	> 1 500
500-1500	500-1 500
200-500	200-500
100-200	100-200
50-100	50-100
< 50	< 50

4.3.3 HE CHP: sectors of use

To provide a picture of the final use of the energy generated by high-efficiency CHP units, a survey was carried out of the sectors that used the heat and electricity from high-efficiency CHP plants in 2018, by identifying the sector of the company owning each CHP plant. If the owner was an ESCO or a utilities company, the sector to which the final users of the thermal energy produced by the high-efficiency CHP plant belong was also taken into account.

In 2018, 75% of the heat produced by high-efficiency CHP was used in the industrial sector and 25% for services and district heating. The contribution from the residential and agricultural sectors was negligible.

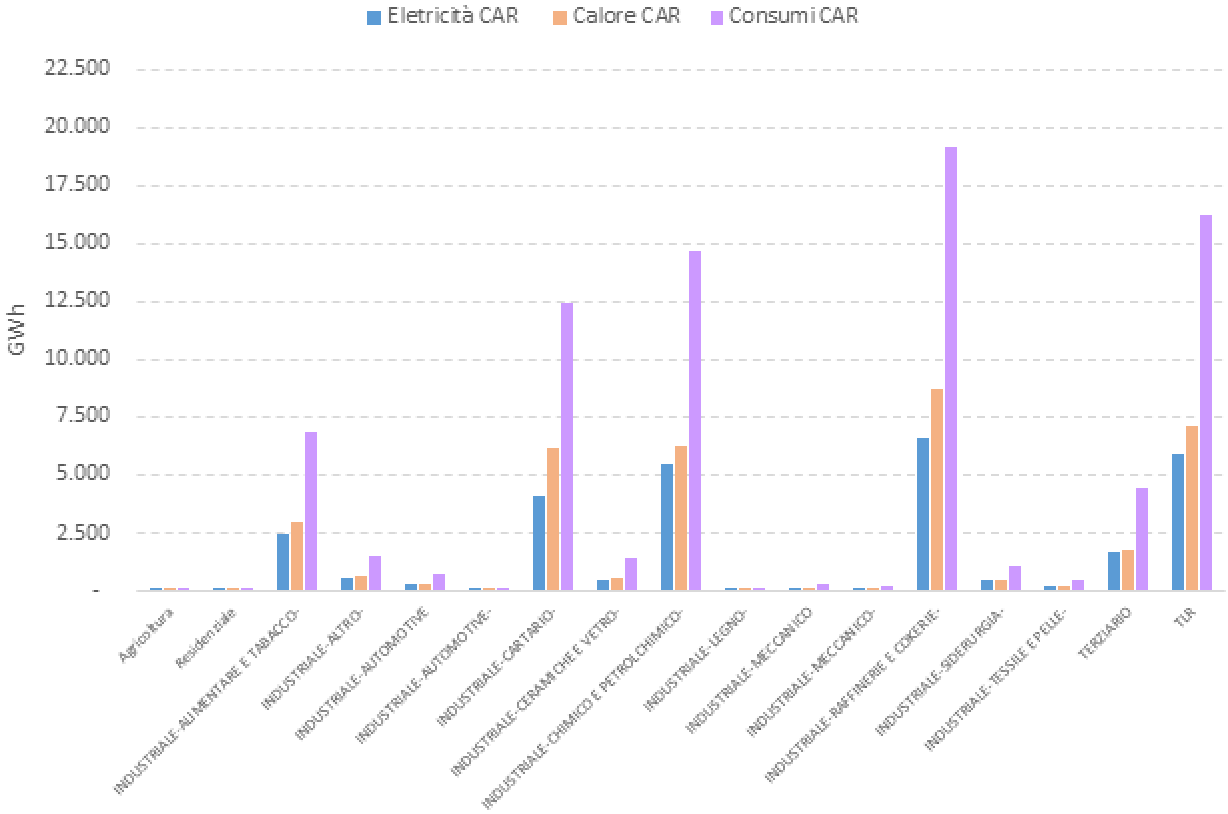
Figure 63: Breakdown of the final uses of the heat produced by high-efficiency CHP by sector



0,16%	0.16%
0,03%	0.03%
20%	20%
5%	5%
75%	75%
agricoltura	agriculture
residenziale	residential
industriale	industrial
terziario	services
TLR	DH

The industrial sector is the main end-use sector for heat from high-efficiency CHP. Within industry, the greatest end-users are refineries and coke ovens, the chemicals and petrochemicals industry, and the paper industry.

Figure 64: Electricity and useful heat and consumption from individual high-efficiency CHP units by sector



Electricità CAR	HE CHP electricity
Calore CAR	HE CHP heat
Consumi CAR	HE CHP consumption
22.500	22 500
20.000	20 000
17.500	17 500
15.000	15 000
12.500	12 500
10.000	10 000
7.500	7 500
5.000	5 000
2.500	2 500
GWh	GWh
Agricoltura	Agriculture
Residenziale	Residential
INDUSTRIALE-ALIMENTARE E TABACCO-	INDUSTRIAL – FOOD AND TOBACCO –
INDUSTRIALE-ALTRO-	INDUSTRIAL – OTHER –
INDUSTRIALE-AUTOMOTIVE	INDUSTRIAL – AUTOMOTIVE –
INDUSTRIALE-AUTOMOTIVE-	INDUSTRIAL – AUTOMOTIVE –
INDUSTRIALE-CARTARIO-	INDUSTRIAL – PAPER –
INDUSTRIALE-CERAMICHE E VETRO-	INDUSTRIAL – CERAMICS AND GLASS –

INDUSTRIALE-CHIMICOE PETROL CHIMICO-	INDUSTRIAL – CHEMICALS AND PETROCHEMICALS –
INDUSTRIALE-LEGNO-	INDUSTRIAL – WOOD –
INDUSTRIALE-MECCANICO-	INDUSTRIAL – MECHANICAL –
INDUSTRIALE-MECCANICO-	INDUSTRIAL – MECHANICAL –
INDUSTRIALE-RAFFINERIE E COKERIE-	INDUSTRIAL – REFINERIES AND COKE OVENS –
INDUSTRIALE-SIDERURGIA-	INDUSTRIAL – STEEL –
INDUSTRIALE-TESSILE E P ELLE	INDUSTRIAL – TEXTILE AND LEATHER –
TERZIARIO	SERVICES
TLR	DH

At a regional level, the highest consumption of heat from HE CHP takes place in Lombardy, Piedmont, Sicily and Tuscany, which account for 63% of the total. The highest consumption of heat from HE CHP in the industrial sector was recorded in Sicily.

Table 41: Regional distribution of CHP heat consumption by sector (GWh)

Region	Sector					Overall total
	Industrial	Services	Residential	Agriculture	DH	
ABRUZZO	521	0				521
BASILICATA	186					186
CALABRIA	1	26		27		54
CAMPANIA	231	14		1	7	254
EMILIA-ROMAGNA	1 947	205	7	13	488	2 660
FRIULI-VENEZIA GIULIA	927	69			1	997
LAZIO	961	164	0		57	1 182
LIGURIA	244	40			19	303
LOMBARDY	3 897	738	3	12	2 372	7 022
MARCHE	369	25			7	401
MOLISE	38	0				39
AUTONOMOUS PROVINCE OF BOLZANO	86	15			31	132
AUTONOMOUS PROVINCE OF TRENTO	599	9	0		533	1 141
PIEDMONT	3 288	98	0		2 711	6 097
APULIA	211	5			621	837
SARDINIA	1 343					1 343
SICILY	5 312	22				5 334
TUSCANY	3 961	87	0			4 047
UMBRIA	142	19			20	181
VALLE D'AOSTA	1			30	31	
VENETO	2 329	192	0	2	204	2 728
Italy	**26 593**	**1 730**	**11**	**56**	**7 103**	**35 492**

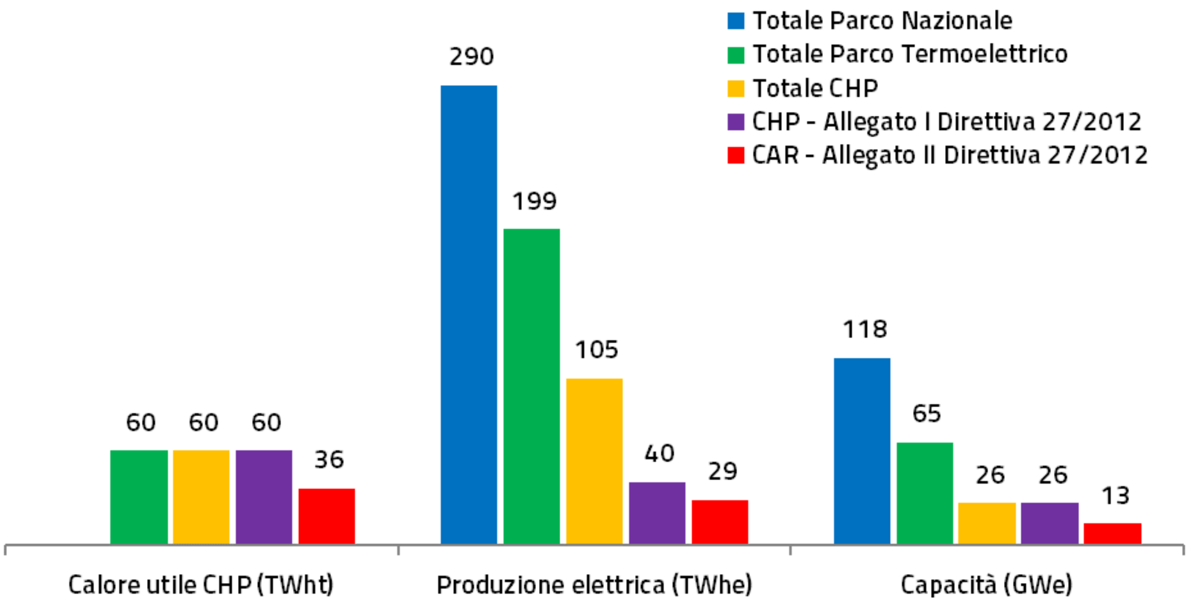
4.4 Overview of the national stock of power plants

This section provides an overview of the national stock of power plants. It provides data on installed capacity, both total and in cogeneration mode, and on the associated production of electricity and heat under the various meanings of cogeneration set out in the legislation.

As of 2018, the national stock of electric power plants has a capacity of 118 GW. The amount of electricity produced was 290 TWhe.

- A subset of the national stock of power plants is the stock of thermal power stations, which has a capacity of 65 GW and an output of 199 TWhe.
- The Italian stock of thermal power stations includes a share of plants operating in cogeneration mode: this further subset has a capacity of 26 GW and produces 105 TWhe of electricity and 60 TWht of useful heat.
- According to Directive 2012/27/EU, it is important to identify the share of electricity that is truly cogenerated in cogeneration plants. The method set out in Annex I for calculating the amount of 'electricity from cogeneration' was applied to determine the quantity of electricity produced in cogeneration mode, which totalled 40 TWhe. The value of the useful heat produced remains 60 TWht.
- The information from the applications submitted to GSE for recognition of high-efficiency cogeneration, pursuant to the Ministerial Decree of 4 August 2011, was used to identify the subset of plants meeting the restrictive criteria set out in Annex II to Directive 2012/27/EU. The total capacity of the submitted applications is 13 GW, the useful heat produced is 36 TWht and the electricity produced in high-efficiency cogeneration mode is 29 TWhe.

Figure 65: Summary diagram of the national stock of thermal power stations, specifying capacity[20] (GWe), electricity production (TWhe) and useful heat (TWht)



Totale Parco Nazionale	Total national stock
Totale Parco Termoelettrico	Total thermal power plants
Totale CHP	Total HE CHP
CHP - Allegato I Direttiva 27/2012	CHP – Annex I Directive 2012/27/EU
CAR - Allegato II Direttiva 27/2012	CHP – Annex II Directive 2012/27/EU
60	60
60	60
60	60
36	36
Calore utile CHP(TWht)	Useful heat CHP (TWht)
290	290
199	199
105	105
40	40
29	29
Produzione elettrica (TWhe)	Electricity production (TWhe)
118	118
65	65
26	26
26	26
13	13
Capacità (GWe)	Capacity (GWe)

[20] The capacity refers to the overall capacity of plants, including units which in 2018 produced energy in CHP mode. As to the capacity of high-efficiency CHP systems, this figure shows the capacity of the plants which applied for high-efficiency CHP classification (however, the high-efficiency CHP production is that of approved high-efficiency CHP plants).

5 Renewable energy in the thermal sector

In 2018, the consumption of energy from renewable sources in the thermal sector in Italy totalled approximately 10.7 Mtoe[21].

Approximately 91% of thermal energy is consumed directly by households and businesses; the remaining 9% represents the production of derived heat, i.e. heat produced in energy transformation plants powered by renewables and sold to third parties, including through district heating networks.

Approximately 90% of the derived heat is produced in plants operating in cogeneration mode, and the remaining 10% in plants used only for heat production.

It should be noted that the following tables do not include the contribution of biomethane (14 ktoe in total), as current national policies focus on its use in the transport sector, and the allocation to the thermal sector for 2018 was purely for accounting purposes[22].

Table 42: Renewable energy in the thermal sector. Direct consumption and derived heat broken down by Region/Autonomous Province in 2018

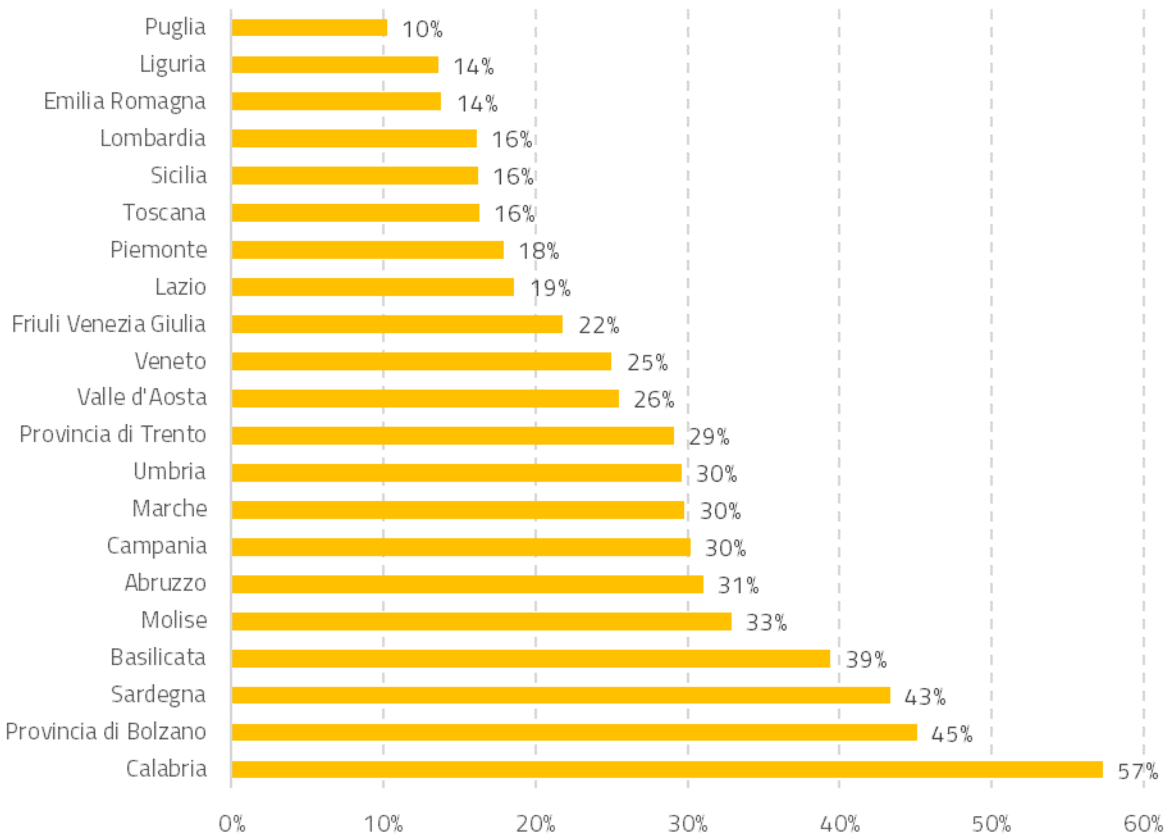
Type	Direct uses (ktoe)	Heat only (ktoe)	CHP (ktoe)	Total (ktoe)	Total (GWh)
Abruzzo	382	0	3	385	4 479
Basilicata	159	-	6	165	1 917
Bolzano	204	46	53	303	3,522
Calabria	483	-	11	494	5 747
Campania	652	-	17	669	7 775
Emilia-Romagna	773	8	112	893	10 381
Friuli-Venezia Giulia	381	1	15	397	4 615
Lazio	559	0	46	605	7 040
Liguria	166	0	0	167	1 937

[21] For further information about measuring the use of renewables in the thermal sector, please refer to the Statistical Report 'Energy from renewables in Italy', drawn up annually by GSE, from which some of the data and analyses set out in this chapter are taken (https://www.gse.it/dati-e-scenari/statistiche), and of which extensive excerpts are given in this chapter.

[22] In 2018, in order to achieve the targets set by Directive 2009/28/EC, biomethane was divided between the different consumption sectors (electricity, thermal and transport), as it was not possible to demonstrate its sustainability, a mandatory requirement for biofuels. As of 2019, with the full implementation of the Ministerial Decree of 2 March 2018, the biomethane fed into the grid is sustainable and is therefore allocated to transport in order to verify that the targets set by the Directive have been reached.

Lombardy	1 492	10	287	1 789	20 803
Marche	286	0	2	288	3 351
Molise	85	-	4	89	1 032
Piedmont	856	7	103	965	11 227
Apulia	339	-	13	353	4 101
Sardinia	322	-	4	326	3 789
Sicily	261	-	22	284	3 301
Tuscany	553	16	14	583	6 777
Trento	168	8	15	191	2 219
Umbria	298	0	9	306	3 564
Valle d'Aosta	42	4	2	48	554
Veneto	1 252	1	108	1 361	15 830
Overall total	**9 710**	**101**	**847**	**10 659**	**123 961**

Figure 66: Share of total energy consumption covered by renewables in the heating sector in 2018, broken down by Region/Autonomous Province*



Puglia	Apulia
Liguria	Liguria
Emilia Romagna	Emilia-Romagna
Lombardia	Lombardy
Sicilia	Sicily

Toscana	Tuscany
Piemonte	Piedmont
Lazio	Lazio
Friuli Venezia Giulia	Friuli-Venezia Giulia
Veneto	Veneto
Valle d'Aosta	Valle d’Aosta
Provincia di Trento	Autonomous Province of Trento
Umbria	Umbria
Marche	Marche
Campania	Campania
Abruzzo	Abruzzo
Molise	Molise
Basilicata	Basilicata
Sardegna	Sardinia
Provincia di Bolzano	Autonomous Province of Bolzano
Calabria	Calabria
10%	10%
14%	14%
14%	14%
16%	16%
16%	16%
16%	16%
18%	18%
19%	19%
22%	22%
25%	25%
26%	26%
29%	29%
30%	30%
30%	30%
30%	30%
31%	31%
33%	33%
39%	39%
43%	43%
45%	45%
57%	57%
0%	0%
10%	10%
20%	20%
30%	30%
40%	40%
50%	50%
60%	60%

*The target is calculated with the rules used to formulate the calculation regarding achievement of the target set out in Article 23 of Directive 2018/2001/EC. In particular, in line with the INECP, the contribution of waste heat recovered from district heating systems is not taken into account, but biomethane is counted. In the denominator, final consumption for heating does not include electricity consumption nor ambient energy from heat pumps, in line with Directive 2018/2001.

The following sections provide some insight into the main sources used.

5.1Direct use of renewables in the thermal sector

The direct use of renewable sources for heating and cooling is measured annually by GSE as part of its institutional activities, specifically producing statistics as a member of Sistan (National Statistical System).

In 2018, 9.7 Mtoe of energy from renewable sources was consumed directly by households and businesses through the use of a wide range of traditional or innovative systems and appliances (stoves, boilers, heat pump appliances, solar thermal collectors, etc.).
The most commonly used of these sources was solid biomass, linked to the widespread use of appliances fuelled by firewood and pellets (especially in the residential sector), with total consumption of over 6.5 Mtoe, or 66.5% of total direct consumption.
Supplying around 2.6 Mtoe of renewable energy, heat pumps accounted for 26.7% of total direct consumption in 2018; followed by waste, solar, geothermal energy and biogas, all with less than 3% of consumption. Regional and sectoral data for 2018 are presented in the table below.

Table 43: Direct consumption from renewable sources in 2018, broken down by sector and Region/Autonomous Province (figures in ktoe)

Type	Residential	Services	Industry	Agriculture	Total
Abruzzo	332.3	48.8	0.6	0.1	381.7
Basilicata	150.1	4.6	4.1	0.0	158.7
Bolzano	127.8	51.9	21.0	2.8	203.5
Calabria	450.5	25.2	6.9	0.1	482.7
Campania	560.6	81.4	8.6	0.7	651.3
Emilia-Romagna	322.7	432.3	15.9	1.5	772.3
Friuli-Venezia Giulia	216.0	108.3	55.1	1.1	380.5
Lazio	469.9	84.4	2.7	1.2	558.2
Liguria	150.3	14.2	1.1	0.4	166.1
Lombardy	608.9	738.2	142.0	8.4	1 497.5
Marche	187.9	91.9	5.5	0.5	285.8
Molise	78.9	2.2	3.4	0.0	84.5
Piedmont	655.2	186.4	11.6	1.7	854.8
Apulia	267.2	59.9	5.3	6.5	338.9
Sardinia	277.7	38.5	5.5	0.1	321.8
Sicily	164.2	84.4	12.6	0.2	261.4
Tuscany	454.4	45.6	10.4	41.9	552.3
Trento	132.8	31.2	3.2	0.5	167.7
Umbria	227.2	36.9	31.7	1.9	297.7
Valle d'Aosta	36.1	4.9	0.8	0.0	41.8

Veneto	643.2	535.2	58.3	14.1	1 250.8
Total	**6 514.0**	**2 706.5**	**406.3**	**83.5**	**9 710.2**

5.1.1 Biomass

Table 44: Direct consumption of solid biomass in the residential sector

	Lower heating value (MJ/kg)	2016		2017		2018	
		Quantity used (1 000 tonnes)	Energy (ktoe)	Quantity used (1 000 tonnes)	Energy (ktoe)	Quantity used (1 000 tonnes)	Energy (ktoe)
Firewood	13 911	**15 991**	**5 313**	**17 481**	**5 808**	**15 940**	**5 296**
First homes		15 820	5 256	17 225	5 723	15 709	5 220
Second homes		171	57	257	85	230	77
Pellets	17 284	**1 976**	**816**	**2 203**	**909**	**2 205**	**910**
First homes		1 957	808	2 171	896	2 174	898
Second homes		20	8	31	13	31	13
Charcoal	30.8	**60**	**44**	**54**	**40**	**62**	**45**
Total		**18 028**	**6 173**	**19 738**	**6 757**	**18 206**	**6 252**

*Source: GSE processing of ISTAT data

In 2018, a total of 18.2 million tonnes of solid biomass were used in the residential sector, producing a total energy content of 6 252 ktoe; a drop in consumption of approximately 7.5% compared to 2017.

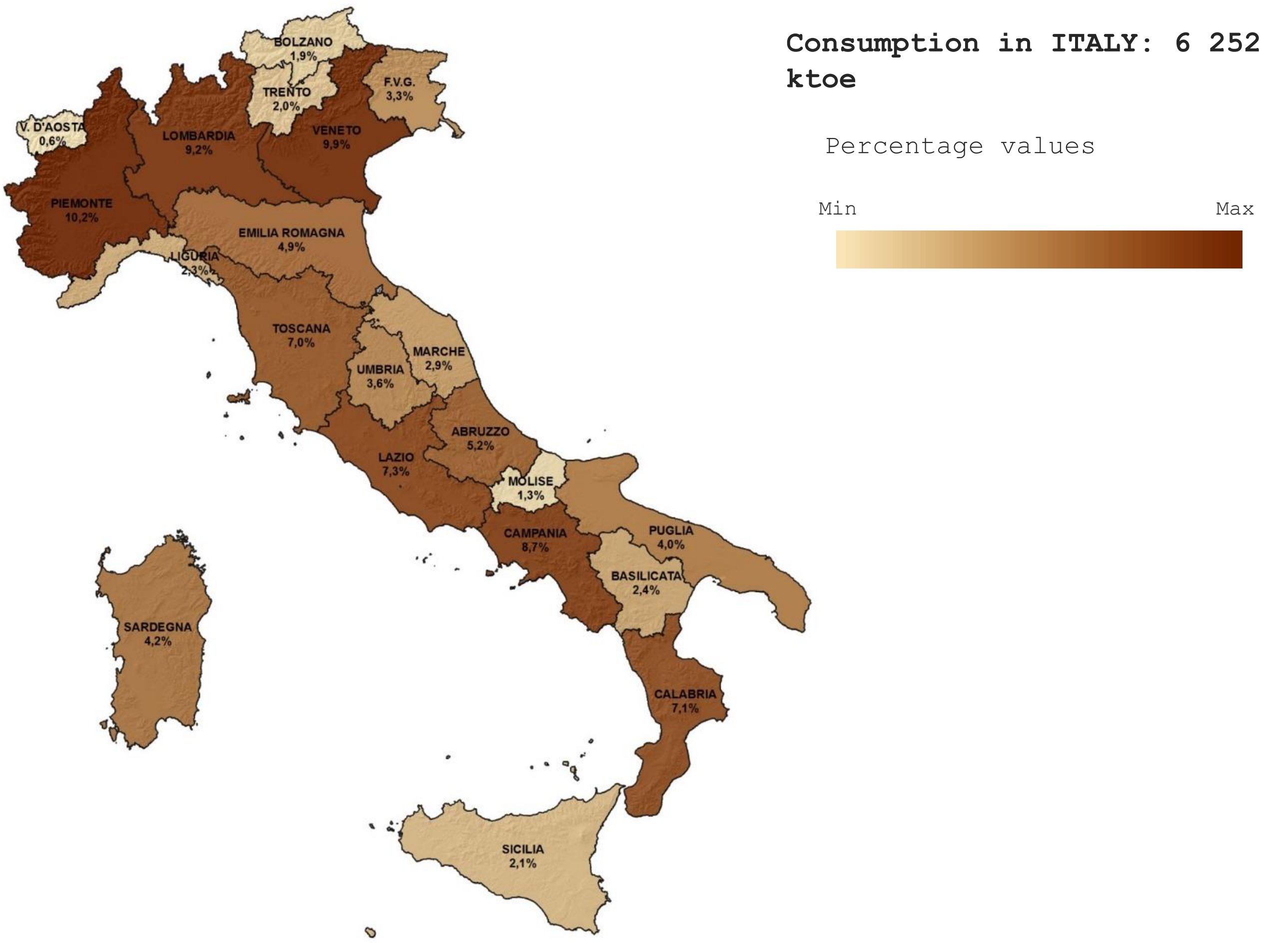
The data reported are calculated on the basis of the results of the household energy consumption survey conducted by ISTAT in 2013, appropriately processed to take climate variations into account (measured through heating degree days), the use of solid biomass for heating in second homes and changes in the stock of appliances linked to sales (stock increases) and the disposal of obsolete ones (stock decreases).

Table 45: Direct consumption of solid biomass in the residential sector by Region and Autonomous Province (ktoe)

	2013	2014	2015	2016	2017	2018	2018 (%)	Change % 2018/2017
Abruzzo	338	313	328	298	336	328	5.2%	-2.4%
Basilicata	156	141	157	145	165	148	2.4%	-10.4%
Bolzano	124	116	116	123	125	120	1.9%	-4.2%
Calabria	484	429	461	396	519	443	7.1%	-14.8%
Campania	586	495	578	525	605	545	8.7%	-9.9%
Emilia-Romagna	313	244	300	307	311	307	4.9%	-1.2%
Friuli-Venezia Giulia	212	181	210	213	223	206	3.3%	-7.5%
Lazio	539	458	509	461	522	455	7.3%	-12.8%
Liguria	149	114	126	137	147	144	2.3%	-2.0%
Lombardy	614	517	568	596	608	574	9.2%	-5.5%
Marche	188	164	177	181	182	184	2.9%	1.2%
Molise	82	76	83	76	86	78	1.3%	-8.9%
Piedmont	660	584	618	651	650	636	10.2%	-2.2%
Apulia	266	229	281	248	289	253	4.0%	-12.3%
Sardinia	297	247	288	243	297	260	4.2%	-12.5%
Sicily	148	125	146	124	151	131	2.1%	-12.8%
Tuscany	462	374	444	431	476	439	7.0%	-7.7%
Trento	131	118	121	127	131	123	2.0%	-6.0%
Umbria	238	210	233	234	252	225	3.6%	-10.8%
Valle d'Aosta	35	34	33	35	36	35	0.6%	-3.4%
Veneto	613	508	616	625	647	617	9.9%	-4.7%
Total	**6 633**	**5 676**	**6 393**	**6 173**	**6 757**	**6 252**	**100.0%**	**-7.5%**

The table shows the regional distribution of thermal energy consumption from solid biomass in Italy in the residential sector. As is clear, the use of solid biomass (firewood, pellets, charcoal) to heat homes is a widespread phenomenon in all Regions of Italy.

Figure 67: Direct consumption of solid biomass in the residential sector by Region and Autonomous Province



BOLZANO 1,9%	BOLZANO 1.9%
TRENTO 2,0%	TRENTO 2.0%
V. D'AOSTA 0,6%	VALLE D'AOSTA 0.6%
F.V.G. 3,3%	FRIULI-VENEZIA GIULIA 3.3%
LOMBARDIA 9,2%	LOMBARDY 9.2%
PIEMONTE 10,2%	PIEDMONT 10.2%
VENETO 9,9%	VENETO 9.9%
EMILIA ROMAGNA 4,9%	EMILIA-ROMAGNA 4.9%
LIGURIA 2,3%	LIGURIA 2.3%
TOSCANA 7,0%	TUSCANY 7.0%
UMBRIA 3,6%	UMBRIA 3.6%
MARCHE 2,9%	MARCHE 2.9%
LAZIO 7,3%	LAZIO 7.3%
ABRUZZO 5,2%	ABRUZZO 5.2%
MOLISE 1,3%	MOLISE 1.3%
CAMPANIA 8,7%	CAMPANIA 8.7%
PUGLIA 4,0%	APULIA 4.0%
BASILICATA 2,4%	BASILICATA 2.4%
CALABRIA 7,1%	CALABRIA 7.1%
SARDEGNA 4,2%	SARDINIA 4.2%
SICILIA 2,1%	SICILY 2.1%

The consumption of thermal energy produced from solid biomass in the Italian non-residential sector has significantly different regional distribution compared to the residential sector (previous section); in this case, distribution is mainly correlated to the presence of medium to large industrial plants that use this renewable source.

Table 46: Direct consumption of solid biomass in the non-residential sector by Region and Autonomous Province (ktoe)

	2013	2014	2015	2016	2017	2018	2018 (%)	Change % 2018/2017
Abruzzo	0.3	0.4	0.4	0.4	0.4	0.5	0.2%	17.6%
Basilicata	0.4	0.4	0.4	0.4	0.4	0.5	0.2%	9.0%
Bolzano	32.6	59.6	56.2	47.9	46.8	48.9	23.7%	4.4%
Calabria	6.6	6.3	8.3	9.3	9.8	5.6	2.7%	-43.3%
Campania	0.2	0.9	1.0	0.9	4.7	5.6	2.7%	20.2%
Emilia-Romagna	1.4	2.3	2.6	2.7	2.7	3.0	1.4%	8.7%
Friuli-Venezia Giulia	0.0	1.8	3.2	2.7	2.0	2.2	1.1%	7.6%
Lazio	0.6	0.7	0.8	0.8	0.9	0.9	0.5%	4.8%
Liguria	0.2	1.0	1.1	1.1	1.1	1.2	0.6%	5.2%
Lombardy	1.1	20.9	37.8	44.8	32.9	33.4	16.2%	1.4%
Marche	5.9	4.5	3.9	4.9	4.9	5.0	2.4%	1.7%
Molise	-	0.0	0.1	0.1	0.1	0.2	0.1%	18.2%
Piedmont	10.6	13.0	13.5	28.6	27.6	21.2	10.3%	-23.2%
Apulia	0.0	0.4	6.6	0.9	1.0	0.9	0.4%	-9.8%
Sardinia	2.4	2.5	2.3	2.0	3.4	5.2	2.5%	50.9%
Sicily	7.5	7.5	9.5	8.5	6.5	11.2	5.4%	71.5%
Tuscany	9.7	11.3	21.4	20.2	20.0	8.3	4.0%	-58.5%
Trento	2.7	3.5	4.5	4.7	7.0	10.3	5.0%	46.9%
Umbria	0.0	2.4	31.7	21.3	19.2	17.2	8.3%	-10.3%
Valle d'Aosta	1.0	2.0	2.7	3.2	3.3	3.3	1.6%	0.6%
Veneto	9.0	22.6	22.5	23.2	22.6	21.9	10.6%	-3.2%
Total	**92.2**	**164.1**	**230.7**	**228.7**	**217.6**	**206.3**	**100.0%**	**-5.2%**

5.1.2 Heat pumps

Ambient heat, the renewable heat captured by heat pumps, has been taken into account in regular energy statistics by Eurostat/the IEA since the 2017 reporting year.

The table shows monitoring data[23] relating to all the renewable energy (Eres) supplied for winter use by the over 19.6 million heat pump appliances (with total capacity of around 124 GW) installed in Italy. This value, which in 2018 totalled around 2.6 Mtoe, corresponds to the difference between the total useful heat produced by the appliances (defined as 'Qusable') and the energy consumption of the heat pumps.

Table 47: Thermal energy provided by heat pumps

	2013	2014	2015	2016	2017	2018	2018 (%)
Appliances installed at the end of the year (millions of units)	17.8	18.3	18.5	19.1	19.5	19.6	0.2%
Installed thermal capacity (GW)	119.6	121.7	122.2	124.7	126.4	123.8	-2.1%
Renewable energy provided by heat pumps (Eres) (TJ)	**105 480**	**108 010**	**108 208**	**109 219**	**110 949**	**108 684**	**-2.0%**
Thermal energy provided by heat pumps (Eres) (ktoe)	**2 519**	**2 580**	**2 584**	**2 609**	**2 650**	**2 596**	**-2.0%**
- of which is aero thermal (ktoe)	*2 447*	*2 501*	*2 500*	*2 523*	*2 563*	*2 507*	*-2.2%*
- of which is hydrothermal (ktoe)	*7*	*8*	*8*	*9*	*9*	*9*	*1.9%*
of which is geothermal	*65*	*71*	*76*	*77*	*78*	*80*	*1.9%*
Useful heat produced (Qusable) (ktoe)	4 069	4 166	4 172	4 211	4 278	4 190	-2.1%
general average Seasonal Performance Factor (SPF)	2.6	2.6	2.6	2.6	2.6	2.6	0.0%
Energy consumption of heat pumps (ktoe)	1 550	1 586	1 588	1 602	1 628	1 594	-2.1%

In terms of thermal uses of renewables, this is the most common after final consumption of biomass. The vast majority of appliances use the heat contained in the ambient air (97%), while a much smaller number of heat pumps are powered by geothermal and hydrothermal heat.

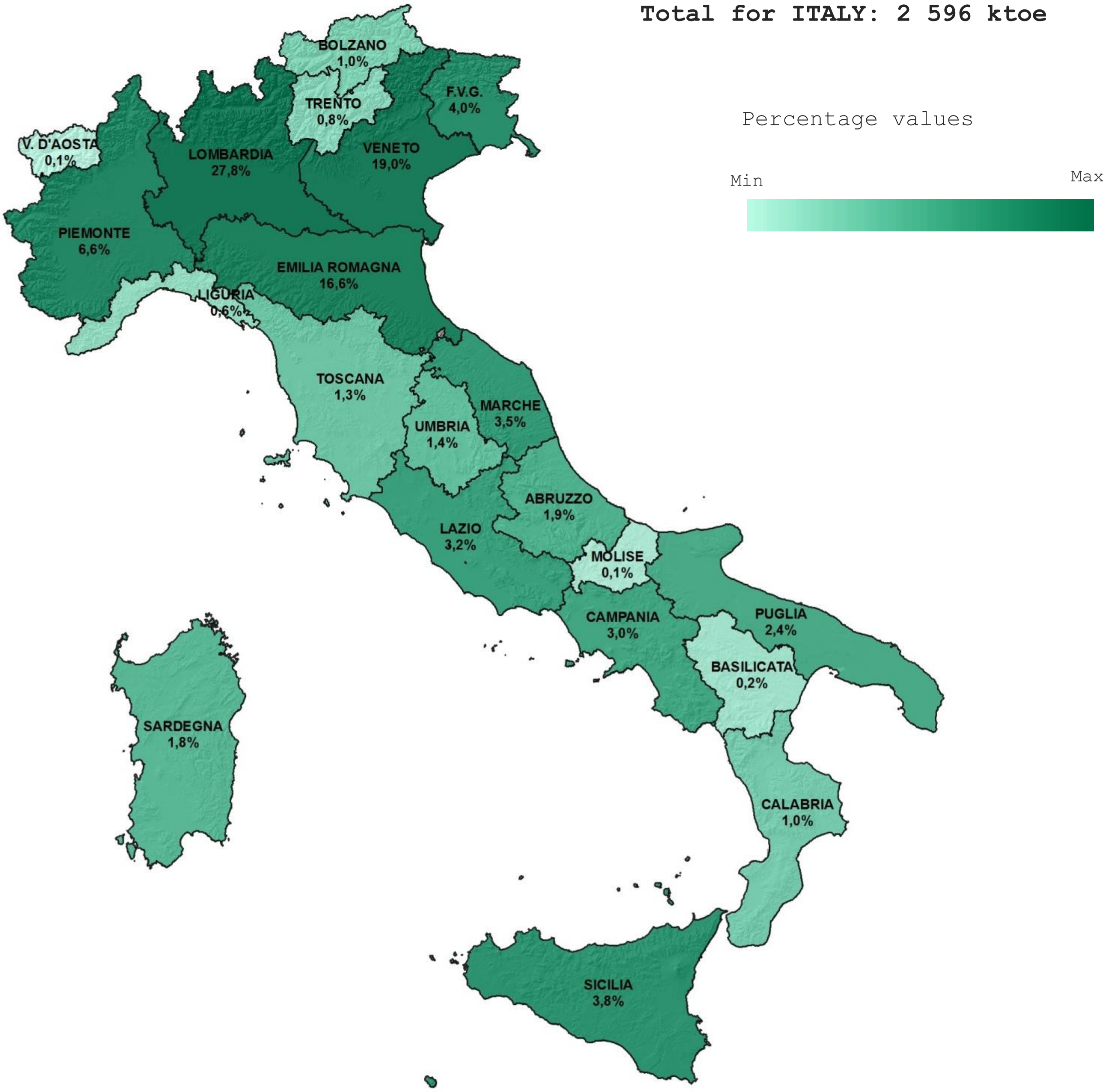
The following table illustrates the regional distribution of energy supplied by heat pumps in Italy.

[23] For the sake of simplicity, the data presented in this section take account only of the values useful for monitoring the renewables targets set by Directive 2009/28/EC; these thus do not include machines with levels of performance below the minimum level set by Directive 2009/28/EC and the corresponding energy supplied (this figure, around 0.5 ktoe, is also mentioned in Chapter 2 of the report).

Table 48: Renewable energy provided by heat pumps for heating purposes, broken down by Region and Autonomous Province

	2013	2014	2015	2016	2017	2018	2018 (%)	Change % 2018/2017
Abruzzo	48.6	49.7	49.8	50.2	51.0	49.9	1.9%	-2.1%
Basilicata	5.3	5.4	5.5	5.5	5.6	5.5	0.2%	-1.8%
Bolzano	24.5	25.0	25.0	25.2	25.7	25.1	1.0%	-2.2%
Calabria	26.0	26.7	26.8	27.1	27.5	27.0	1.0%	-1.8%
Campania	74.9	77.0	77.4	78.2	79.4	77.9	3.0%	-1.8%
Emilia-Romagna	419.9	429.7	430.2	434.2	441.1	431.9	16.6%	-2.1%
Friuli-Venezia Giulia	100.1	102.4	102.6	103.5	105.1	102.9	4.0%	-2.1%
Lazio	79.6	81.8	82.2	83.0	84.3	82.8	3.2%	-1.8%
Liguria	15.4	15.8	15.9	16.1	16.3	16.0	0.6%	-1.8%
Lombardy	700.7	717.1	718.0	724.6	736.1	720.7	27.8%	-2.1%
Marche	87.5	89.6	89.7	90.5	91.9	90.0	3.5%	-2.1%
Molise	1.8	1.9	1.9	1.9	1.9	1.9	0.1%	-1.8%
Piedmont	166.2	170.0	170.2	171.8	174.5	170.9	6.6%	-2.1%
Apulia	59.4	61.0	61.3	61.9	62.9	61.7	2.4%	-1.8%
Sardinia	44.7	45.9	46.2	46.6	47.4	46.5	1.8%	-1.8%
Sicily	95.1	97.7	98.2	99.1	100.7	98.9	3.8%	-1.8%
Tuscany	32.2	33.1	33.3	33.6	34.2	33.5	1.3%	-1.8%
Trento	21.4	21.9	21.9	22.1	22.4	21.9	0.8%	-2.2%
Umbria	34.5	35.3	35.3	35.7	36.2	35.5	1.4%	-2.1%
Valle d'Aosta	1.8	1.9	1.9	1.9	1.9	1.9	0.1%	-2.2%
Veneto	479.7	490.9	491.4	496.0	503.8	493.3	19.0%	-2.1%
Total	**2 519.3**	**2 579.8**	**2 584.5**	**2 608.7**	**2 650.0**	**2 595.9**	**100.0%**	**-2.0%**

Figure 68: Regional distribution of renewable energy provided by heat pumps for heating purposes in Italy in 2018 (%)



BOLZANO 1,0%	BOLZANO 1.0%
TRENTO 0,8%	TRENTO 0.8%
V. D'AOSTA 0,1%	VALLE D'AOSTA 0.1%
F.V.G. 4,0%	FRIULI-VENEZIA GIULIA 4.0%
LOMBARDIA 27,8%	LOMBARDY 27.8%
PIEMONTE 6,6%	PIEDMONT 6.6%
VENETO 19,0%	VENETO 19.0%
EMILIA ROMAGNA 16,6%	EMILIA-ROMAGNA 16.6%
LIGURIA 0,6%	LIGURIA 0.6%
TOSCANA 1,3%	TUSCANY 1.3%
UMBRIA 1,4%	UMBRIA 1.4%

MARCHE 3,5%	MARCHE 3.5%
LAZIO 3,2%	LAZIO 3.2%
ABRUZZO 1,9%	ABRUZZO 1.9%
MOLISE 0,1%	MOLISE 0.1%
CAMPANIA 3,0%	CAMPANIA 3.0%
PUGLIA 2,4%	APULIA 2.4%
BASILICATA 0,2%	BASILICATA 0.2%
CALABRIA 1,0%	CALABRIA 1.0%
SARDEGNA 1,8%	SARDINIA 1.8%
SICILIA 3,8%	SICILY 3.8%

The Regions which recorded the highest consumption of energy from heat pumps for space heating purposes are Lombardy (27.8% of the national total), Veneto (19%) and Emilia-Romagna (16.6%). Just over 14.2% of the total energy is consumed in the southern Regions.

5.1.3 Geothermal energy

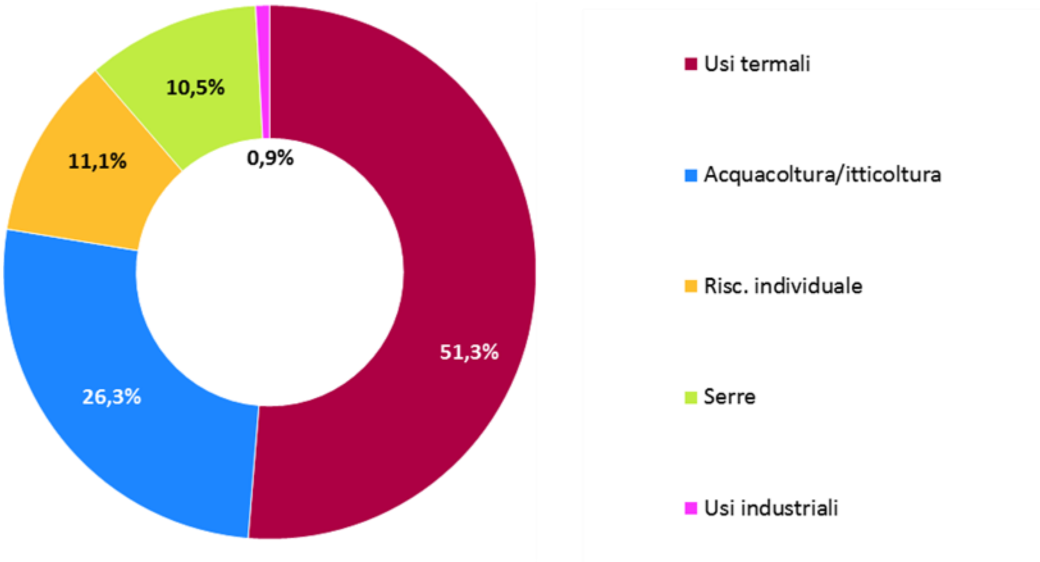
The table shows the regional distribution of direct consumption of thermal energy produced from geothermal sources in Italy; it can be noted that this consumption is mostly concentrated in Tuscany and Veneto.

Table 49: Direct consumption of thermal energy in the Regions and Autonomous Provinces

	2013	2014	2015	2016	2017	2018	2018 (%)	Change % 2018/2017
Abruzzo	-	-	-	-	-	-	-	-
Basilicata	-	-	-	-	-	-	-	-
Bolzano	0.1	-	-	-	-	-	-	-
Calabria	0.2	0.2	0.2	0.3	0.3	0.1	0.1%	-41.8%
Campania	11.6	11.0	11.0	11.1	12.1	11.9	9.3%	-1.5%
Emilia-Romagna	0.9	0.8	0.8	0.1	0.1	0.1	0.1%	58.5%
Friuli-Venezia Giulia	3.7	-	3.2	3.4	3.4	3.3	2.6%	-0.6%
Lazio	7.7	7.3	7.3	7.3	7.5	7.4	5.8%	-1.8%
Liguria	0.0	0.0	0.0	0.0	0.0	0.0	0.0%	0.0%
Lombardy	2.7	2.6	2.6	2.6	2.5	2.5	1.9%	0.0%
Marche	0.1	0.1	0.1	0.0	0.0	0.0	0.0%	0.0%
Molise	-	-	-	-	-	-	-	-
Piedmont	1.6	1.5	1.5	1.5	1.3	1.2	1.0%	-6.7%
Apulia	5.7	5.7	5.7	5.7	5.9	5.8	4.5%	-1.0%
Sardinia	1.1	0.9	0.9	0.9	1.5	1.5	1.1%	0.0%
Sicily	2.5	1.9	1.9	2.0	2.0	1.6	1.3%	-17.6%

Tuscany	42.2	39.6	40.3	51.3	55.5	54.0	42.1%	-2.7%
Trento	–	–	–	–	–	–	–	–
Umbria	–	–	–	–	–	–	–	–
Valle d'Aosta	0.0	0.0	0.0	0.0	0.0	0.0	0.0%	0.0%
Veneto	39.0	39.6	38.5	38.6	38.9	38.5	30.1%	-0.8%
Total	**119.1**	**111.3**	**114.1**	**124.7**	**130.8**	**128.1**	**100.0%**	**-2.1%**

Figure 69: Geothermal energy by type of use (%)



10,5%	10.5%
11,1%	11.1%
0,9%	0.9%
26,3%	26.3%
51,3%	51.3%
Usi termali	Thermal uses
Acquacoltura/itticoltura	Aquaculture/fish farming
Risc. individuale	Individual heating
Serre	Greenhouses
Usi industriali	Industrial uses

Direct consumption of geothermal energy in Italy in 2018 totalled 128 ktoe. The largest share (more than 51%) is associated with spas, belonging to the service sector; followed by the aquaculture/fish farming sector (26.3%), individual heating uses (11.1%, mostly accommodation facilities and agri-tourism) and heating of greenhouses (10.5%). Use of geothermal energy in the industrial sector is more limited (1%).

5.1.4 Solar power

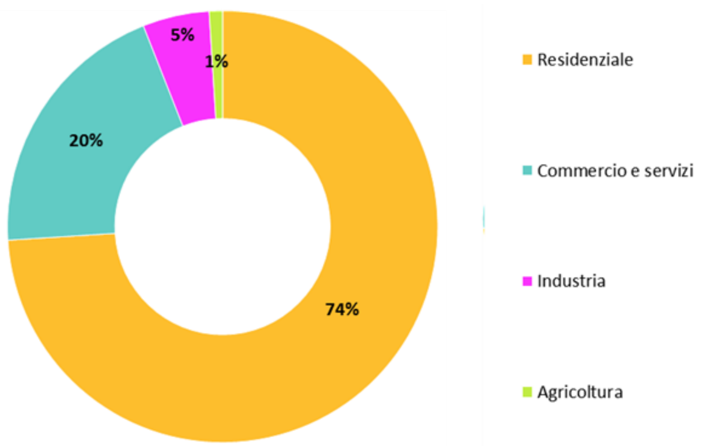
At the end of 2018, about 4.2 million m^2 of solar thermal collectors were installed in Italy (in terms of aperture area[24]). According to the information provided by the manufacturers' associations, the majority of the installed panels can be found on residential buildings. The most commonly used solar collectors are the flat ones for producing domestic hot water.

Table 50: Direct consumption of thermal energy from solar power in the Regions and Autonomous Provinces

	2013	2014	2015	2016	2017	2018
Direct consumption	**168.1**	**179.5**	**190.0**	**200.1**	**208.8**	**218.4**
Residential	124.4	132.9	140.6	148.1	154.5	161.6
Commercial and services	*33.6*	*35.9*	*38.0*	*40.0*	*41.8*	*43.7*
Industry	*8.4*	*9.0*	*9.5*	*10.0*	*10.4*	*10.9*
Agriculture	*1.7*	*1.8*	*1.9*	*2.0*	*2.1*	*2.2*
Total	**168.1**	**179.5**	**190.0**	**200.1**	**208.8**	**218.4**

The total thermal energy obtained in Italy from solar power during 2018 amounts to approximately 218 ktoe.

Figure 70: Direct consumption of thermal energy from solar power in 2018



5%	5%
1%	1%
20%	20%
74%	74%
Residenziale	Residential
Commercio e servizi	Commercial and services
Industria	Industry

[24] The aperture area of the solar collectors is obtained by hypothetically reducing the gross panel area by 10%. The figure refers to the total installed aperture area at the end of each calendar year, while, as stated, a reduction coefficient is applied to the area installed in the last year to calculate the energy provided by the collectors.

Agricoltura	Agriculture

74% of the energy supplied by solar thermal collectors in 2018 and directly consumed in Italy is used in the residential sector (mainly appliances for producing domestic hot water); 20% is used in the commercial and service sector (frequently by sports facilities). Consumption in the industrial and agricultural sectors is much lower (around 5% and 1% respectively of the total).

The table shows the regional distribution of thermal energy consumption from solar power in Italy.

Table 51: Direct consumption of thermal energy from solar power in the Regions and Autonomous Provinces (ktoe)

	2013	2014	2015	2016	2017	2018	2018 (%)	Change % 2018/2017
Abruzzo	1.8	1.9	2.1	2.3	2.3	2.4	1.1%	4.3%
Basilicata	0.7	0.7	0.8	1.1	1.2	1.3	0.6%	14.9%
Bolzano	11.9	11.0	10.7	10.6	9.9	9.2	4.2%	-7.1%
Calabria	3.1	2.7	3.1	4.0	4.9	6.0	2.7%	23.2%
Campania	5.0	4.1	4.7	5.6	5.8	6.4	2.9%	10.6%
Emilia-Romagna	11.1	12.7	13.7	14.8	14.3	14.3	6.5%	0.0%
Friuli-Venezia Giulia	8.5	9.6	10.1	10.9	10.8	10.8	4.9%	-0.3%
Lazio	8.4	7.8	7.9	8.2	8.0	8.3	3.8%	3.1%
Liguria	2.6	3.4	3.4	3.9	3.9	3.9	1.8%	0.0%
Lombardy	27.2	32.1	34.7	31.8	36.2	35.9	16.4%	-0.8%
Marche	2.9	3.1	3.5	3.9	3.8	3.9	1.8%	2.0%
Molise	0.5	0.4	0.5	0.6	0.7	0.9	0.4%	20.5%
Piedmont	14.9	16.6	17.1	18.0	21.2	21.2	9.7%	0.1%
Apulia	6.4	5.9	7.0	8.7	9.7	12.1	5.5%	24.0%
Sardinia	7.1	6.6	7.0	7.6	7.5	7.9	3.6%	5.6%
Sicily	5.5	4.8	6.2	8.5	11.4	16.7	7.7%	46.1%
Tuscany	11.4	11.9	12.1	12.7	12.1	12.1	5.5%	-0.1%
Trento	12.1	12.3	12.5	12.6	12.2	12.2	5.6%	-0.5%
Umbria	2.4	2.2	2.3	2.6	2.6	2.7	1.2%	5.2%
Valle d'Aosta	1.4	1.5	1.8	1.9	1.9	1.9	0.9%	-0.3%
Veneto	23.2	28.2	28.8	29.6	28.3	28.4	13.0%	0.3%
Total	**168.2**	**179.5**	**190.0**	**200.1**	**208.8**	**218.4**	**100.0%**	**4.6%**

5.1.5 Renewable industrial waste

In 2018, direct energy consumption from the biodegradable fraction of waste totalled around 268 ktoe; it is important to specify that this figure refers only to energy uses of special waste (solid recovered fuels are also considered to be special, irrespective of the type of waste from which they were produced); final consumption of energy from urban waste, which is instead used in cogeneration plants, is not recorded.

Table 52: Direct consumption of waste (renewable share) by sector of use

	2013	2014	2015	2016	2017	2018	Change % 2018/2017
Direct consumption	**189.1**	**213.1**	**225.3**	**231.0**	**244.7**	**267.8**	**5.9%**
Industry – non-metallic mineral products	79.7	89.2	100.5	94.5	95.7	101.4	5.9%
Industry: wood and wood products	*84.0*	*93.3*	*97.9*	*99.6*	*122.4*	*140.3*	*14.6%*
Industry – food and tobacco	*1.6*	*1.8*	*1.1*	*0.4*	*0.1*	*0.0*	*-85.6%*
Industry – mechanics	*0.6*	*0.5*	*0.4*	*0.1*	*0.1*	*0.1*	*-10.8%*
Industry – other sectors/not specified	*23.3*	*28.2*	*25.5*	*36.4*	*26.5*	*26.0*	*-1.7%*
Total	**189.1**	**213.1**	**225.3**	**231.0**	**244.7**	**267.8**	**9.4%**

The table shows the regional distribution of consumption of thermal energy produced from the biodegradable fraction of solid waste in Italy.

Table 53: Direct consumption of waste (renewable share) in the Regions and Autonomous Provinces (ktoe)

	2013	2014	2015	2016	2017	2018	2018 (%)	Change % 2018/2017
Abruzzo	1.0	0.6	0.1	0.1	0.1	0.2	0.1%	64.5%
Basilicata	2.4	4.2	4.8	2.1	0.4	3.6	1.3%	769.0%
Bolzano	0.0	-	-	-	-	-	-	-
Calabria	-	-	-	-	0.4	0.9	0.3%	108.0%
Campania	3.0	5.5	4.1	1.3	1.8	2.7	1.0%	56.0%
Emilia-Romagna	11.3	12.8	12.2	11.4	13.2	12.6	4.7%	-4.8%
Friuli-Venezia Giulia	21.4	33.9	33.1	38.7	39.5	54.1	20.2%	37.0%
Lazio	0.1	0.2	0.0	0.1	0.0	0.0	0.0%	68.1%
Liguria	-	-	-	-	-	-	-	-
Lombardy	84.4	93.5	102.7	96.6	108.9	115.1	43.0%	5.7%

Marche	2.0	2.2	2.2	2.2	2.1	1.7	0.6%	-20.5%
Molise	2.6	1.9	2.3	2.6	3.6	3.2	1.2%	-9.8%
Piedmont	12.7	7.4	6.4	9.6	1.6	1.8	0.7%	13.6%
Apulia	6.1	4.7	5.7	5.7	0.8	4.1	1.5%	410.5%
Sardinia	0.3	0.3	0.0	0.0	0.0	-	0.0%	-57.7%
Sicily	0.1	0.1	-	-	-	-	-	-
Tuscany	5.5	4.6	2.9	1.2	1.7	2.8	1.1%	63.6%
Trento	0.6	0.8	0.9	0.7	-	-	-	-
Umbria	0.6	0.5	0.6	10.6	16.3	16.7	6.2%	2.3%
Valle d'Aosta	-	-	-	-	-	-	-	-
Veneto	35.1	39.7	47.3	48.1	54.2	48.2	18.0%	-11.2%
Total	**189.1**	**213.1**	**225.3**	**231.0**	**244.7**	**267.8**	**100.0%**	**9.4%**

5.2 Derived heat

The table shows the derived heat produced by heat-only units and plants operating in cogeneration mode (CHP), powered by renewables.

Table 54: Derived heat from renewable sources, broken down by source and Region/Autonomous Province in 2018 (figures in ktoe).

	Solid biomass and waste	Biogas	Sustainable bioliquids	Geothermal energy	Solar power	Total
Abruzzo	-	2.1	1.2	-	-	3.2
Basilicata	3.5	0.5	2.0	-	-	6.0
Bolzano	91.8	3.6	3.8	-	-	99.2
Calabria	9.4	2.0	-	-	-	11.4
Campania	5.9	7.2	3.8	-	-	16.9
Emilia-Romagna	61.5	39.5	12.1	6.5	0.0	119.6
Friuli-Venezia Giulia	5.2	9.2	1.8	-	-	16.2
Lazio	38.9	2.7	4.8	-	0.0	46.4
Liguria	0.1	0.0	0.1	-	-	0.3
Lombardy	220.8	70.4	5.3	-	0.1	296.7
Marche	0.1	2.0	0.0	-	-	2.1
Molise	4.0	0.1	-	-	-	4.2
Piedmont	85.9	22.2	1.7	-	-	109.8
Apulia	10.1	3.3	0.0	-	-	13.5
Sardinia	1.3	2.7	0.0	-	-	4.0
Sicily	21.6	0.7	0.1	-	-	22.4
Tuscany	9.4	4.6	2.0	13.9	-	29.9

Trento	20.0	2.6	0.3	-	-	22.9
Umbria	4.8	2.2	1.7	-	-	8.6
Valle d'Aosta	5.3	0.3	0.1	-	-	5.8
Veneto	65.3	35.8	8.0	0.5	-	109.6
Total	**664.9**	**213.8**	**48.9**	**21.0**	**0.1**	**948.7**

6 Availability of sources for generating heating

This chapter presents an analysis of the geographical availability of the main renewable and non-renewable resources which can be used to generate heat to supply district heating networks.

6.1 Waste heat

According to Article 2(9) of Directive (EU) 2018/2001 (also known as RED II), waste heat means '*unavoidable heat or cold generated as by-product in industrial or power generation installations, or in the tertiary sector, which would be dissipated unused in air or water without access to a district heating or cooling system, where a cogeneration process has been used or will be used or where cogeneration is not feasible*'.
According to the above-mentioned Directive, waste heat, as thermal energy that has not already been used or cannot be used for cogeneration, is thus identified as a potential energy contribution to district heating and cooling systems (DH).

A more detailed description of waste heat is provided in Recommendation (EU) 2019/1659, Annex IV, which states that '*In principle, heat is considered as waste heat only when it is a by-product of another process that would be emitted into the environment, until supplied for off-site use. In other words, industrial waste heat is equivalent to the energy load that is not extracted otherwise and requires external cooling*'. On the other hand, waste heat does not include '*heat that was generated with the main purpose of being directly used on- or off-site and is not a by-product of another process, irrespective of the energy input*', '*cogenerated heat from combined heat and power (CHP) plants*' and '*heat that is or could be recovered internally on the same site*'.

In order to quantify the amount of waste heat emitted throughout the whole of Italy, the largest stationary installations in the country were examined, which include the following types of plant:

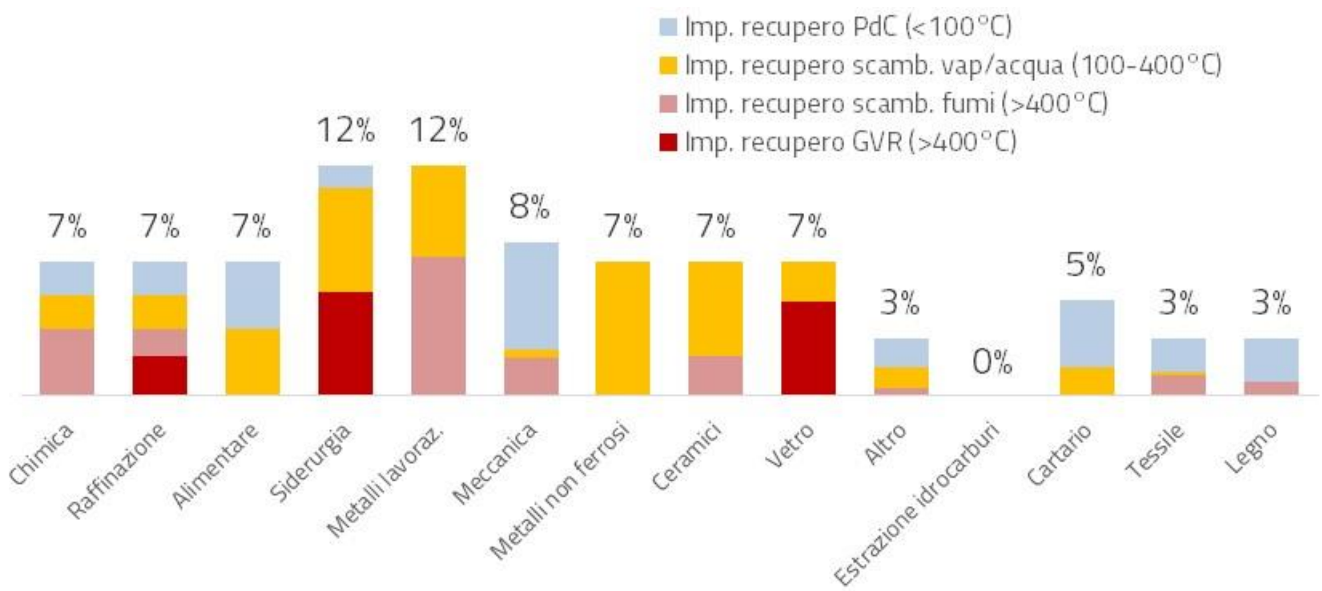
- Industrial plants
- Thermal power plants
- Incineration plants

6.1.1 Waste heat from industrial plants

Waste heat has been estimated on the basis of heat recovery factors for each sector that express the ratio between the potentially recoverable waste heat emitted by an installation and its energy consumption. These factors have been calculated with the technical collaboration of RSE, with the assistance

of whom a wide bibliographic survey has been carried out, several real cases of waste heat recovery from industrial plants have been analysed and several other assessments have been carried out regarding priority of recovery, in favour of internal plant processes and the continuity of the processes themselves.
The recovery factors vary according to the industrial processes involved and are also characterised by the different temperatures at which these thermal wastes become available and at which specific recovery systems are used (>400°C: recovery steam generators or flue gas/water heat exchangers, 100-400°C: steam/water exchangers, <100°C: heat pumps).

Figure 71: Waste heat recovery factors by industrial sector



Imp. recupero PdC (<100°C)	Heat pump recovery system (<100°C)
Imp. recupero scamb. vap/acqua (100-400°C)	Steam/water exchangers (100-400°C)
Imp. recupero scamb. fumi (>400°C)	Flue gas/water heat exchangers (>400°C)
Imp. recupero GVR (>400°C)	Recovery steam generators (>400°C)
7%	7%
7%	7%
7%	7%
12%	12%
12%	12%
8%	8%
7%	7%
7%	7%
7%	7%
3%	3%
0%	0%
5%	5%
3%	3%
3%	3%
Chimica	Chemicals
Raffinazione	Refineries

Alimentare	Food
Siderurgia	Steel industry
Metalli lavoraz.	Metal processing
Meccanica	Mechanics
Metalli non ferrosi	Non-ferrous metals
Ceramici	Ceramics
Vetro	Glass
Altro	Other
Estrazione idrocarburi	Hydrocarbon extraction
Cartario	Paper
Tessile	Textiles
Legno	Wood

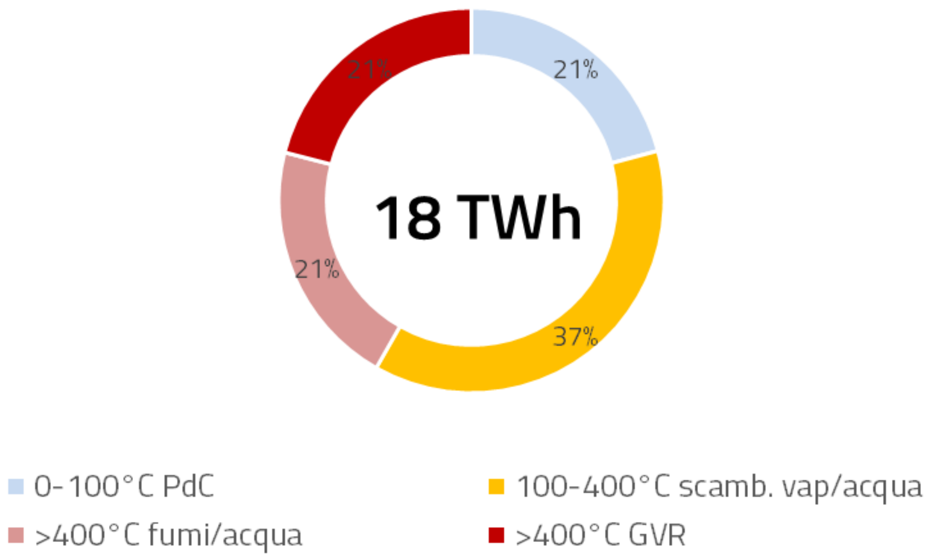
The group of industrial plants analysed corresponds to the installations participating in the ETS, the identification data for which can be found in the Union Registry.
Applying the heat recovery factors to the energy consumption input to each installation, total waste heat was estimated to be 18 TWh, mainly from the refinery, steel, chemicals and ceramics sectors.

Figure 72: Waste heat by industrial sector, excluding thermoelectrics and waste

4%	4%
27%	27%
23%	23%
15%	15%
12%	12%
6%	6%
6%	6%
18 TWh	18 TWh
Raffinazione	Refineries
Ceramica, cemento	Ceramics, cement
Altri settori industriali	Other industrial sectors
Siderurgia	Steel industry

Metalli lavorazione	Metal processing
Vetro	Glass
Chimica Carta	Chemicals, paper
Alimentare	Food

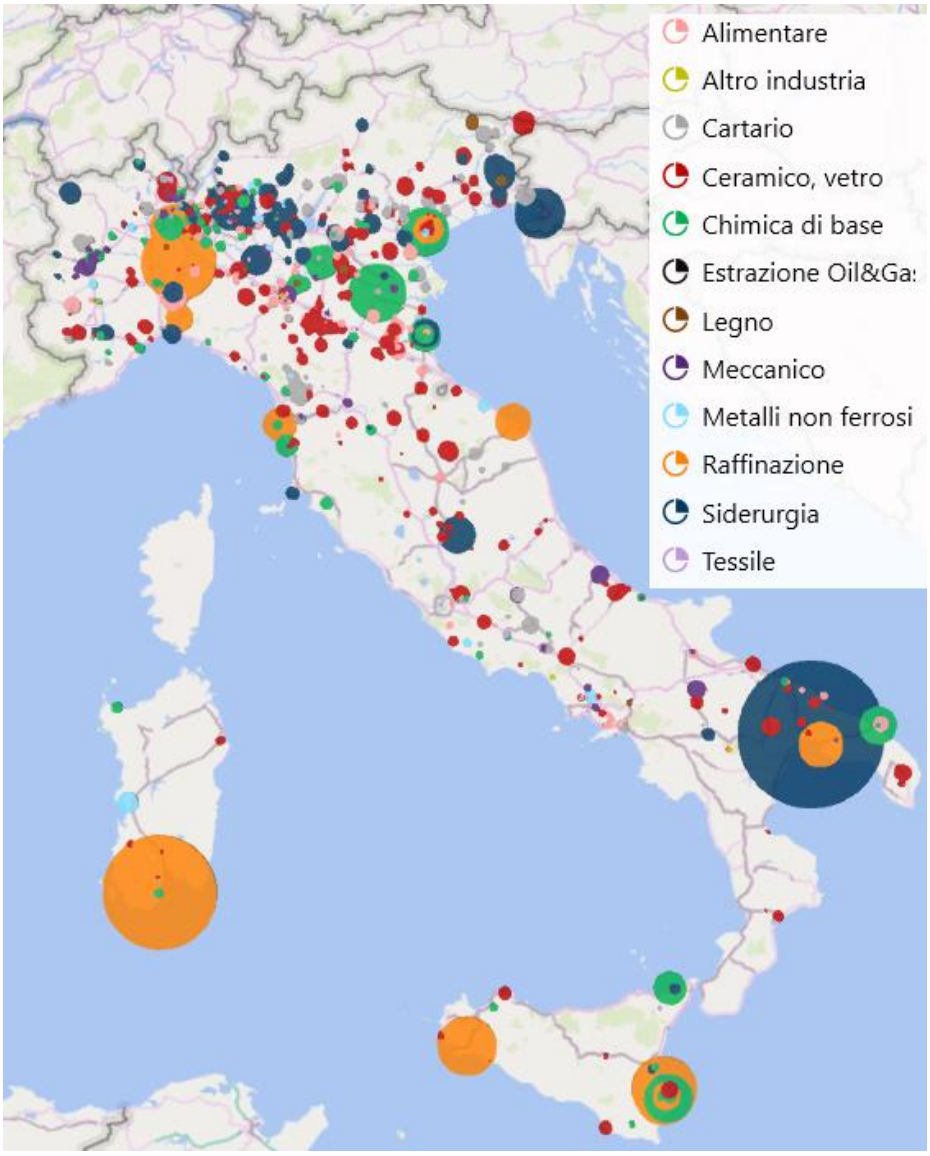
Figure 73: Industrial waste heat by temperature range and type of recovery system



21%	21%
21%	21%
37%	37%
21%	21%
18 TWh	18 TWh
0-100°C PdC	0-100°C heat pumps
>400°C fumi/acqua	>400°C flue gas/water heat exchangers
100-400°C scamb. vap/acqua	100-400°C steam/water exchangers
>400°C GVR	>400°C recovery steam generators

In order to calculate the most accurate site-specific heat recovery costs for each installation, the size of the different types of recovery system (recovery steam generators, flue gas/water heat exchangers, steam/water exchangers, heat pumps) has been estimated on the basis of the volumes of waste heat that can be recovered in the different temperature ranges and with the operating hours of the industrial installations assumed to be 7 500 hours.

Figure 74: Map of waste heat from industrial plants, broken down by sector



Alimentare	Food
Altro industria	Other industry
Cartario	Paper
Ceramico, vetro	Ceramics, glass
Chimica di base	Basic chemicals
Estrazione Oil&Ga:	Oil and gas extraction
Legno	Wood
Meccanico	Mechanics
Metalli non ferrosi	Non-ferrous metals
Raffinazione	Refineries
Siderurgia	Steel industry
Tessile	Textiles

6.1.2 Waste heat from incinerators

The waste register of the Italian National Institute for Environmental Protection and Research (ISPRA)[25] shows that there were 38 incineration plants[26] in operation in Italy in 2018, which processed 6.3 million tonnes of waste.

For each incinerator, energy data were calculated for primary energy consumption, electricity production, cogenerated useful heat, heat fed into the DH networks (sources: ISPRA, Terna, GSE).

The ratio of cogenerated useful heat to primary energy consumed is on average 33% in incinerators producing electricity in cogeneration mode. This value has been taken as the minimum heat production target to be achieved by all incinerators in operation. For incineration plants with values below this threshold, this target value was applied and the useful heat already produced by DH networks and for other uses was subtracted, obtaining an incremental potential heat production value of 3.9 TWh.

This useful heat production target can be achieved predominantly by retrofitting plants and modifying the operating set-up in order to increase the share of cogenerated thermal energy while partially reducing electricity production[27].

In the final results, the increase in heat production from waste is accounted for as waste-fuelled CHP.

[25] https://www.catasto-rifiuti.isprambiente.it/index.php?pg=&width=1366&height=768.

[26] This figure refers to municipal waste incineration plants, and does not include co-incineration plants. They are all waste-to-energy plants producing electricity, in just over half of the cases in cogeneration mode.

[27] In line with the findings on waste-fired HE CHP plants, a factor of 0.2 was considered, resulting in a reduction in electricity production of 0.2 MWh for each MWh of cogenerated heat, compared to non-cogeneration mode.

Figure 75: Map of waste treated in incinerators in Italy in 2018

6.1.3 Waste heat from thermal power plants

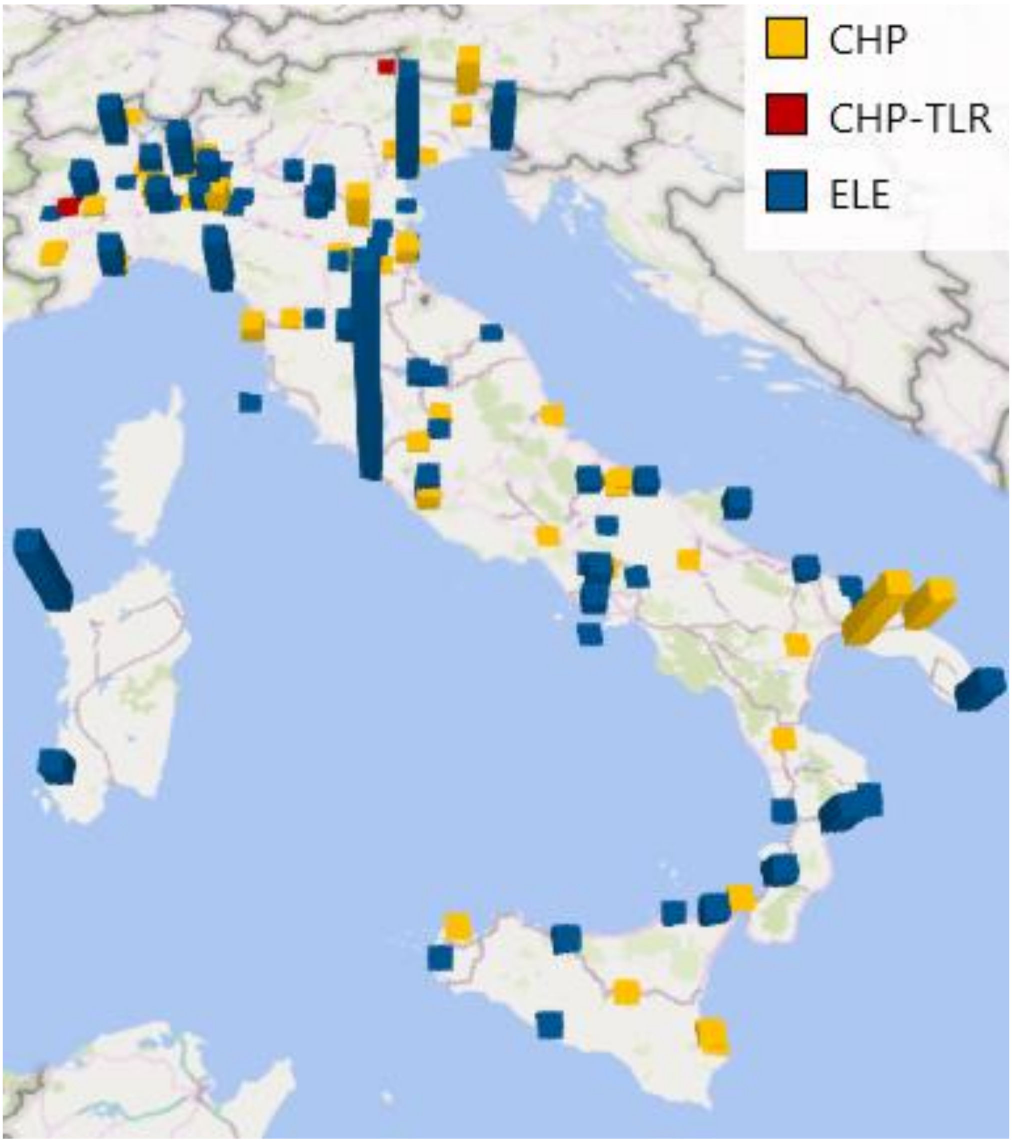
Analysis of the operating data of HE CHP plants served by district heating networks in 2018 reveals the following average annual efficiencies (calculated as the ratio of useful heat to total plant consumption).

Table 55: Average annual thermal efficiencies of HE CHP plants by capacity class

Typical capacity	η_H
<10 MWe	37%
10-100 MWe	34%
>100 MWe	18%

These indicative efficiencies were applied to the fuel consumption of the thermal power plants participating in the ETS and the share of heat already produced in cogeneration mode was deduced in order to estimate the incremental useful heat that could be produced if all the ETS thermal power plants achieved the thermal performance of CHP DH plants.

Figure 76: Map of waste heat from thermal power plants in Italy



CHP	CHP
CHP-TLR	CHP-DH
ELE	ELECTRIC

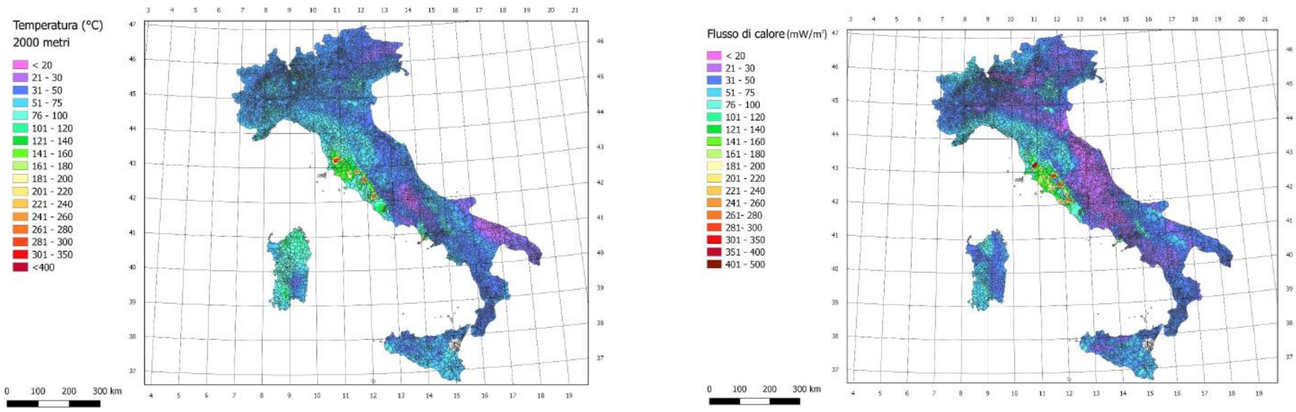
On the basis of the above, an estimated 45 TWh of incremental useful heat can be produced by thermal power plants.
This potential useful heat production target can be achieved predominantly by retrofitting plants and modifying the operating set-up in order to increase the share of cogenerated thermal energy while partially reducing electricity production. In the final results, the increase in recoverable heat from thermal power plants is accounted for as gas-fuelled CHP.

6.2 Geothermal energy

The analysis of the potential of geothermal energy sources was based on data from 'Geothermal zoning in Italy' published by the Ministry of Economic Development in 2017, which categorised the country's subsoil from a geothermal point of view on a municipal basis, obtaining the following data:

- **minimum, average and maximum temperature (°C) at** 1 000, 2 000 and 3 000 metres depth;
- **minimum, average and maximum heat flow (mW/m²);**
- **minimum, average and maximum depth (metres)** of carbonate reservoir roof, where mapped

Figure 77: Map of temperatures at 2 000 m depth and superficial heat flow

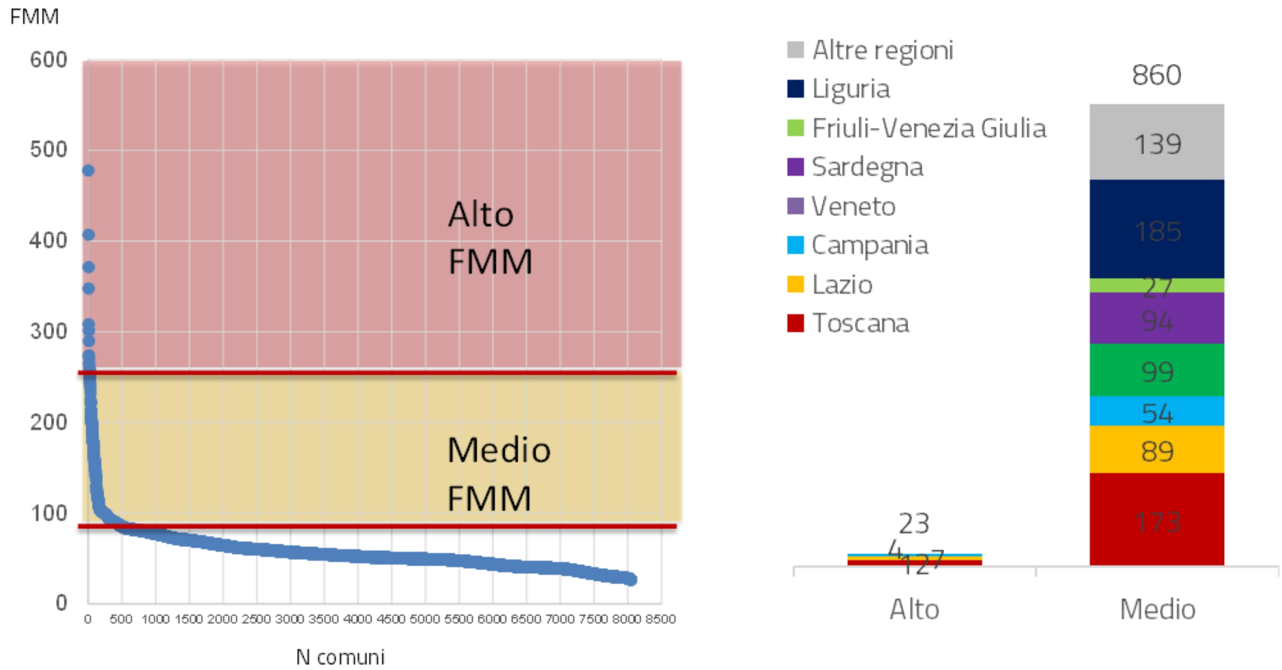


Temperatura (°C) 2000 metri	Temperature (°C) 2 000 metres
<20	<20
21 - 30	21–30
31 - 50	31–50
51 - 75	51–75
76 - 100	76–100
101 - 120	101–120
121 - 140	121–140
141 - 160	141–160
161 - 180	161–180
181 - 200	181–200
201 - 220	201–220
221 - 240	221–240
241 - 260	241–260
261 - 280	261–280
281 - 300	281–300
301 - 350	301–350
<400	<400
300 km	300 km
Flusso di calore (mW/m²)	Heat flow (mW/m²)
<20	<20
21 - 30	21–30
31 - 50	31–50
51 - 75	51–75
76 - 100	76–100
101 - 120	101–120
121 - 140	121–140
141 - 160	141–160
161 - 180	161–180
181 - 200	181–200
201 - 220	201–220

221 - 240	221–240
241 - 260	241–260
261 - 280	261–280
281 - 300	281–300
301 - 350	301–350
351 - 400	351–400
401 - 500	401–500
300 km	300 km

The municipalities were grouped into high, medium and low surface heat flow zones based on the range of values found within the 'FMM' parameter, calculated as the arithmetic average of the maximum and average surface heat flow in the municipality. This parameter, calculated for all municipalities, was generally higher for municipalities which use high- and medium-enthalpy geothermal energy and therefore allowed them to be identified, albeit with a certain degree of approximation.

Figure 78: Clustering of municipalities by geothermal superficial heat flow (FMM)



FMM	FMM
600	600
500	500
400	400
300	300
200	200
100	100
0	0
Alto FMM	High FMM
Medio FMM	Medium FMM

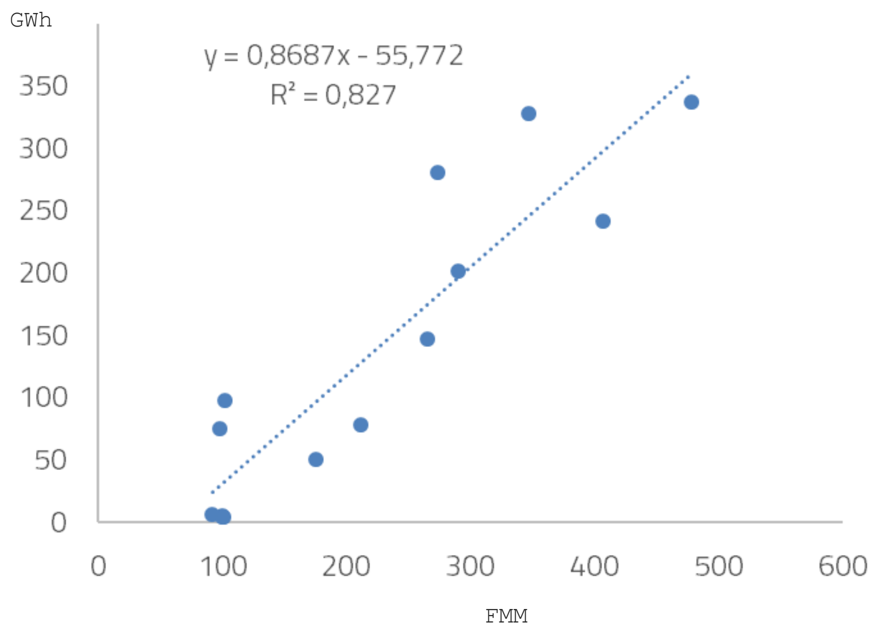
0	0
500	500
1000	1 000
1500	1 500
2000	2 000
2500	2 500
3000	3 000
3500	3 500
4000	4 000
4500	4 500
5000	5 000
5500	5 500
6000	6 000
6500	6 500
7000	7 000
7500	7 500
8000	8 000
8500	8 500
N comuni	No of municipalities
Altre regioni	Other Regions
Liguria	Liguria
Friuli-Venezia Giulia	Friuli-Venezia Giulia
Sardegna	Sardinia
Veneto	Veneto
Campania	Campania
Lazio	Lazio
Toscana	Tuscany
860	860
139	139
185	185
27	27
94	94
99	99
54	54
89	89
173	173
Medio	Medium
23	23
4	4
127	127
Altro	Other

In order to estimate the heat that could potentially be produced using geothermal energy in each municipality[28], an empirical parametric function, surface flows-thermal energy, has been developed. Areas with low-enthalpy geothermal potential, which were not well represented by the modelling

[28] The estimate of geothermal potential developed here using the surface flow variable cannot replace a more comprehensive assessment of site-specific subsurface conditions.

described, have been considered as part of the estimate of heat pump potential.

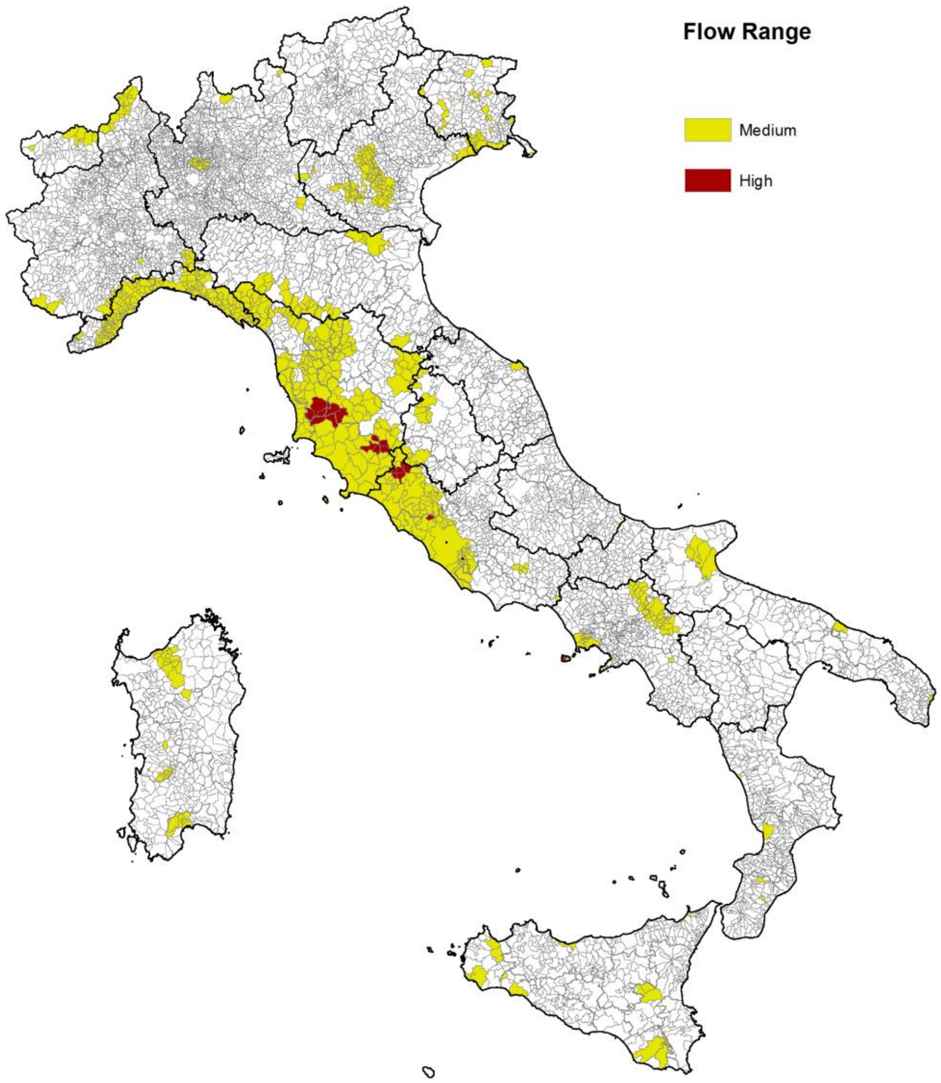
Figure 79: Parametric geothermal energy – surface heat flow

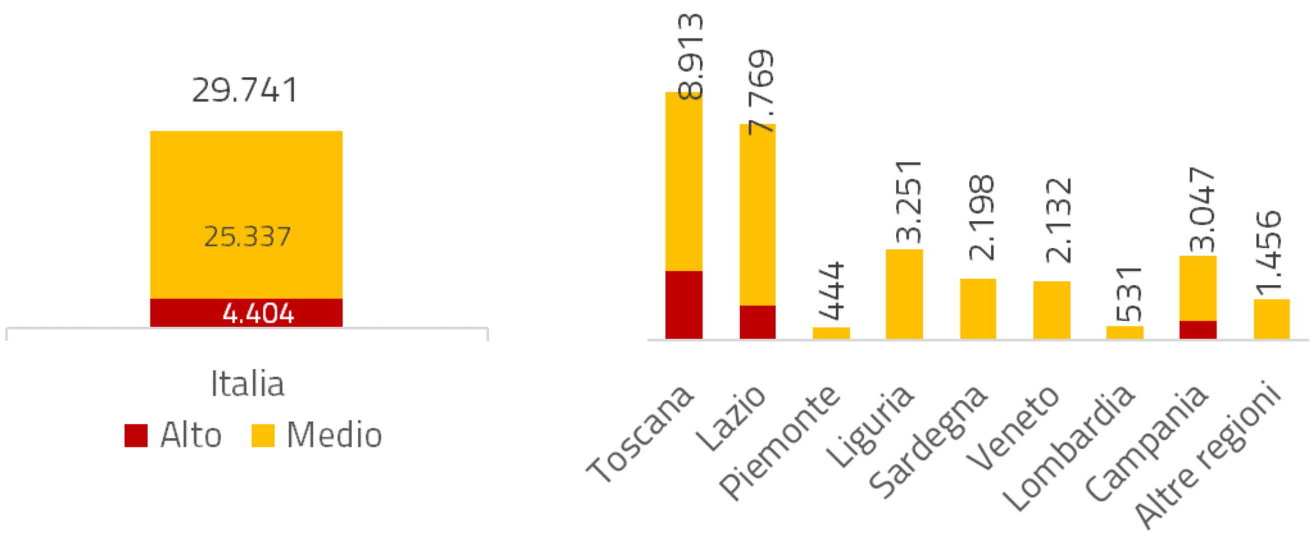


On the basis of the methodology set out, an estimated potential of almost 30 TWh of energy can be produced using geothermal energy. Tuscany and Lazio have a potential of over 16 TWh, while other Regions such as: Liguria, Campania, Sardinia and Veneto could produce a good amount of medium-enthalpy geothermal energy.

It should also be noted that this considerable quantity of medium- to high-enthalpy geothermal energy is concentrated in around 500 municipalities, often with limited urbanisation, and in some cases mild climatic conditions (for example, Campi Flegrei, Sardinia). For these reasons, the aforementioned potential supply of thermal energy produced using geothermal energy is limited by the demand for district heating in these areas, as highlighted in Section 7.3.2.

Figure 80: Potential geothermal energy per surface flow cluster, map and graphs (GWh)





29.741	29 741
25.337	25 337
4.404	4,404
Italia	Italy
Alto	High
Medio	Medium
Toscana	Tuscany
Lazio	Lazio
Piemonte	Piedmont
Liguria	Liguria
Sardegna	Sardinia
Veneto	Veneto
Lombardia	Lombardy
Campania	Campania
Altre regioni	Other Regions
8.913	8 913
7.769	7 769
444	444
3.251	3 251
2.198	2 198
2.132	2 132
531	531
3.047	3 047
1.456	1 456

6.3Biomass

6.3.1 Zoning of areas suitable for biomass use

The technical potential of biomass was assessed at a local level, on the basis of a series of indicators aimed at illustrating the extent to which each municipality was suitable for biomass use. This depends on multiple factors beyond the availability of local forest resources, which nevertheless remains an enabling factor.

The indicators taken into account for zoning refer to the following aspects:
- demand for biomass for energy purposes
- supply of local forest biomass for energy purposes
- natural gas distribution
- availability of district heating networks
- particulate levels
- altitude
- level of urbanisation
- climate zones
- ecoregions.

A calculation model has therefore been developed which, by assigning appropriate weighting and scores to the aforementioned indicators, is able to determine a weighted dimensionless indicator representative of the areas most suitable for biomass use (IAVB).

Table 56: Drivers, weighting and scoring criteria used for weighting the IAVB indicator

Indicator	Weight %	Score		
		1	2	3
Supply of forest biomass	25%	<5 GWh/ha of felling	>5 and <20 GWh/ha	>20 GWh/ha of felling
Natural gas distribution	20%	Municipalities with natural gas supply	-	Municipalities without natural gas supply
Residential demand for biomass	15%	Demand covered by biomass <2 GWh and share of households using biomass <30%	Demand covered by biomass between 2-10 GWh or share of households using biomass >30%	Demand covered by biomass >10 GWh
Particulate levels	(*)	> 35 breaches of the threshold	Between 10 and 35 breaches of the threshold	0-10 breaches of the threshold
Level of urbanisation	10%	High level of urbanisation	Moderate urbanisation	Predominantly rural municipalities
Climate	10%	Zone A-B	Zone C-D	Zone E-F
Altitude	10%	Plain (in the range 0-300 metres above sea level)	Inland/coastal hills (300-600 metres above sea level)	Inland/coastal mountains (more than 600 metres above sea level)
Availability of district heating networks	10%	No DH networks available	DH networks not powered by biomass available	DH networks powered by biomass available
Ecoregions	0%	Sections: Po Valley, Sardinian, Sicilian	Sections: central-northern Tyrrhenian, central Adriatic, southern Adriatic, southern Apennine, southern Tyrrhenian	Sections: western Alpine, central-eastern Alpine, northern and northwestern Apennine, central Apennine

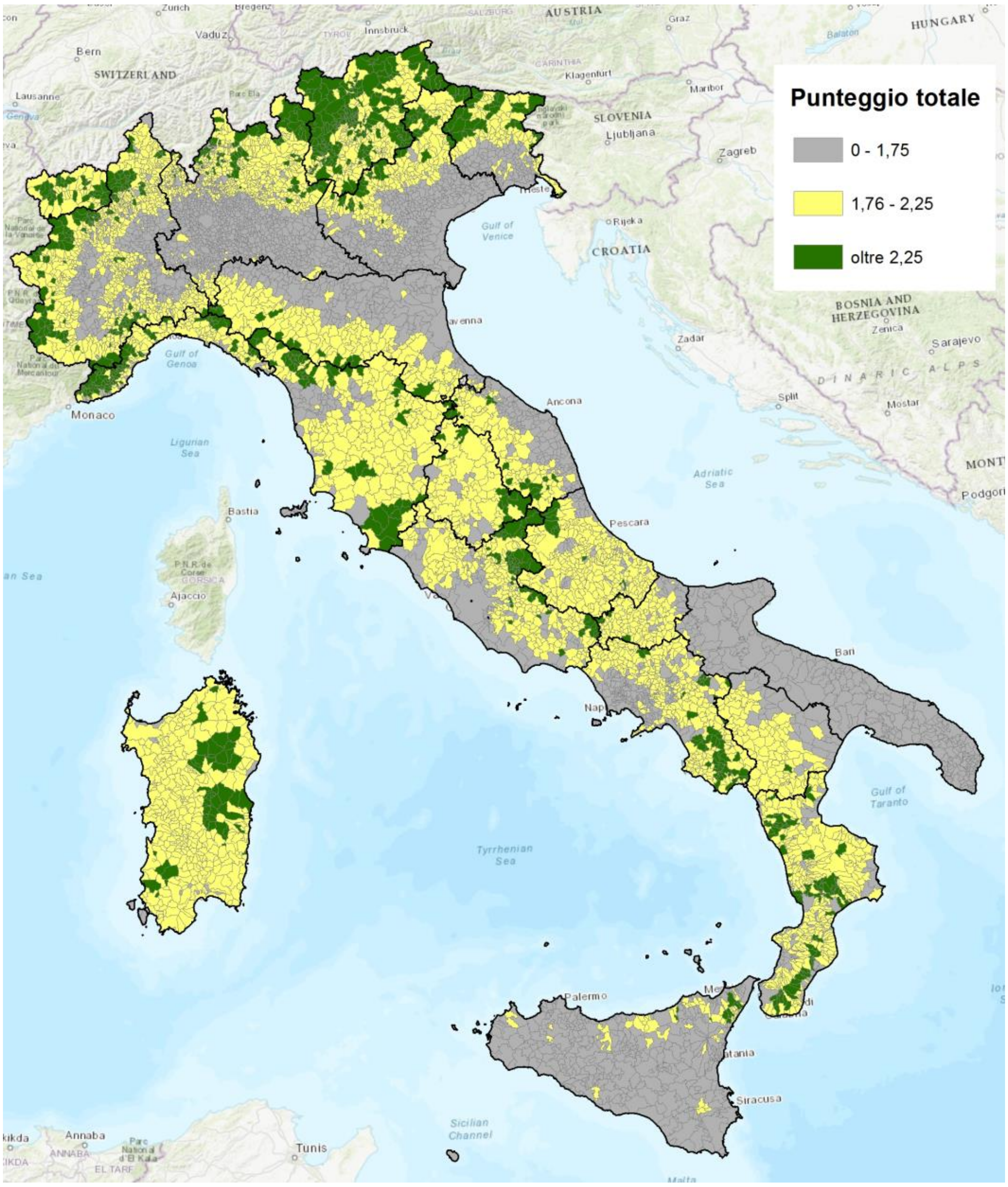
(*) A value of 100% is assumed for levels detected with a score of 1 or 2.

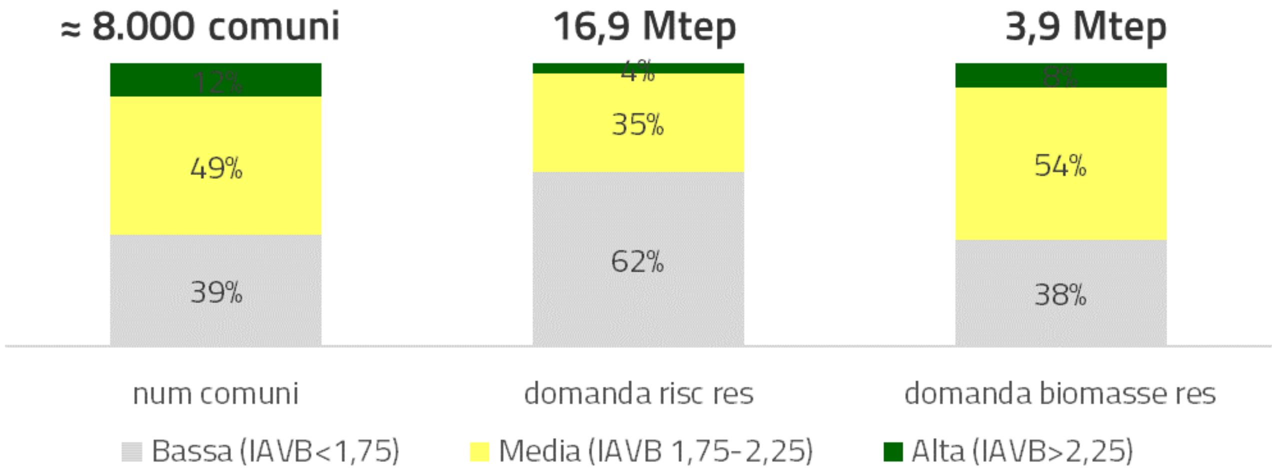
The indicator for areas suitable for biomass use (IAVB), calculated for each municipality using the weighting of various indicators, tends to reward municipalities with territorial features that are unfavourable to the development of particulate matter problems, where there is a high level of both demand and supply of biomass, and which have infrastructures in which biomass could play a significant role (for example, without a natural gas supply, with a district heating network that allows a more optimal use of biomass resources). The municipalities were divided into three scoring groups:

- IAVB>2.25: good compatibility with biomass use, all of the drivers have been assessed in a generally positive way, they are located, as shown on the map below, in mountainous areas of the country with a good potential supply of local forestry, not served by natural gas pipelines, a low level of urbanisation and, more generally, conditions that do not favour the development of particulate matter problems.

- IAVB 1.75–2.25: average compatibility with biomass use. The assessment of the drivers as a whole was intermediate, and included different types of municipalities and case types.
- IAVB <1.75: low compatibility with biomass use. The assessment of the drivers as a whole was rather low, comprising low-lying, highly urbanised areas with a natural gas supply and in various cases with particulate matter problems.

Figure 81: Map and graphs showing the indicator for areas suitable for biomass use (IAVB) by municipality





Punteggio totale	Total scores
0 - 1,75	0–1.75
1,76 - 2,25	1.76–2.25
oltre 2,25	over 2.25
Zurich	Zurich
Bregenz	Bregenz
Bern	Bern
Lausanne	Lausanne
SWITZERLAND	SWITZERLAND
Vaduz	Vaduz
Innsbruck	Innsbruck
SALZBURG	SALZBURG
AUSTRIA	AUSTRIA
GARINTHIA	CARINTHIA
Graz	Graz
Klagenfurt	Klagenfurt
Maribor	Maribor
SLOVENIA	SLOVENIA
Ljubijana	Ljubljana
Zagreb	Zagreb
Balaton	Balaton
HUNGARY	HUNGARY
Guif of Venice	Gulf of Venice
Rijeka	Rijeka
CROATIA	CROATIA
Zadar	Zadar
Ancona	Ancona
BOSNIA AND HERZEGOVINA	BOSNIA AND HERZEGOVINA
Zenica	Zenica
Sarajevo	Sarajevo
Spilt	Split
Mostar	Mostar
Pescara	Pescara
Bari	Bari
Adriatic Sea	Adriatic Sea
MONT	MONTENEGRO

Podgori	Podgori
Monaco	Monaco
Ligurian Sea	Ligurian Sea
Bastia	Bastia
P.N.R de Corse	Regional Natural Park of Corsica
GORSICA	CORSICA
Ajaccio	Ajaccio
Tyrrhenian sea	Tyrrhenian sea
Gulf of Taranto	Gulf of Taranto
Palermo	Palermo
Annaba	Annaba
ANNABA	ANNABA
Pare Nation al d'El	El Kala National Park
EL TARF	EL TAREF
Tunis	Tunis
Sicilian channel	Sicilian channel
Siracusa	Syracuse
= 8.000 comuni	= 8 000 municipalities
49%	49%
39%	39%
num comuni	No of municipalities
Bassa (IAVB<1,75)	Low (IAVB <1.75)
16,9 Mtep m	16.9 Mtoe
4%	4%
35%	35%
62%	62%
domanda rise res	Residential demand for heating
Media (IAVB 1,75-2,25)	Average (IAVB 1.75–2.25)
3,9 Mtep	3.9 Mtoe
54%	54%
38%	38%
domanda biomasse res	Residential demand for biomass
Alta(IAVB>2,25)	High (IAVB >2.25)

The individual indicators will now be reviewed, with a brief description of each and of the official source used to create the database for the analyses carried out by interpolating the various indicators, in order to identify the areas most suitable for biomass use.

6.3.2 Local supply of forest biomass

Italy has around 9 million hectares of forest and almost 2 million hectares of other wooded land, mainly shrubland, thickets and scrubland. Therefore, the availability of forest biomass and the energy that can be obtained from it can be estimated on the basis of a forest area estimated at 11 million hectares by the National Inventory of Forests and Forest Carbon Sinks (INFC) in 2015. However, the quality and quantity of the forest area to be considered need to be carefully examined: according to the 2015 estimates from the INFC, forest area covers 11 million hectares, but over 1.8 million hectares are covered by other wooded land, with a very limited logging rate.

In addition, approximately 12% of actual forest area is subject to logging restrictions and must be deducted from the 9 million hectares of actual forest cover. Therefore, looking at this conservative analysis as a whole, around 5 million hectares could be reached with the minimum road system necessary to allow ordinary logging activities.

Overall, forestry covers more than 35% of the Italian territory and in some Regions is the most common form of land cover, occupying around 50% or more of the Regional land area, as is the case in Trentino-Alto Adige, Liguria, Tuscany, Umbria and Sardinia. Apulia and Sicily are the Regions with the lowest percentage of forest area. Forest cover has increased steadily over the last century, thanks to the spontaneous colonisation of remote areas; a slowdown in the expansion of forest areas has recently been observed, probably due to the decreasing availability of suitable areas[29].

The following table illustrates the regional distribution of forest cover in Italy. The most significant percentage is in Sardinia, with over 583 000 hectares of forest and 653 000 hectares of other wooded land, followed by Tuscany.

Table 57: Forest cover by Region/Autonomous Province in hectares (INFC 2015)

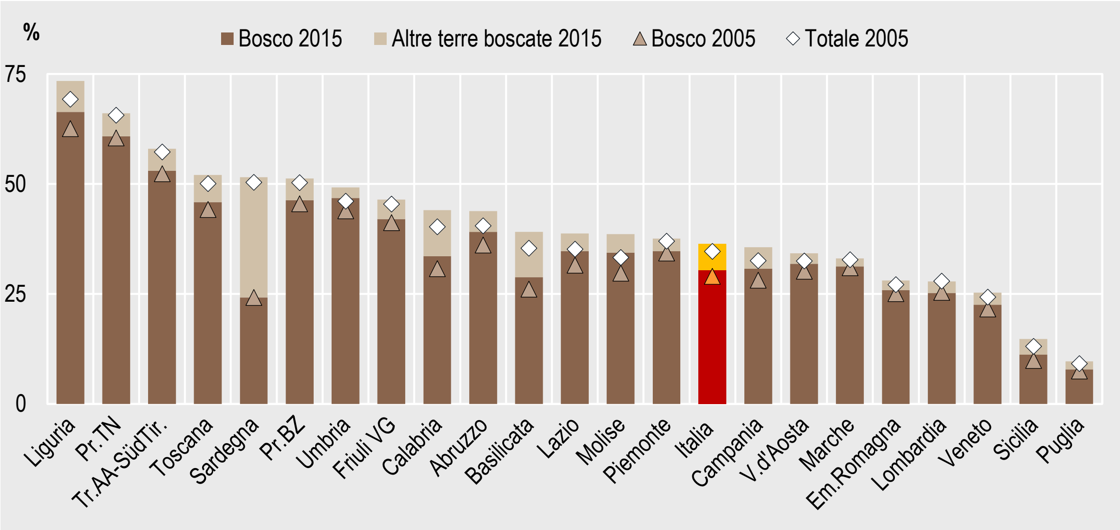
Region	Forest area 2015 (ha)
Abruzzo	475 093
Basilicata	393 864
Calabria	670 968
Campania	486 945
Emilia-Romagna	629 624
Friuli-Venezia Giulia	365 486
Lazio	667 704
Liguria	397 531
Lombardy	664 192
Marche	311 032
Molise	172 222
Piedmont	955 111
Apulia	189 086
Sardinia	1 241 408
Sicily	381 647
Tuscany	1 196 992
Autonomous Province of Trento	410 201
Autonomous Province of Bolzano	378 903
Umbria	416 660
Valle d'Aosta	111 718
Veneto	465 625

[29] Source: Italy Forestry Report 2019 on INFC data

Italy	10 982 013

The regional forest area should be commensurate with the size of the Region and also with the type of forest and the different timber yields that can be obtained therefrom.

Figure 82: Forest area per Region 2005 and 2015 (Percentage of the total)



%	%
75	75
50	50
25	25
0	0
Bosco 2015	Forest 2015
Altre terre boscate 2015	Other wooded land 2015
Bosco 2005	Forest 2005
Totale 2005	Total 2005
Liguria	Liguria
Pr.TN	Autonomous Province of Trento
Tr.AA-SüdTir.	Trentino-Alto Adige
Toscana	Tuscany
Sardegna	Sardinia
Pr.BZ	Autonomous Province of Bolzano
Umbria	Umbria
Friuli VG	Friuli-Venezia Giulia
Calabria	Calabria
Abruzzo	Abruzzo
Basilicata	Basilicata
Lazio	Lazio
Molise	Molise
Piemonte	Piedmont
Italia	Italy
Campania	Campania
V.d'Aosta	Valle d'Aosta

Marche	Marche
Em.Romagna	Emilia-Romagna
Lombardia	Lombardy
Veneto	Veneto
Sicilia	Sicily
Puglia	Apulia

Although forest biomass is not the only type of biomass used to fuel domestic heating appliances and district heating networks (tree prunings, agricultural waste and scythings, pellets, bark, wood chips, briquettes, etc.), it is the most prevalent and has an important direct connection with local supply chains, which, if carefully stimulated to increase current felling rates, could be a useful driver for local agroforestry economies, and represent a valid alternative to the enormous quantities of wood products imported into Italy from abroad.

Like other sources, wood biomass can be transported, but it is considered more suitable for use in areas in which this resource is available locally, so as to minimise transport, which has significant environmental and economic implications.

In order to estimate the supply of wood for creating energy using forest biomass, the volume of wood available from the increments in forest area in each Region was calculated, by multiplying the regional forest cover (2015 INFC inventory, excluding other wooded land) with the average regional increments in forest area and the density of the phytomass (2005 INFC inventory). The share of these increments to be felled for energy purposes is assumed to be 30%[30] in line with current uses and a lower calorific value of 3.4 kWh/kg compared to seasoned wood for one summer. According to the most recent sources, such as the National Report on the State of Italy’s forests, the proportion of the annual increment felled in Italy is between 18% and 37%, well below the average in southern Europe of 62-67% (State of Europe’s Forests 2015).

These potential regional felling rates were then broken down by municipality using ISPRA data, which provide land cover data for each municipality, indicating the hectares covered by forest.

An indicator of potential felling for biomass purposes per unit of land was obtained by looking at the ratio of felling rates to municipal area; areas with higher indicator values, and thus with more woodland, were assigned a higher score in terms of the area’s readiness for the implementation of district heating networks using this source. This choice obviously leads to the prioritisation of areas which could at least partially provide local forest resources for district heating, reducing the environmental and economic impact in relation to transport and also enabling the development

[30] The value is intended as an average national indicative potential value. A further refinement of the methodology used in this study is expected, in order to modulate this parameter on the basis of site-specific data which take into account the accessibility of local forests and felling rates already in place.

of an entire supply chain aimed at the sustainable use and maintenance of forests.

Figure 83: Biomass supply potential from forest felling per municipality

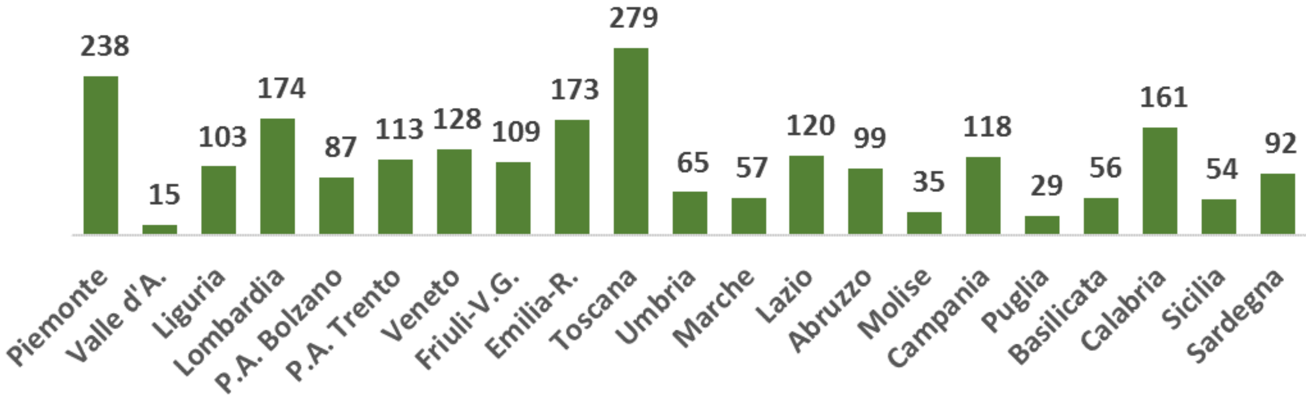
Offerta biomassa Potenziale energetico (tep)	Energy potential of biomass supply (toe)
min	min
max	max
Bern	Bern
Lausanne	Lausanne
SWITZERLAND	SWITZERLAND
GARINTHIA	CARINTHIA
Klagenfurt	Klagenfurt
SLOVENIA	SLOVENIA
Ljubijana	Ljubljana
Guif of Venice	Gulf of Venice
Rijeka	Rijeka
CROATIA	CROATIA
Zadar	Zadar
Ancona	Ancona

Banja Luka	Banja Luka
Tuzia	Tuzia
BOSNIA AND HERZEGOVINA	BOSNIA AND HERZEGOVINA
Zenica	Zenica
Sarajevo	Sarajevo
Spilt	Split
Mostar	Mostar
Pescara	Pescara
Bari	Bari
Adriatic Sea	Adriatic Sea
MONT	MONTENEGRO
Monaco	Monaco
Ligurian Sea	Ligurian Sea
Bastia	Bastia
P.N.R de Corse	Regional Natural Park of Corsica
GORSICA	CORSICA
Ajaccio	Ajaccio
Tyrrhenian sea	Tyrrhenian sea
Guif of Taranto	Gulf of Taranto
Palermo	Palermo
Skikda	Skikda
Annaba	Annaba
ANNABA	ANNABA
Pare Nation al d’El	El Kala National Park
Tunis	Tunis
Sicilian channel	Sicilian channel
Siracusa	Syracuse

The national potential calculated totals 2.3 Mtoe, with a distribution not dissimilar to forest area.

It should be noted that the aim of this analysis is not to determine an absolute amount of biomass that could be felled and used for energy purposes, but rather to provide guidance about an area’s suitability (or lack thereof) to provide local biomass that can also be used for district heating.

Figure 84: Regional potential from forest felling (ktoe)



238	238
15	15
103	103
174	174
87	87
113	113
128	128
109	109
173	173
279	279
65	65
57	57
120	120
99	99
35	35
118	118
29	29
56	56
161	161
54	54
92	92
Piemonte	Piedmont
Valle d'A.	Valle d’Aosta
Liguria	Liguria
Lombardia	Lombardy
P.A. Bolzano	Autonomous Province of Bolzano
P.A. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli-V.G.	Friuli-Venezia Giulia
Emilia-R.	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria

Marche	Marche
Lazio	Lazio
Abruzzo	Abruzzo
Molise	Molise
Campania	Campania
Puglia	Apulia
Basilicata	Basilicata
Calabria	Calabria
Sicilia	Sicily
Sardegna	Sardinia

6.3.3 Local demand for biomass for heating purposes

The requirements of municipal buildings were calculated on the basis of the regional biomass consumption recorded in GSE statistics on renewable sources. Regional biomass demand was estimated by applying transformation efficiencies characteristic of biomass power plants to these consumption values. This regional demand and the number of dwellings with a biomass-fuelled system as the main source of domestic heating (Source: ISTAT 2011 census) were used to obtain an indicator of the specific biomass demand per dwelling, differentiated for the six national climate zones. By applying this indicator to the number of municipal dwellings with a biomass-fuelled system as the main source of domestic heating[31], and standardising this figure in relation to the total regional consumption recorded, it was possible to estimate, with some degree of approximation, the heating demand met by biomass for each municipality.

As a general perspective, it should be emphasised that the INECP envisages stable use of biomass up to 2030, which would thus maintain the current production set-up and make it more efficient through better allocation of the current volumes of biomass available (for example with fewer imports and placing more value on local agro-forestry supply chains), in particular in the thermal sector, whereas for electricity there would be a gradual reduction in overall use of bioenergy.

With this in mind, higher scores were therefore given to municipalities with widespread use of biomass (in terms of absolute demand met by biomass and percentage of dwellings using it) and where district heating could therefore be a key factor in increasing efficiency and reducing emissions.

[31] Processed by GSE on the basis of ISTAT microdata on types of heating system used in dwellings in each census zone, made available by ISTAT to the Polytechnic University of Milan and subsequently shared with GSE.

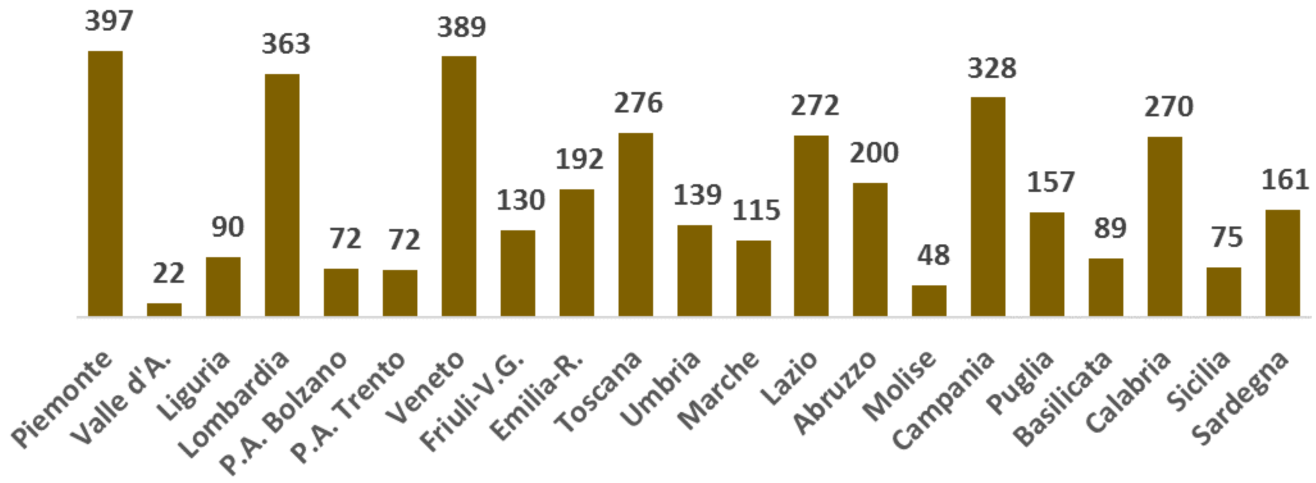
Figure 85: Biomass demand per municipality

Fabbisogno da biomassa (GWh)	Biomass demand (GWh)
min	min
max	max
Bern	Bern
Lausanne	Lausanne
SWITZERLAND	SWITZERLAND
GARINTHIA	CARINTHIA
Klagenfurt	Klagenfurt
Guif of Venice	Gulf of Venice
Rijeka	Rijeka
CROATIA	CROATIA
Zadar	Zadar
Ancona	Ancona
Banja Luka	Banja Luka
Tuzia	Tuzia
BOSNIA AND HERZEGOVINA	BOSNIA AND HERZEGOVINA

Zenica	Zenica
Sarajevo	Sarajevo
Spilt	Split
Mostar	Mostar
Pescara	Pescara
Bari	Bari
Adriatic Sea	Adriatic Sea
MONT	MONTENEGRO
Monaco	Monaco
Ligurian Sea	Ligurian Sea
Bastia	Bastia
P.N.R de Corse	Regional Natural Park of Corsica
GORSICA	CORSICA
Ajaccio	Ajaccio
Tyrrhenian sea	Tyrrhenian sea
Guif of Taranto	Gulf of Taranto
Palermo	Palermo
Skikda	Skikda
Annaba	Annaba
ANNABA	ANNABA
Pare Nation al d'El	El Kala National Park
Tunis	Tunis
Sicilian channel	Sicilian channel
Siracusa	Syracuse

National heating demand covered by biomass totals 3.9 Mtoe (6.2 Mtoe in final consumption). The highest levels of demand can be found in Lombardy, Piedmont and Veneto (30% of national biomass demand).

Figure 86: Residential demand for biomass for heating purposes, broken down by Region/Autonomous Province (ktoe)



397	397
22	22
90	90
363	363
72	72
72	72
389	389
130	130
192	192
276	276
139	139
115	115
272	272
200	200
48	48
328	328
157	157
89	89
270	270
75	75
161	161
Piemonte	Piedmont
Valle d'A.	Valle d’Aosta
Liguria	Liguria
Lombardia	Lombardy
P.A. Bolzano	Autonomous Province of Bolzano
P.A. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli-V.G.	Friuli-Venezia Giulia

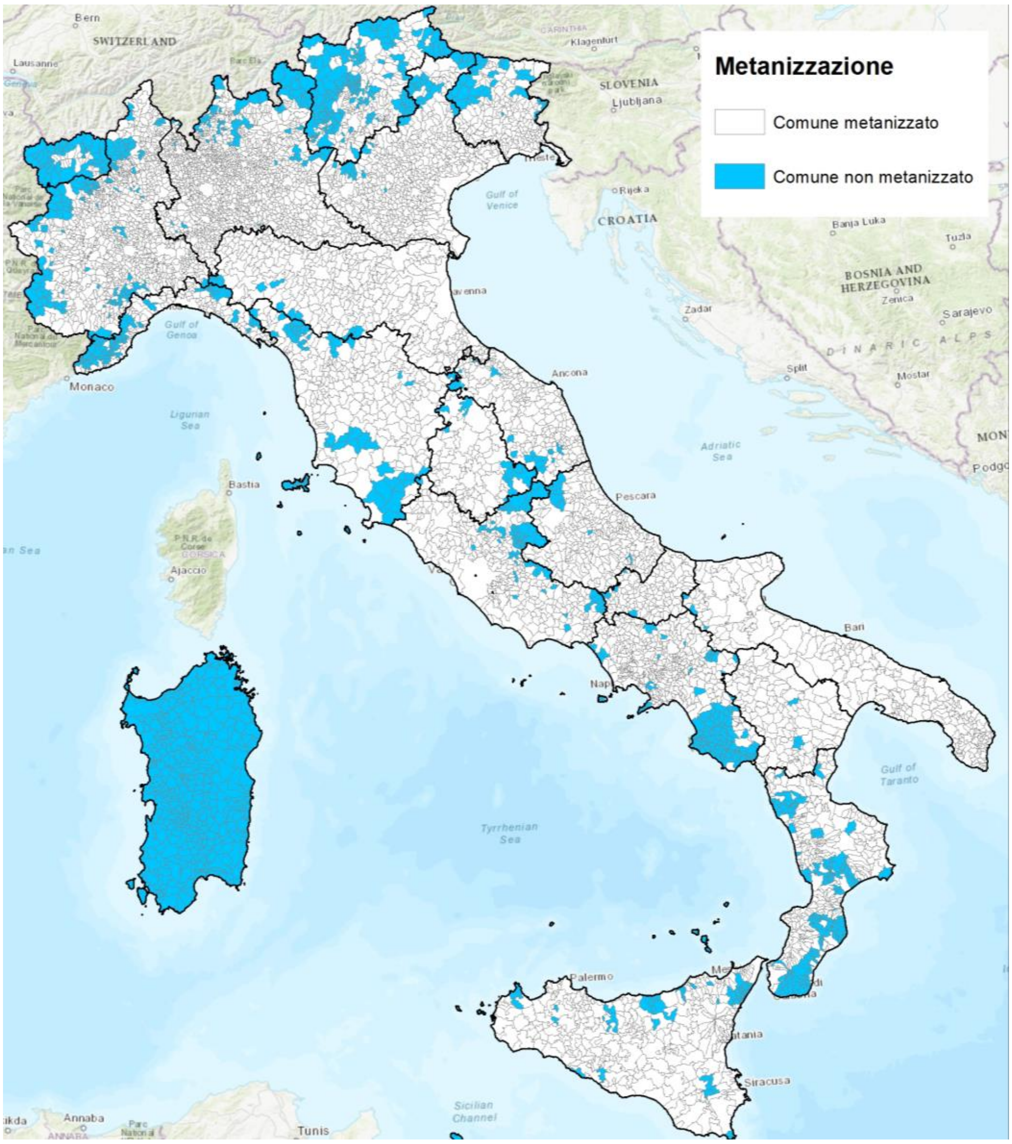
Emilia-R.	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria
Marche	Marche
Lazio	Lazio
Abruzzo	Abruzzo
Molise	Molise
Campania	Campania
Puglia	Apulia
Basilicata	Basilicata
Calabria	Calabria
Sicilia	Sicily
Sardegna	Sardinia

6.3.4 Natural gas distribution

For climate zone E, municipalities without natural gas supply have been counted in light of the contents of the Ministerial Decree from the Ministry of Economy and Finance of 9 March 1999, as amended, and data from the Ministry of Economic Development on natural gas distribution in Italy. Supply of natural gas to municipalities is a very important factor, in terms of identifying an alternative energy source for those municipalities that lack it. This alternative source might be found locally, such as forest biomass, which is the subject of this study. Obviously, the two aforementioned sources may co-exist or be in economic competition, depending on the configuration involving individual users (DH networks or individual heating appliances).

As the situation develops over the years and many municipalities gradually receive a natural gas supply, local energy paradigms clearly change and adapt, with progressive shifts from one technology to another. It is certain that the traditional source of biomass remains a consistent resource and the sole form of heating, particularly for independent individual users, in municipalities without natural gas supply.

Figure 87: Municipalities without natural gas supply

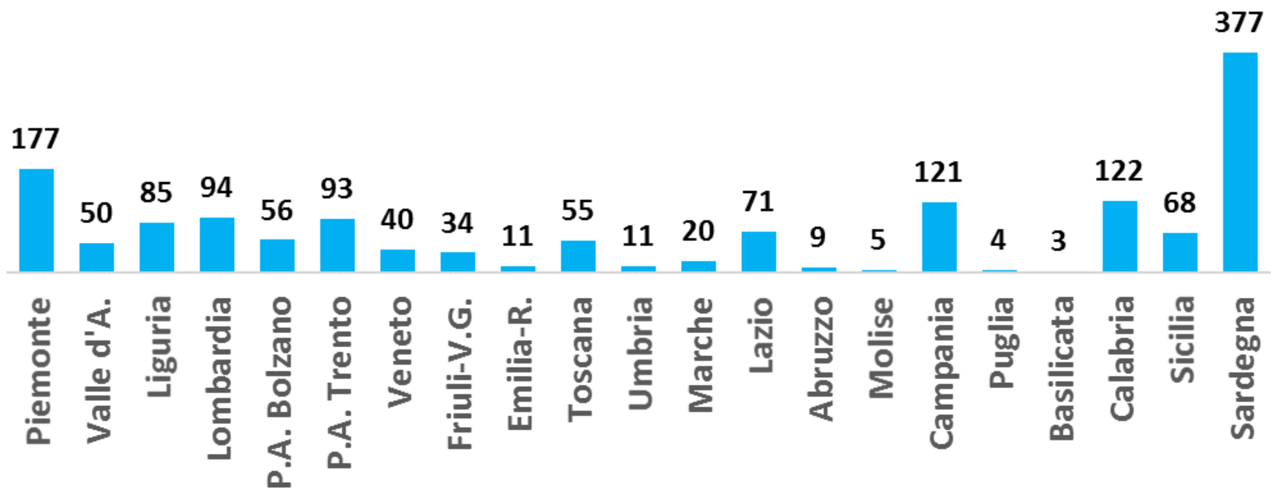


Metanizzazione	Natural gas distribution
Comune metanizzato	Municipalities with natural gas supply
Comune non metanizzato	Municipalities without natural gas supply
Bern	Bern
Lausanne	Lausanne
SWITZERLAND	SWITZERLAND
GARINTHIA	CARINTHIA
Klagenfurt	Klagenfurt
Guif of Venice	Gulf of Venice
Rijeka	Rijeka
CROATIA	CROATIA
Zadar	Zadar
Ancona	Ancona
Banja Luka	Banja Luka
Tuzia	Tuzia
BOSNIA AND HERZEGOVINA	BOSNIA AND HERZEGOVINA
Zenica	Zenica

Sarajevo	Sarajevo
Spilt	Split
Mostar	Mostar
Pescara	Pescara
Bari	Bari
Adriatic Sea	Adriatic Sea
MONT	MONTENEGRO
Monaco	Monaco
Ligurian Sea	Ligurian Sea
Bastia	Bastia
P.N.R de Corse	Regional Natural Park of Corsica
GORSICA	CORSICA
Ajaccio	Ajaccio
Tyrrhenian sea	Tyrrhenian sea
Guif of Taranto	Gulf of Taranto
Palermo	Palermo
Skikda	Skikda
Annaba	Annaba
ANNABA	ANNABA
Pare Nation al d'El	El Kala National Park
Tunis	Tunis
Sicilian channel	Sicilian channel
Siracusa	Syracuse

Biomass (together with heat pumps) is a more sustainable and cost-effective solution for municipalities without natural gas supply, often located in mountainous areas, than oil-based alternatives.

Figure 88: Number of municipalities without natural gas supply by Region and Autonomous Province



177	177
50	50

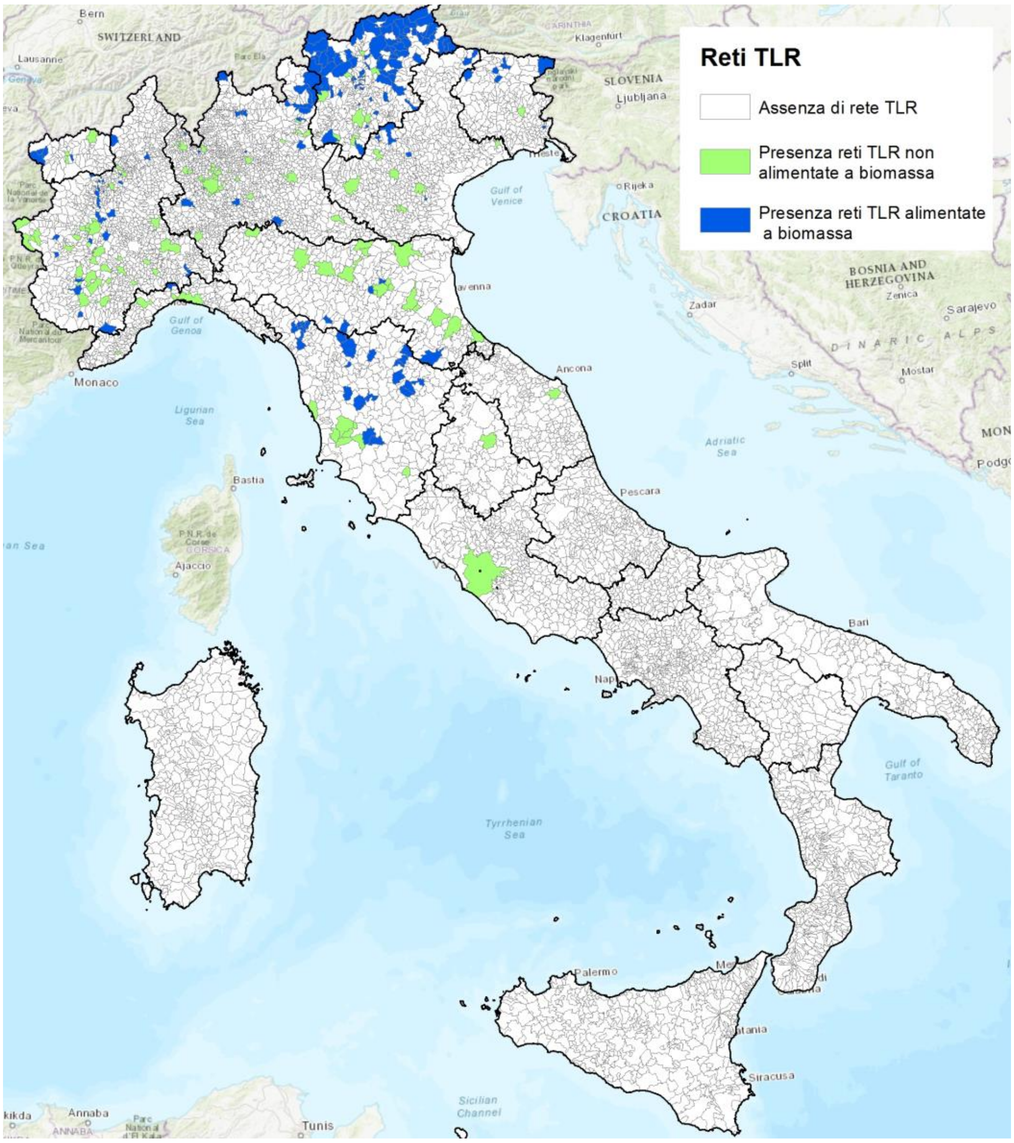
85	85
94	94
56	56
93	93
40	40
34	34
11	11
55	55
11	11
20	20
71	71
9	9
5	5
121	121
4	4
3	3
1	1
122	122
68	68
77	77
Piemonte	Piedmont
Valle d'A.	Valle d’Aosta
Liguria	Liguria
Lombardia	Lombardy
P.A. Bolzano	Autonomous Province of Bolzano
P.A. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli-V.G.	Friuli-Venezia Giulia
Emilia-R.	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria
Marche	Marche
Lazio	Lazio
Abruzzo	Abruzzo
Molise	Molise
Campania	Campania
Puglia	Apulia
Basilicata	Basilicata
Calabria	Calabria
Sicilia	Sicily
Sardegna	Sardinia

6.3.5 Availability of district heating networks

GSE data can be used to analyse the current geographical distribution of district heating networks in Italy and to identify possible economies of scale, in particular in adjacent areas, especially with a view to exploiting local biomass supplies and related logistics.

This creates an opportunity for proximity between the supply of the resource and the demand for energy, where the DH network can act as a link and energy carrier capable of more efficiently integrating the use of biomass and the entire agro-forestry sector, from logging and transport to storage and combustion in heating systems.

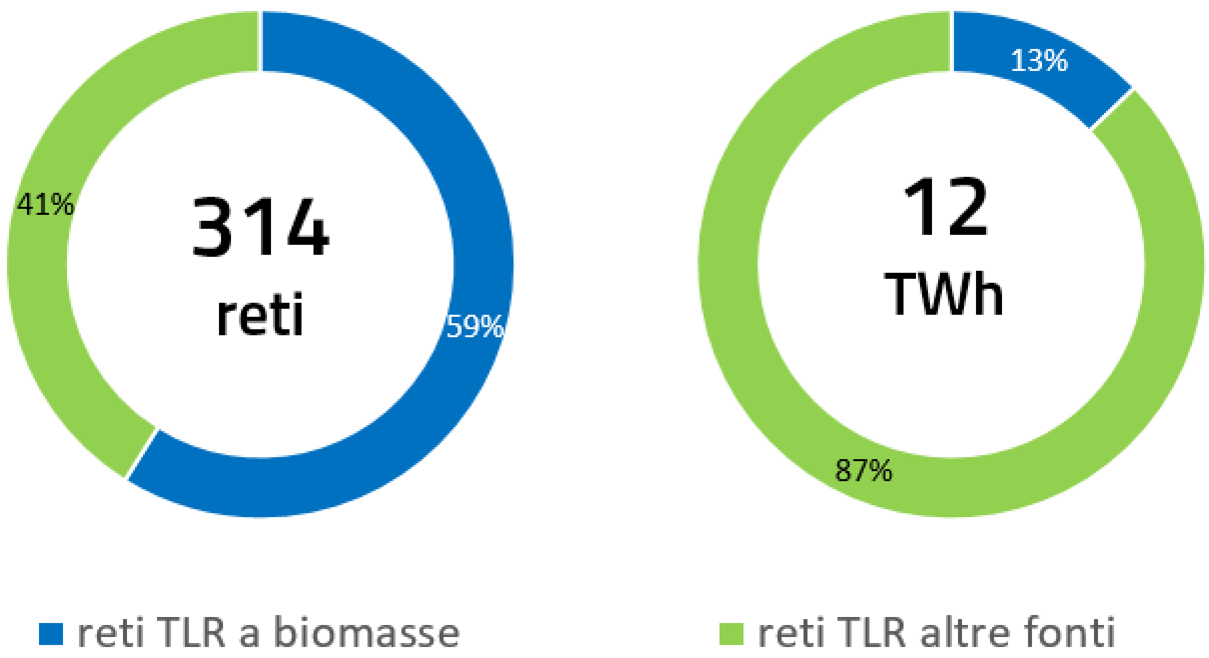
Figure 89: Availability of DH networks at municipal level



Reti TLR	DH networks
Assenza di rete TLR	No DH networks available
Presenza reti TLR non alimentate a biomassa	DH networks not powered by biomass available
Presenza reti TLR alimentate a biomassa	DH networks powered by biomass available

Biomass is a very popular source of district heating, with more than 180 DH networks carrying around 1.5 TWh of thermal energy fed in from biomass.

Figure 90: Number of networks and energy fed in from biomass in district heating



41%	41%
314 reti	314 networks
59%	59%
reti TLR a biomasse	Biomass-fuelled DH networks
13%	13%
12 TWh	12 TWh
87%	87%
reti TLR altre fonti	DH networks fuelled by other sources

6.3.6 Air quality

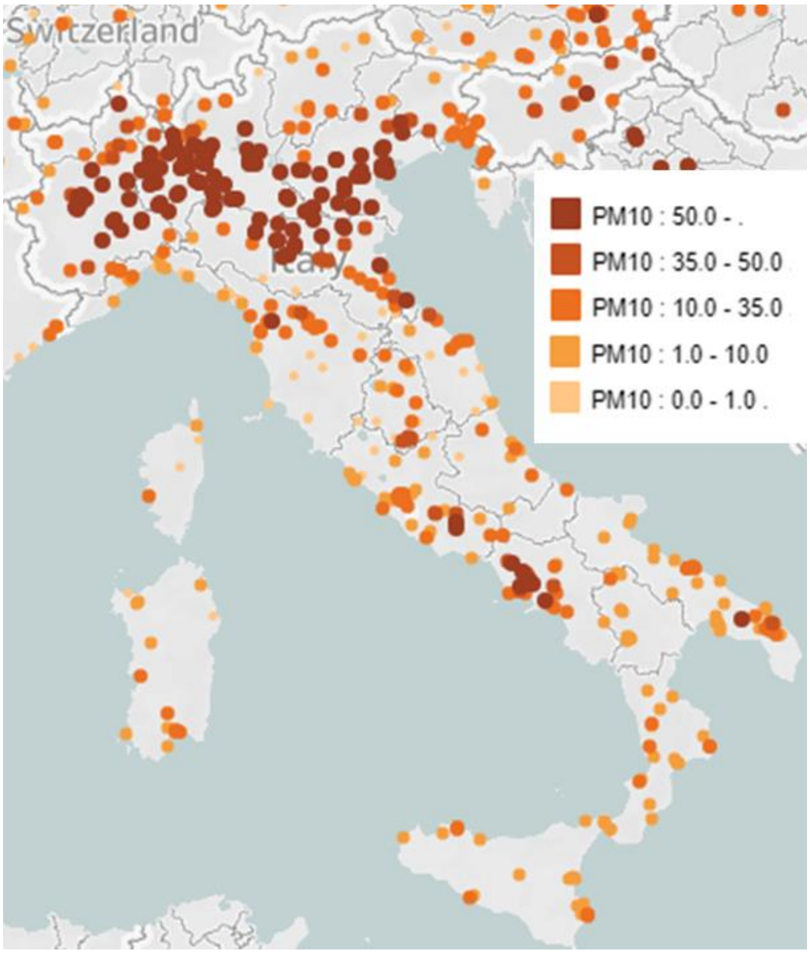
With regard to air pollutants such as PM10, the limit values for which cannot by law be exceeded on more than 35 days a year, the statistics on the European Environmental Agency's portal were consulted, which provide precise references to individual air pollution stations. This is a very decisive indicator in this comparative analysis between parameters that might or might not favour the use of bioenergy in one municipality over another, especially given that the impact of biomass combustion on air quality has always been the subject of much debate, in particular in several river basins on the peninsula, and it is subject to numerous regulatory measures and good practices adopted ad hoc.

EU and Italian legislation provide for the land to be divided into zones and agglomerations where measurements can be made and compliance with target and limit values assessed.

With Regional Council Decree No 2605 of 30 November 2011, the Region of Lombardy has taken steps in this regard to adjust the zoning, dividing the Region into the following zones and agglomerations: agglomeration of Bergamo, agglomeration of Brescia, agglomeration of Milan, zone A – highly urbanised plain, zone B – plains, zone C – mountain, zone D – valley floor. This

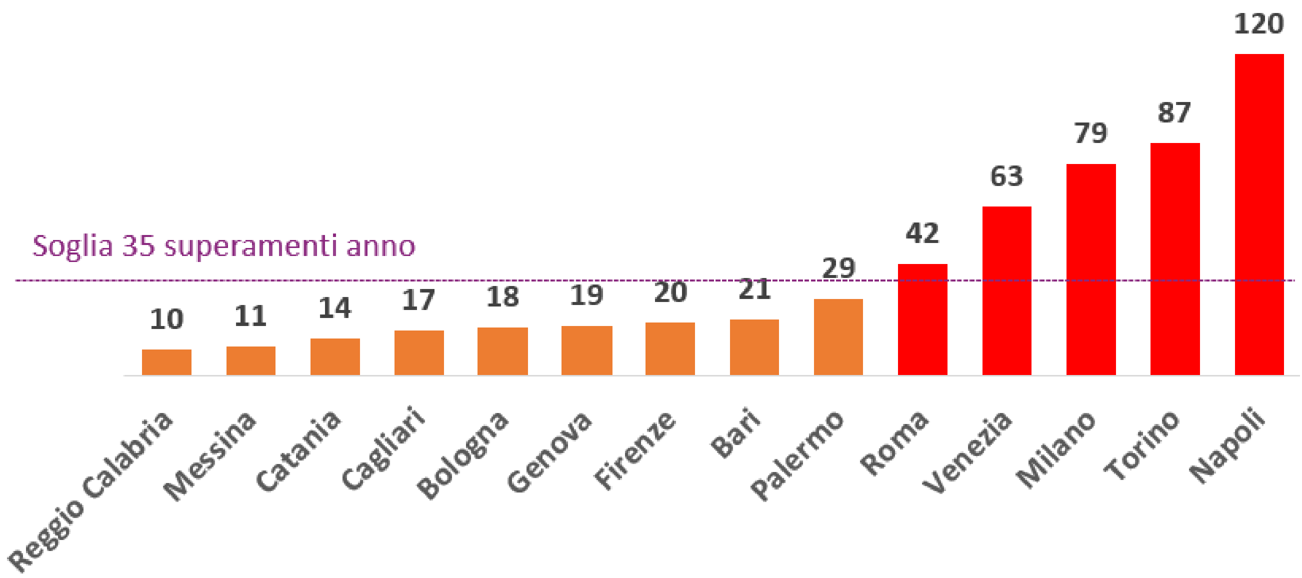
division applies for all pollutants monitored for air quality assessment purposes, while for ozone, zone C is subdivided as follows: zone C1 – the Alpine foothills and Apennine area, zone C2 – Alpine area. In addition to measures relating to vehicle traffic, provisions have also been introduced in relation to the combustion of wood/biomass: from 1 October to 31 March of each year, the use of low-efficiency domestic heating appliances fuelled by wood biomass is prohibited. The restriction applies if there are other domestic heating systems available which use permitted conventional fuels.
The Region of Veneto has used a methodology to divide its territory into zones, first identifying agglomerations and then identifying other zones. As indicated by Legislative Decree No 155/2010, each agglomeration corresponds to an area with a resident population of more than 250 000 and is made up of a main urban area and a group of smaller urban areas that depend on the main one in terms of population, services and the flow of persons and goods. The following five agglomerations were identified: Venice agglomeration, Treviso agglomeration, Padua agglomeration, Vicenza agglomeration, Verona agglomeration. On the basis of the meteorology and climate typical of the mountainous part of the Region, and using the database showing municipal emissions of the main atmospheric pollutants, estimated by the Air Emissions Inventory (INEMAR) for 2005, created by the Regional Air Observatory, the following zones have been identified: Alpine foothills and Alps; Val Belluna; plains and main town on the lower plains; lower plains and hills.

Figure 91: Map of number of days of PM10 exceedance in 2017 (source: EEA)



In this study, the data from the individual measuring stations were associated only with the municipality in which the station is located, while geomorphological drivers (altitude, level of urbanisation), which make it possible to estimate whether conditions are conducive to the development of air quality problems or not, are used for other municipalities[32].

Figure 92: Number of days of PM10 exceedance in metropolitan cities (ISPRA 2018)



Soglia 35 superamenti anno	Threshold 35 exceedances per year
10	10
11	11
14	14
17	17
18	18
19	19
20	20
21	21
29	29
42	42
63	63
79	79
87	87
120	120
Reggio Calabria	Reggio Calabria
Messina	Messina
Catania	Catania
Cagliari	Cagliari
Bologna	Bologna

[32] The methodology used in this study will be further refined in order to extend the coverage of air quality data to the whole country. The network of air quality measuring stations in fact covers reference areas that are larger than the municipalities to which the stations belong and, as a whole, the entire country. In accordance with current regulations, air quality is assessed at regional level for specially designated zones. There are 81 zones in Italy.

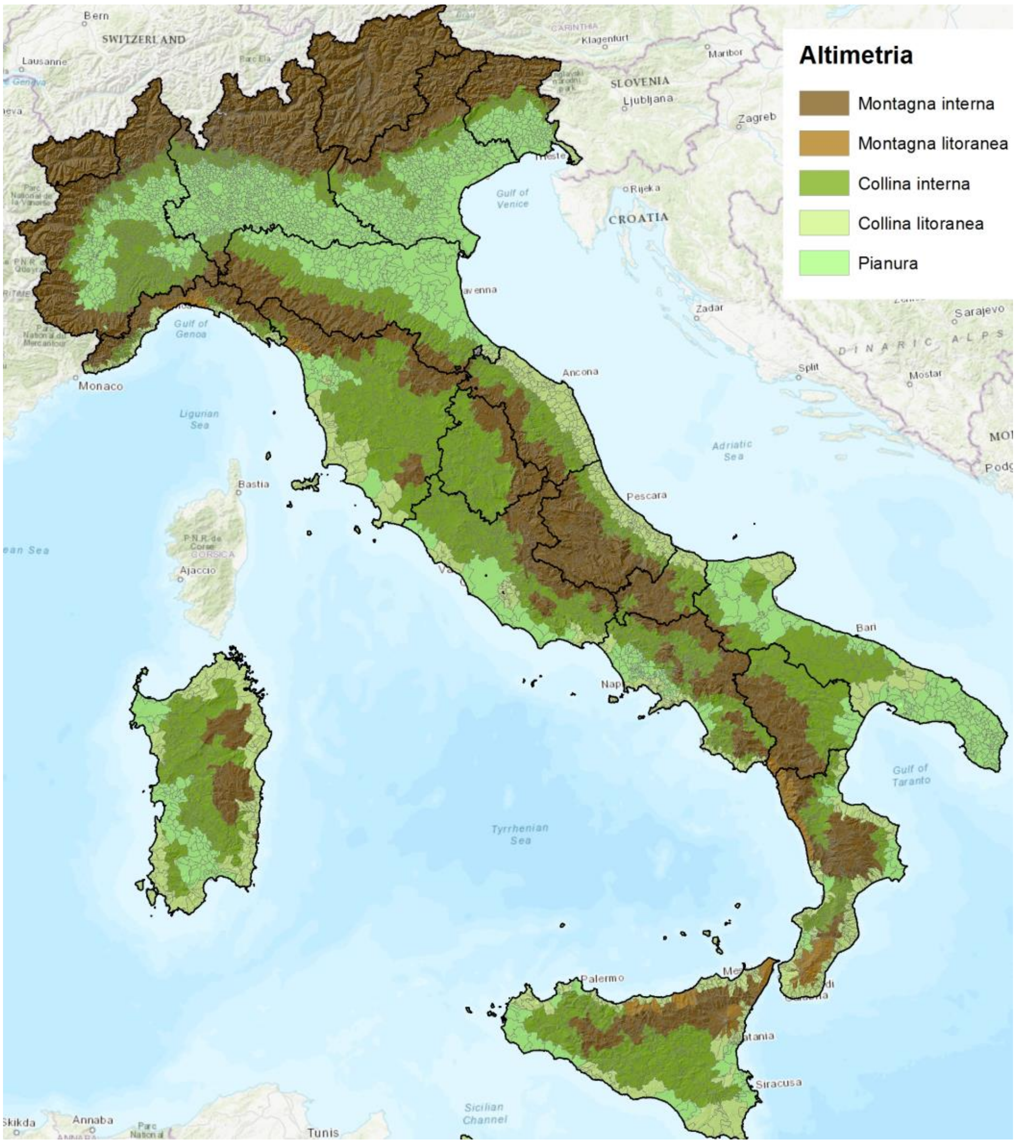
Genova	Genoa
Firenze	Florence
Bari	Bari
Palermo	Palermo
Roma	Rome
Venezia	Venice
Milano	Milan
Torino	Turin
Napoli	Naples

6.3.7 Altitude

The standard ISTAT distinction between inland and coastal mountains, inland and coastal hills and lowlands was taken into account. ISTAT divides municipalities into 8 altitude bands, specifically: 0-299 masl; 300-599 masl; 600-899 masl; 900-1 199 masl, 1 200-1 499 masl, 1 500-1 999 masl, 2 000-2 499 masl and above 2 500 masl. These have been identified taking into account how Italian territory is defined on the basis of altitude (for example, mountain - altitude greater than 600 masl) and also considering the most commonly used phytosociological classifications. Altitude is usually correlated with other geographical and social factors: we know that the most common type of terrain in Italy is hillside (42%), followed by mountains (35%) and then plains (23%).

This is a very important aspect, especially if related to the environmental constraints present in some Regions with regard to air quality and which include, at certain altitudes (usually the 200-300 m range), a specific parameter limiting the use, for example, of obsolete domestic wood-fuelled heating appliances, as well as stipulating their gradual replacement with the latest installations, which are more efficient and less polluting. Altitude and urbanisation are also quite closely linked, since as the altitude increases, urban centres become less urbanised and more divided into rural hamlets, with extensive forest resources which can be used for biomass in local communities.

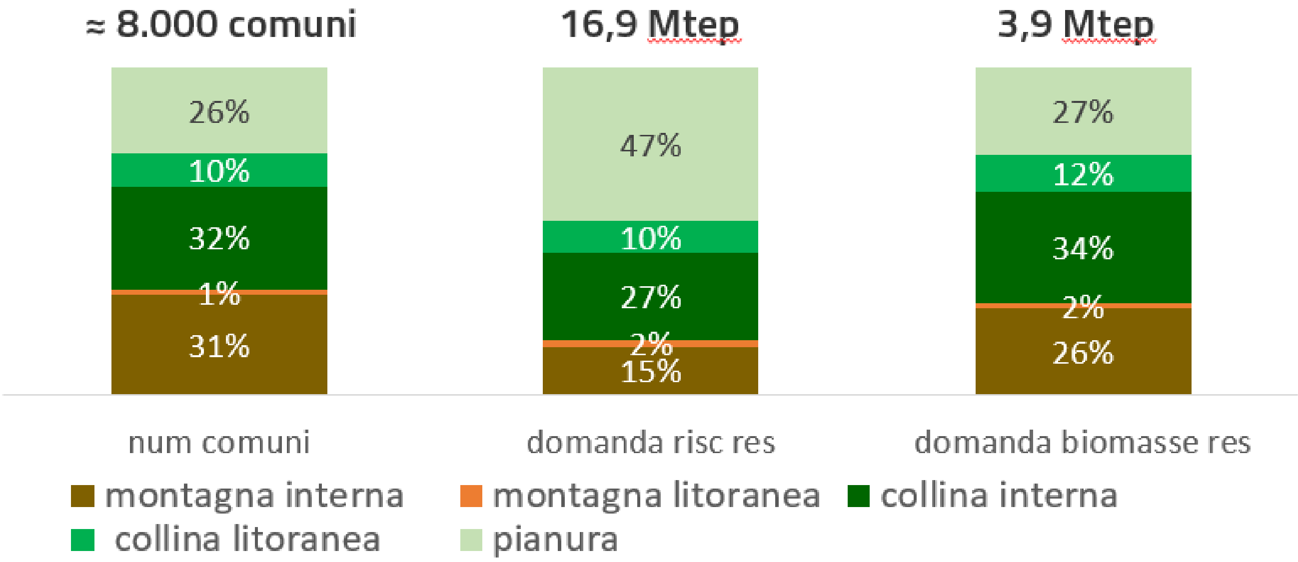
Figure 93: Altitude broken down by municipality



Altimetria	Altitude
Montagna interna	Inland mountains
Montagna litoranea	Coastal mountains
Collina interna	Inland hills
Colina litoranea	Coastal hills
Pianura	Plains

Altitude generally correlates with forest cover, increased heat demand and fewer air quality issues. In some Regions (e.g. Tuscany, Piedmont), environmental constraints are in place to limit the use of biomass heating appliances below a certain altitude (in general 300 metres and limited to appliances with fewer than 4 stars).

Figure 94: Number of municipalities and residential heating demand by altitude zone



= 8.000 comuni	**= 8 000 municipalities**
26%	26%
10%	10%
32%	32%
1%	1%
31%	31%
num comuni	No of municipalities
montagna interna	Inland mountains
collina litoranea	Coastal hills
16,9 Mtep	**16.9 Mtoe**
47%	47%
10%	10%
27%	27%
2%	2%
15%	15%
domanda risc res	Residential heating demand
montagna litoranea	Coastal mountains
pianura	Plains
3,9 Mtep	**3.9 Mtoe**
27%	27%
12%	12%
34%	34%
2%	2%
26%	26%
domanda biomasse res	Residential demand for biomass
collina interna	Inland hills

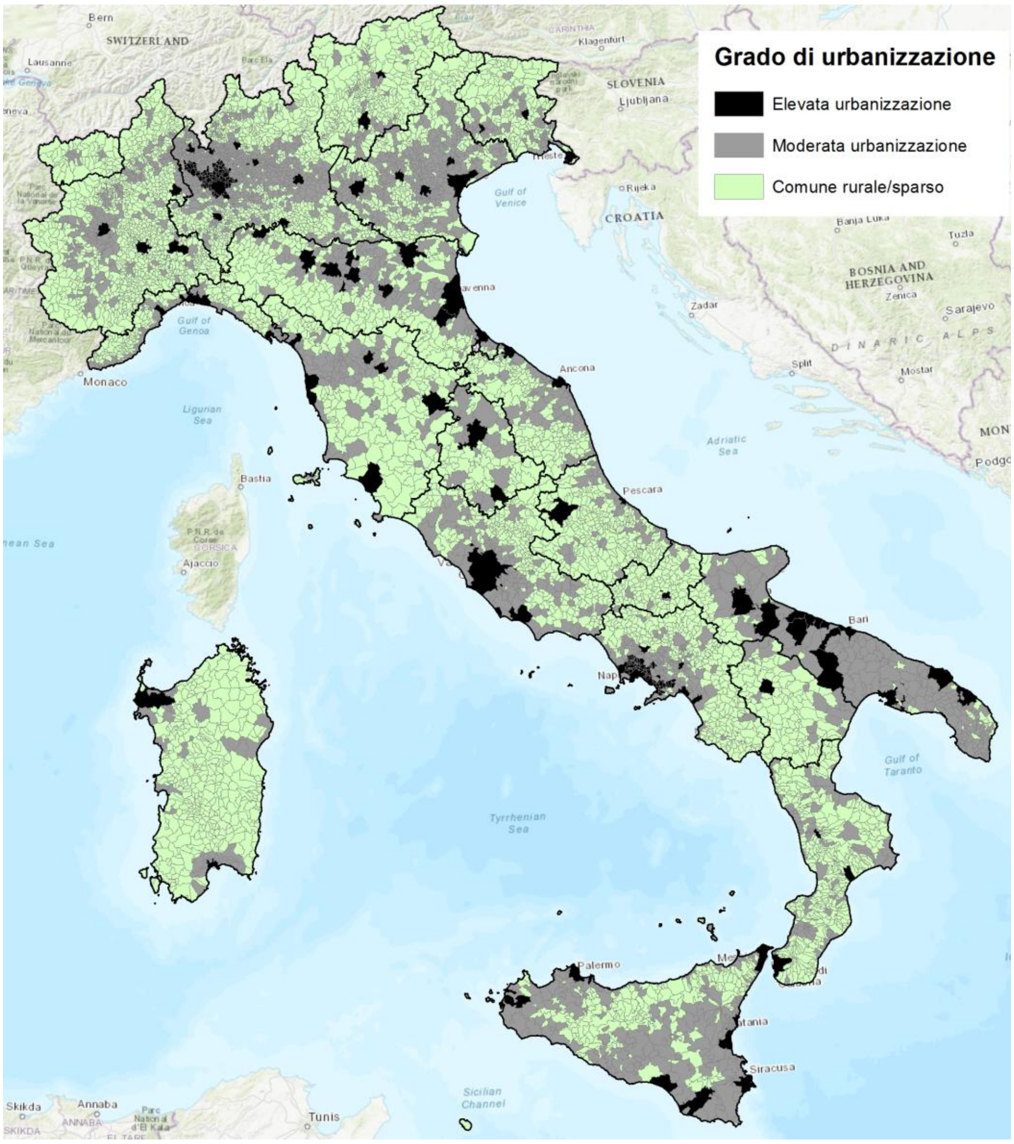
6.3.8 Level of urbanisation

Municipalities are classified by ISTAT according to three levels of urbanisation – high, medium and low – using a tool based on population density and number of inhabitants. In Italy, about 65% of municipalities fall into the low urbanisation class. These are predominantly rural areas, with 24% of the population living on 73% of the total land area. Highly urbanised municipalities, accounting for only 3% of the national total and with a total land area of 5%, are home to 33% of the Italian population. Approximately one third of the municipalities have an average degree of urbanisation, covering 23% of the total land area and home to 42% of the total population.

This is a composite indicator, which in some cases supplements and in others replaces the other parameters relating to the geomorphological information about the areas analysed, since climate-related aspects contribute, for example alongside transport, to establishing environmental pressure in certain contexts, in which the use of individual and collective heating can complement one another.

Clearly, transporting solid biomass poses problems in urban centres, from road traffic to logistics and domestic storage, which do not arise in small, rural, provincial areas: this parameter is therefore strongly correlated with other climate-related indicators which render municipalities more or less suitable for bioenergy use.

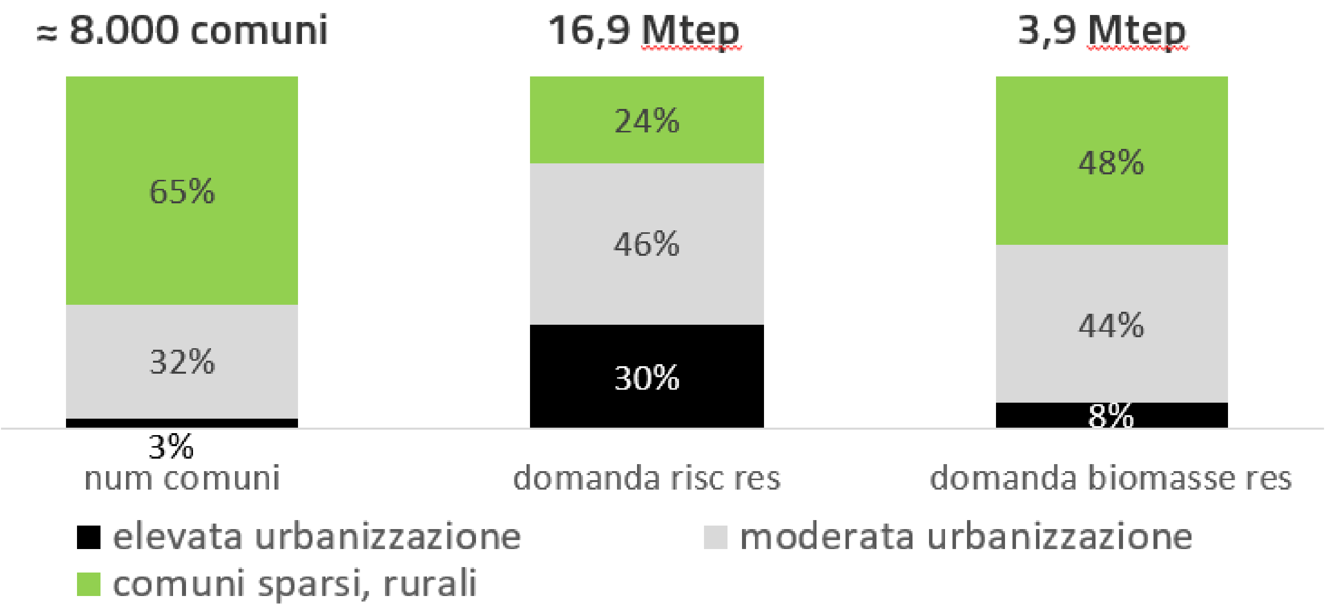
Figure 95: Level of municipal urbanisation



Grado di urbanizzazione	Level of urbanisation
Elevata urbanizzazione	High level of urbanisation
Moderata urbanizzazione	Moderate urbanisation
Comune rurale/sparso	Rural municipality/scattered hamlets

The transport and storage of solid biomass poses major difficulties in urbanised areas, from road traffic to less available space. In addition, in the absence of data relating to particulate matter, the level of urbanisation can be a useful proxy for identifying areas with greater environmental externalities linked to vehicle traffic.

Figure 96: Number of municipalities and residential heating demand broken down by level of urbanisation



= 8.000 comuni	**= 8 000 municipalities**
65%	65%
32%	32%
3%	3%
num comuni	No of municipalities
elevata urbanizzazione	High level of urbanisation
comuni sparsi, rurali	Rural municipalities, scattered hamlets
16,9 Mtep	**16.9 Mtoe**
24%	24%
46%	46%
30%	30%
domanda risc res	Residential heating demand
3,9 Mtep	**3.9 Mtoe**
48%	48%
44%	44%
8%	8%
domanda biomasse res	Residential demand for biomass
moderata urbanizzazione	Moderate urbanisation

6.3.9 Climate zones

Presidential Decree No 412/1993 identifies six climate zones in Italy using degree days and sets the maximum number of hours per day during which heating systems can be used.

City of reference:

A: Lampedusa, Linosa, Porto Empedocle

B: Agrigento, Catania, Crotone, Messina, Palermo, Reggio Calabria, Syracuse, Trapani

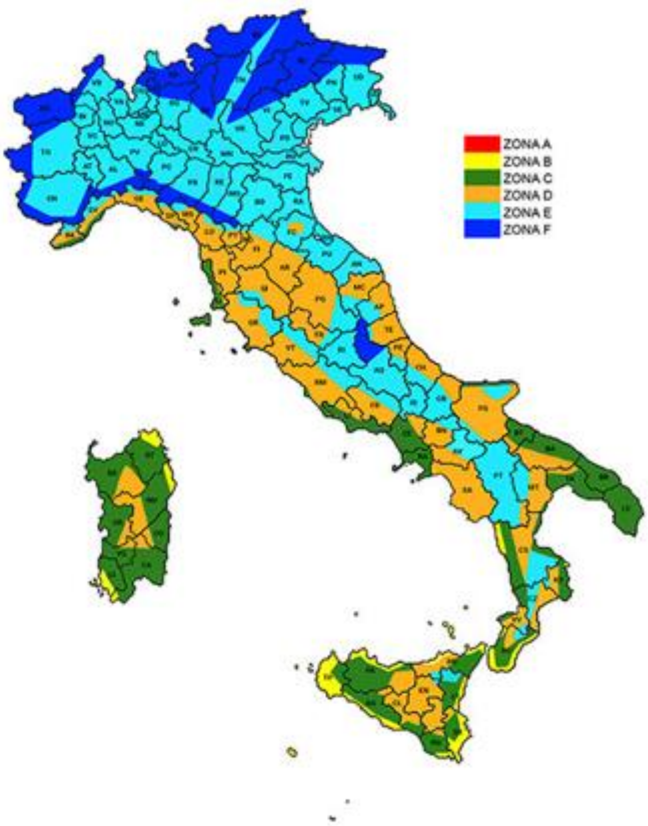
C: Bari, Benevento, Brindisi, Cagliari, Caserta, Catanzaro, Cosenza, Imperia, Latina, Lecce, Naples, Oristano, Ragusa, Salerno, Sassari, Taranto

D: Ancona, Ascoli Piceno, Avellino, Caltanissetta, Chieti, Florence, Foggia, Forlì, Genoa, Grosseto, Isernia, La Spezia, Livorno, Lucca, Macerata, Massa, Carrara, Matera, Nuoro, Pesaro, Pescara, Pisa, Pistoia, Prato, Rome, Savona, Siena, Teramo, Terni, Verona, Vibo Valentia, Viterbo

E: Alessandria, Aosta, Arezzo, Asti, Bergamo, Biella, Bologna, Bolzano, Brescia, Campobasso, Como, Cremona, Enna, Ferrara, Cesena, Frosinone, Gorizia, L'Aquila, Lecco, Lodi, Mantua, Milan, Modena, Novara, Padua, Parma, Pavia, Perugia, Piacenza, Pordenone, Potenza, Ravenna, Reggio Emilia, Rieti, Rimini, Rovigo, Sondrio, Turin, Trento, Treviso, Trieste, Udine, Varese, Venice, Verbania, Vercelli, Vicenza

F: Belluno, Cuneo

Figure 97: Reference climate zones at provincial level

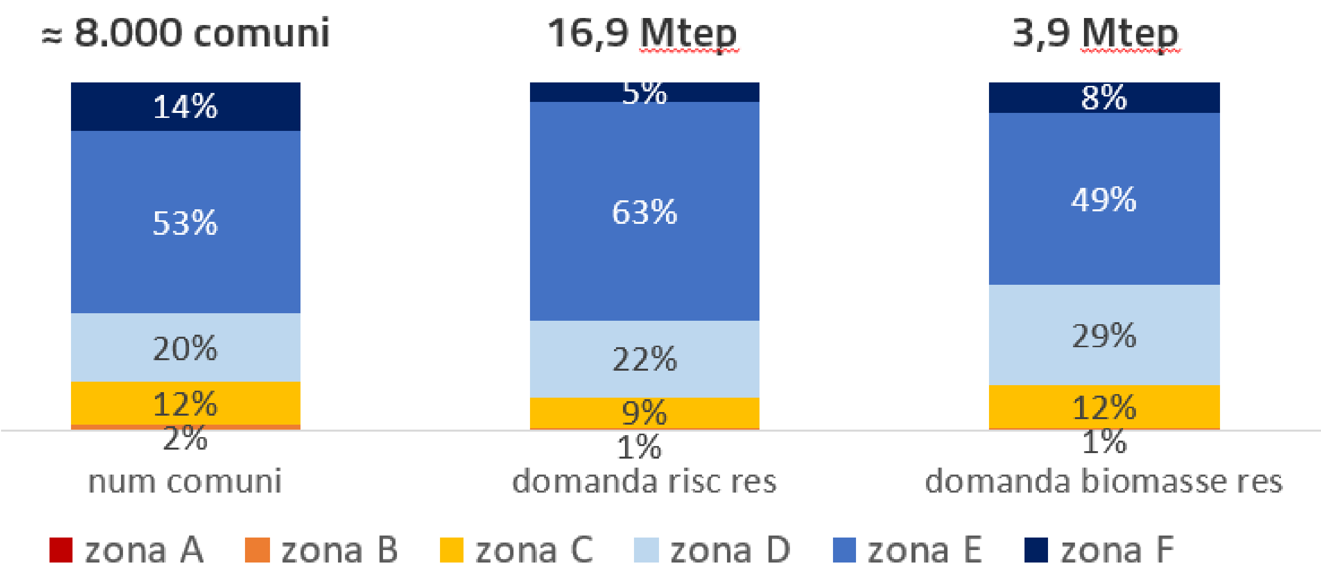


ZONA A	ZONE A
ZONA B	ZONE B

ZONA C	ZONE C
ZONA D	ZONE D
ZONA E	ZONE E
ZONA F	ZONE F

Most of Italy's heat demand (68%) is concentrated in zones E and F. Cold climates obviously lead to higher heating costs and using biomass is a possible way to limit these costs. Zone E is highly varied in terms of geographical distribution.

Figure 98: Number of municipalities and residential heating demand broken down by climate zone



= 8.000 comuni	**= 8 000 municipalities**
14%	14%
53%	53%
20%	20%
12%	12%
2%	2%
num comuni	No of municipalities
16,9 Mtep	**16.9 Mtoe**
5%	5%
63%	63%
22%	22%
9%	9%
1%	1%
domanda risc res	Residential heating demand
3,9 Mtep	**3.9 Mtoe**
8%	8%
49%	49%
29%	29%
12%	12%
1%	1%

domanda biomasse res	Residential demand for biomass
Zona A	Zone A
Zona B	Zone B
Zona C	Zone C
Zona D	Zone D
Zona E	Zone E
Zona F	Zone F

6.3.10 Ecoregions

This takes into account the ecoregions identified by ISTAT, i.e. a classification of municipalities based on similar climate, biogeographical, physiographic and hydrographic factors. Ecoregions, or ecological regions, are quite extensive, ecologically homogeneous sections of land in which species and natural communities interact in a distinctive way with the physical features of the environment. At an international level, ecological classification processes for defining ecoregions are used as a tool to guide sustainable land management and development strategies of varying scale. The approach adopted in Italy creates a hierarchical classification and division of the land into units with an increasing degree of similarity, in line with specific combinations of climate, biogeographical, physiographic and hydrographic factors which determine the presence and distribution of various species, communities and ecosystems.

An important part of this new way of classifying municipalities is the fact that it allows a new understanding of the area, on the basis of which socio-demographic and economic statistics can be analysed in conjunction with the inherent characteristics of the ecoregions, in terms of the similar climate, biogeographical, physiographic and hydrographic factors.

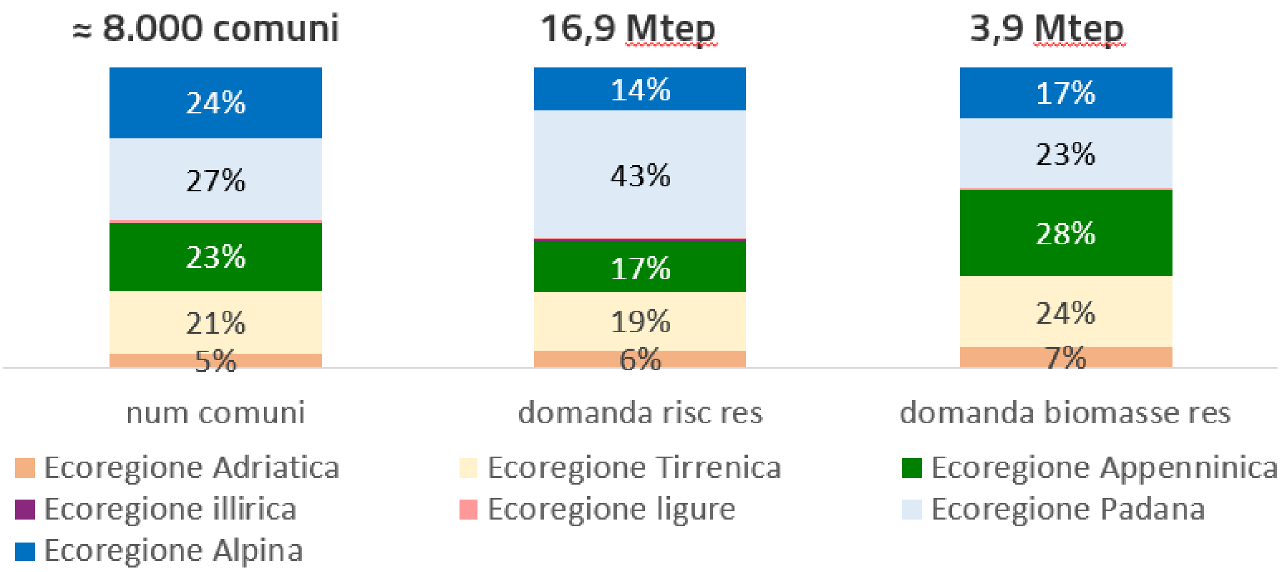
Climate zones, which are classified from A to F in accordance with degree days, have already been used to update the list of municipalities without natural gas supply; however, it seems that ecoregions, as a composite indicator, including of climate, are able to offer a more varied wealth of geographically driven information that climate zones do not provide.

Figure 99: The ecoregions

1A	**1A**
2A	**2A**
1B	**1B**
1C	**1C**
1D	**1D**
2B	**2B**
2C	**2C**
1A - Provincia Alpina	1A – Alpine Province
1B - Provincia Padana	1B – Po Valley Province
1C - Provincia Appeninca	1C – Apennine Province
1D - Porzione Italiana della Provincia [illegible]	1D – Italian portion of the Illyrian Province
2A - Porzione Italiana della Provincia Ligura Provenzia	2A – Italian portion of the Ligurian-Provençal Province
2B - Provincia Terrencia	2B – Tyrrhenian Province
2C - Provincia Adriatica	2C – Adriatic Province
Limiti Regionali	Regional limits

A joint analysis of socio-demographic, economic and energy statistics in terms of ecoregions, which have similar climate, biogeographical, physiographic and hydrographic factors, could make it possible to overcome certain incongruities found within regional/provincial administrative borders, which often make it difficult to identify local ad hoc solutions.

Figure 100: Number of municipalities and residential heating demand broken down by ecoregion



~ 8.000 comuni	**= 8 000 municipalities**
24%	24%
27%	27%
23%	23%
21%	21%
5%	5%
num comuni	No of municipalities
Ecoregione Adriatica	Adriatic ecoregion
Ecoregione illirica	Illyrian ecoregion
Ecoregione Alpina	Alpine ecoregion
16,9 Mtep	**16.9 Mtoe**
14%	14%
43%	43%
17%	17%
19%	19%
6%	6%
domanda risc res	Residential heating demand
Ecoregione Tirrenica	Tyrrhenian ecoregion
Ecoregione ligure	Ligurian ecoregion
3,9 Mtep	**3.9 Mtoe**
17%	17%
23%	23%
28%	28%
24%	24%
7%	7%
domanda biomasse res	Residential demand for biomass

Ecoregione Appenninica	Apennine ecoregion
Ecoregione Padana	Po Valley ecoregion

The set of indicators, quantified and described on a geographical basis, seeks to provide a fairly broad picture of the many aspects (technical, economic, geographical, environmental) related to the use of biomass.

In order to determine the technical potential for using biomass, a suitable calculation model has also been developed (which brings together the various indicators assessed on a municipal basis) which, by assigning appropriate weighting and scores (which can be modified depending on priority), is able to determine a weighted dimensionless indicator representative of the areas most suitable for biomass use (IAVB).

6.4 Other technologies: heat pumps, solar, natural gas

The technical potential of the other sources that could contribute to supplying the DH networks is less constrained by local energy resources and has therefore been evaluated on the basis of certain assumptions formulated in a standardised way across the country, the results of which are also discussed in Section 7.3.4.

7 Technical and financial potential of district heating

The methodology adopted to assess the potential for developing efficient district heating takes a bottom-up approach, which starts by identifying the technical potential of district heating, based on spatial data relating to demand and supply of heat sources. This technical potential is then subject to an economic analysis aimed at identifying how much of said potential can be exploited from an economic point of view for investors, under current market and regulatory conditions. The same technical potential is then also subject to a further economic system analysis, described in Chapter 9, with an integrated approach to the entire energy sector and its evolution scenarios.

7.1 Methodology for assessing district heating potential

The following is a brief description of the main analysis carried out in order to assess the financial and economic potential of district heating.

Technical potential of district heating demand

- Characterisation of heat demand in the civil sector: the heat demand in the civil sector, illustrated on a geographical basis as described in Chapter 2, has been characterised using a wide set of parameters (density, sector, type of use, hours of heating, etc.);
- Characterisation of district heating demand: the energy supplied by the networks and a series of parameters representing the size and operation of existing district heating networks were determined for each municipality;
- Assessment of technical potential of DH demand: the share of heat demand in the civil sector most suited for connection to district heating was determined for each municipality, according to technical feasibility criteria based on the existing networks and availability of sources to supply the local networks.

Technical potential of district heating supply

- Assessment of technical potential of DH supply: local availability of resources for generation technology (geothermal energy, waste heat, biomass, heat pumps, solar energy, CHP), assessed as described in Chapter 6, was compared with the local district heating demand. The lower of the two between local supply and demand represents the maximum potential for using said technology for district heating at a local level.

Economic analysis of district heating

- DH infrastructure cost analysis: estimating the size of DH networks that need to be developed in order to meet demand (length and diameter of pipes, substations, thermal power in the power station, etc.) and estimating the corresponding investment and operating costs.
- DH generation cost analysis: assessing the costs of generating heat using each form of heat production technology on a local basis, and identifying, on economic merit, the mix of sources capable of meeting district heating demand at the lowest cost.
- Revenue analysis: evaluating revenue from the sale of heat and electricity and from any incentives granted.

Economic and financial potential of district heating and environmental externalities

- Economic and financial potential of district heating: the economic sustainability of the initiative was assessed using a project business plan for each municipality, based on current commodity prices and existing measures in support of the sector. This economic and financial potential was determined by considering the percentage of the technical potential implemented, calculated on the basis of the IRR (100% implementation for IRR>= 15%, 0% implementation for IRR <= 7%, linear interpolation for IRR between 7% and 15%).
- Evaluation of the environmental benefits conferred by the financial and economic potential in terms of primary energy savings and emissions prevented.

7.2 Technical potential of district heating demand

The assessment of municipal heat demand in the civil sector, geographically broken down by census zone and used as input for calculating the technical potential, is described in Chapter 2 of this report.

It is useful to highlight some overall indicators for the analysis below:

- 89% of heating and DHW demand in the civil sector is supplied in Italian climate zones D, E and F;
- 64% of the heating and DHW demand comes from the residential sector, and 36% from the service sector;
- 21% of homes have central heating, 55% have independent heating in apartment blocks, 24% have independent heating in single-family homes.

The survey of municipal heat demand currently covered by district heating networks was obtained by processing data acquired by GSE as part of its monitoring activities in the district heating sector for SISTAN, as described in Chapter 3 of this report.

A number of significant indicators are highlighted in order to identify some of the main drivers of district heating development in Italy:

- district heating currently covers 2.6% of heat demand in the civil sector;
- 100% of the energy supplied by DH networks is in the climate zones with the coldest winters (climate bands D-E-F), and in particular 97% in bands E-F;

- 64% of the energy supplied by DH networks goes to the residential sector, only in 7% of municipalities with district heating is the number of residential users negligible (with less than 5% of the energy supplied to the residential sector compared to the total);
- the service sector consumes 34% of the energy supplied by DH networks, 81% of which consumption takes place in climate zone E;
- the industrial sector consumes only 3% of the energy supplied and has not been considered in these assessments.

Table 58: Head demand in the civil sector and energy supplied by DH by climate zone

Climate zone	Heat demand + DHW in the civil sector (GWh)	Residential heat demand (GWh)	Residential DHW demand (GWh)	Heat demand + DHW in the service sector (GWh)	Total DH supplied in 2018 (GWh)	DH supplied to the residential sector in 2018 (GWh)	DH supplied to the service sector in 2018 (GWh)	DH supplied to industry in 2018 (GWh)
A	35	12	13	11	-	-	-	-
B	5 599	2 028	1 742	1 829	-	-	-	-
C	33 001	17 054	7 409	8 539	0	0	0	0
D	71 263	43 676	9 515	18 072	265	158	73	33
E	237 016	122 890	19 220	94 906	8 159	5 329	2 665	164
F	19 068	10 512	1 415	7 140	1 363	753	548	62
Total	**365 983**	**196 172**	**39 314**	**130 497**	**9 787**	**6 241**	**3 287**	**260**

Table 59: Heat demand in the civil sector and energy supplied by DH by Region/Autonomous Province

Region	Heat demand + DHW in the civil sector (GWh)	Residential heat demand (GWh)	Residential DHW demand (GWh)	Heat demand + DHW in the service sector (GWh)	Total DH supplied in 2018 (GWh)	DH supplied to the residential sector in 2018 (GWh)	DH supplied to the service sector in 2018 (GWh)	DH supplied to industry in 2018 (GWh)
Abruzzo	8 630	5 468	933	2 229	-	-	-	-
Basilicata	2 712	2 005	418	288	-	-	-	-
Calabria	7 189	5 179	1 039	971	-	-	-	-
Campania	14 777	7 743	3 291	3 743	-	-	-	-
Emilia-Romagna	43 046	20 122	3 131	19 793	1 101	540	556	5
Friuli-Venezia Giulia	10 856	5 956	803	4 098	42	16	25	0
Lazio	23 237	14 043	3 783	5 411	74	66	8	-
Liguria	8 165	5 372	1 125	1 668	76	19	26	31
Lombardy	82 841	40 974	6 884	34 983	3 706	2 468	1 115	123
Marche	9 631	4 971	997	3 663	14	7	7	-
Molise	1 659	1 231	191	238	-	-	-	-

Autonomous Province of Bolzano	5 317	2 655	523	2 139	992	562	393	38
Autonomous Province of Trento	5 259	2 830	447	1 982	257	88	147	23
Piedmont	39 197	22 851	3 228	13 118	2 875	2 024	818	34
Apulia	12 400	7 761	2 385	2 254	-	-	-	-
Sardinia	5 703	3 603	967	1 132	-	-	-	-
Sicily	10 783	5 378	2 743	2 661	-	-	-	-
Tuscany	21 218	12 484	2 408	6 326	166	136	26	3
Umbria	6 242	3 584	575	2 083	12	3	9	-
Valle d'Aosta	998	686	81	231	118	76	43	-
Veneto	46 124	21 275	3 365	21 484	352	235	114	3
Total	**365 983**	**196 172**	**39 314**	**130 497**	**9 787**	**6 241**	**3 287**	**260**

The technical potential of district heating ($P_{i\,TLR}$) has been assessed at municipal level on the basis of the following formula, which includes a set of statistical and empirical parameters characterising the development of district heating networks in Italy.

$$P_{i\,TLR} = E_{i\,TLR} + P_{i\,INCR-TLR}$$

where:

$$P_{\,i\,INCR-TLR} = MAX[P_{\,i\,STOR-TLR}; \mathrm{MIN}\,[(F_{i\,RES} \cdot K_{i\,LHD} \cdot K_{i\,SWITCH} \cdot K_{i\,ASETT} \cdot K_{MIN} - E_{i\,TLR}); K_{i\,MAX}]]$$

where:

$\boldsymbol{E_{i\,TLR}}$: thermal energy supplied by existing DH in the nth municipality.

$\boldsymbol{P_{i\,INCR-TLR}}$: incremental technical potential of energy that can be supplied from district heating for the nth municipality.

$\boldsymbol{Pi_{\,STOR-TLR}}$: incremental potential of energy supplied by existing DH networks on the basis of historical trends. In municipalities where there is no DH network in operation, the value is 0.

$\boldsymbol{F_{RESi}}$: residential heating demand in the nth municipality.

$\boldsymbol{K_{i\,LHD}}$: linear density factor, ratio between the residential heat demand in municipal census zones which have a linear heat density over a certain threshold and the residential heat demand of the entire municipality. The threshold value was set at 1 both for municipalities without natural gas supply and for all those with geothermal potential, biomass that can be used locally or neighbouring waste heat sources (up to five municipalities away) and at 2 for all other municipalities, i.e. municipalities with natural gas supply and without significant local renewable sources of thermal energy.

$\boldsymbol{K_{i\,SWITCH}}$: rate of connection to district heating, i.e. the share of users that are expected to connect to the network, of those reached by the infrastructure. This factor was weighted for each municipality on the basis of the type of systems available (centralised/independent), assuming it to be 100% for users with centralised systems, 50% for single-family homes and zero for dwellings in apartment blocks with independent heating, due to the significant work required to adapt the systems prior to connection.

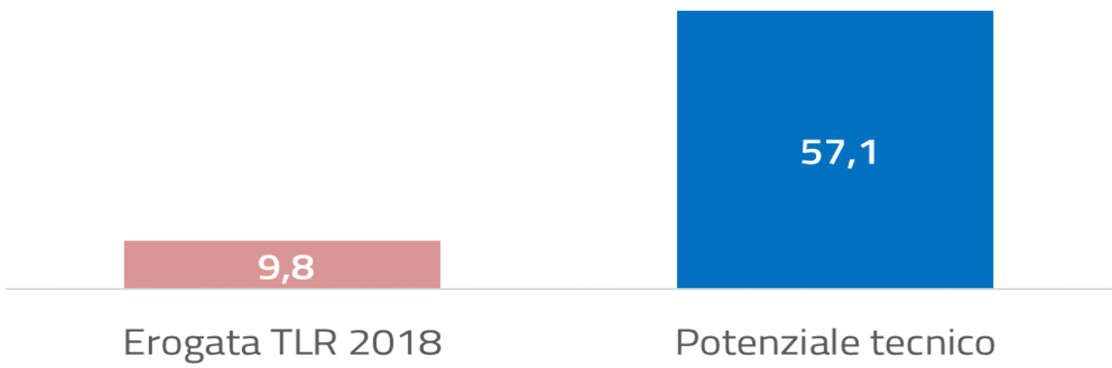
$K_{i\,ASETT}$: incremental rate to account for energy to be supplied to sectors other than the residential sector, assumed to be the ratio of total energy supplied to the residential sector. In municipalities where DH is already available, the characteristic value of the individual networks was used, for municipalities without networks in operation, the ratio calculated using the national totals was used (157%).

K_{MIN}: is a factor of 0 if $F_{RESi} \cdot K_{i\,SAT} \cdot K_{SWITCH} \cdot K_{TERZ}$ is < 2 GWh for areas with natural gas supply < 1 GWh for areas without natural gas supply. If there is already a DH network in the municipality, or if the potential values calculated are greater than the thresholds indicated, the factor is set at 1. The aim of this factor is to identify a minimum demand threshold in order to start developing a new DH infrastructure.

K_{iMAX}: maximum growth of the DH networks that can be developed by 2030, taken from the historical maximum development data recorded for the networks. For municipalities that do not have district heating, this cap has been set at 50% of the municipal volume, multiplied by the specific volume requirement, while for municipalities that already have district heating, it has been set at 4 Mmc per year for the specific volume requirement for the remaining years.

The total technical potential of district heating calculated for each municipality using the analytical formula just described totals 57 TWh of thermal energy that can be supplied by district heating, around 16% of total heat demand in the civil sector and around six times the current DH development levels.

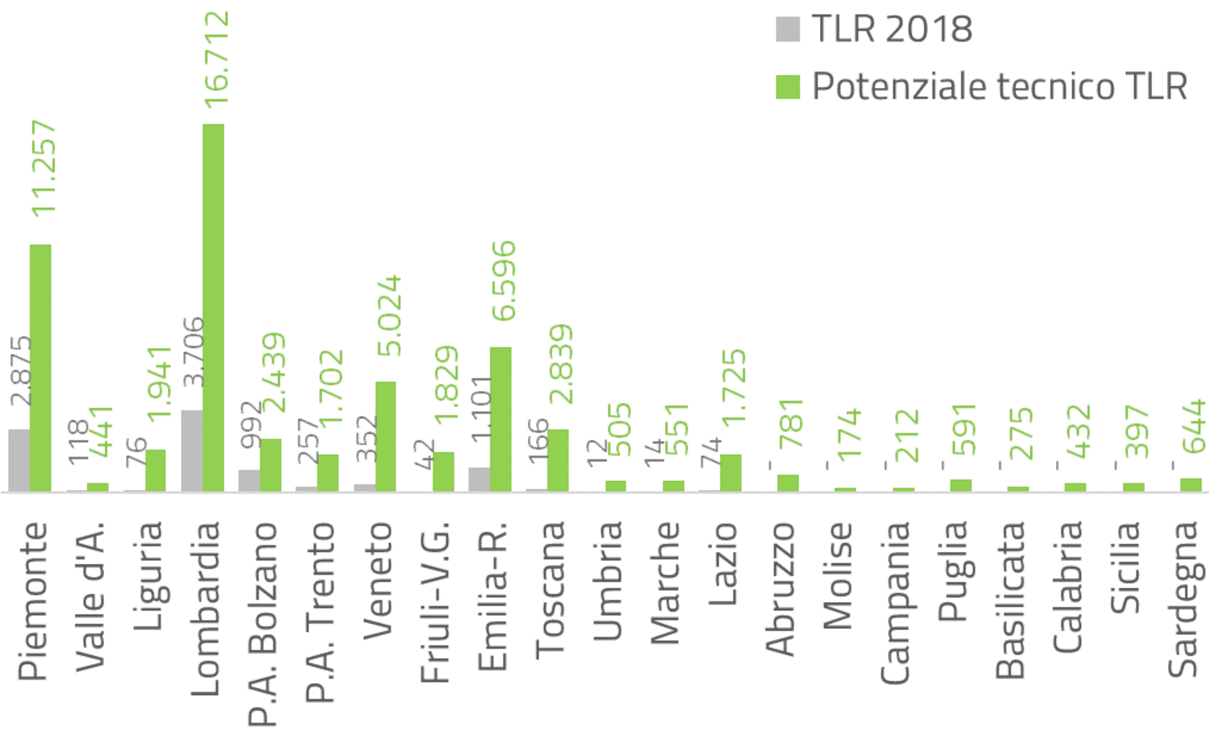
Figure 101: Comparison between energy from district heating in 2018 and technical potential (TWh)



9,8	9.8
Erogata TLR 2018	DH supplied in 2018
57,1	57.1
Potenziale tecnico	Technical potential

The technical potential of district heating covers more than 3 000 municipalities located in all Regions of Italy, with a fairly significant number in the northern Regions of the country (84% of district heating demand).

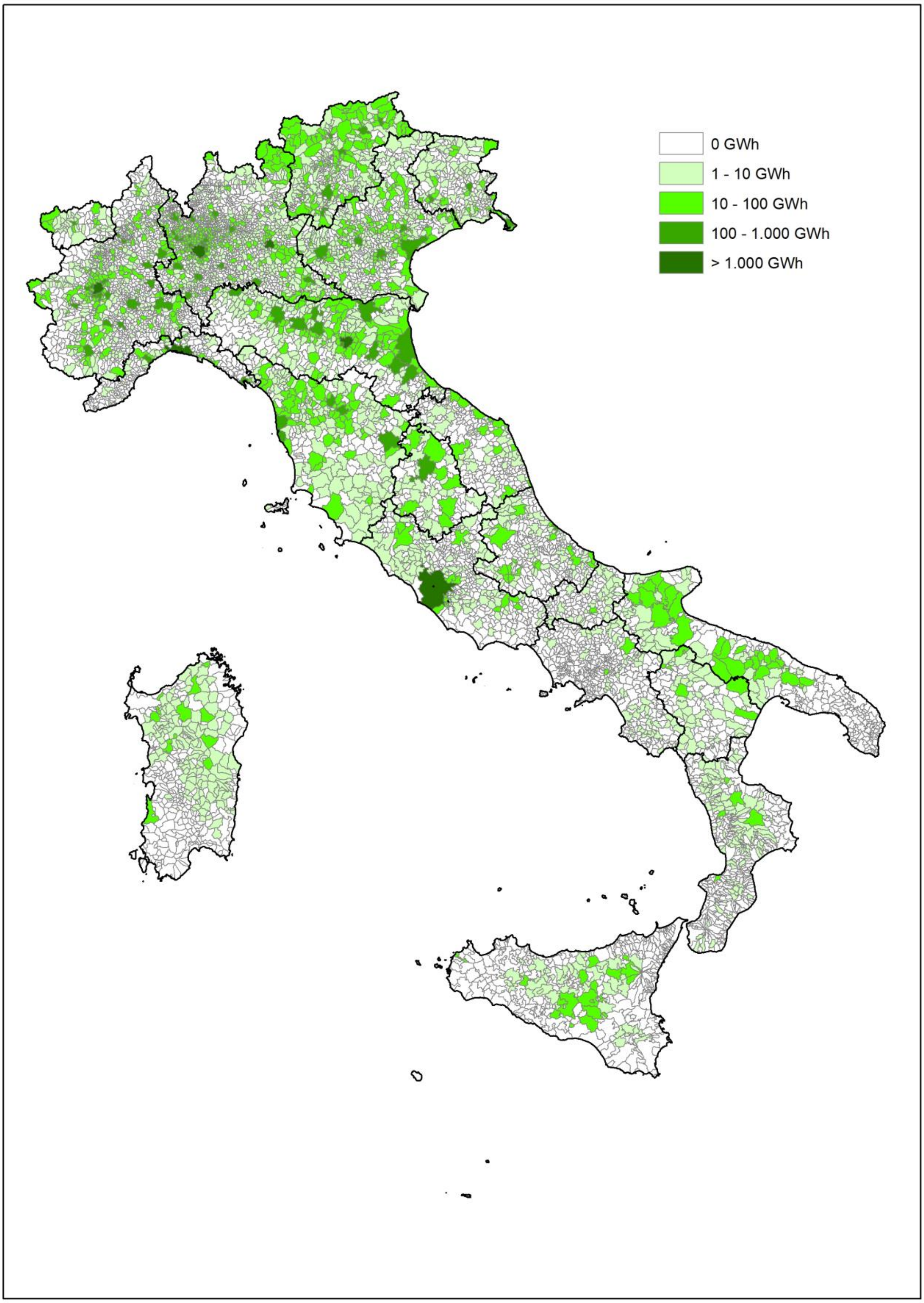
Figure 102: Energy supplied by district heating in 2018 and technical potential, broken down by Region/Autonomous Province



Piemonte	Piedmont
Valle d'A.	Valle d'Aosta
Liguria	Liguria
Lombardia	Lombardy
P.A. Bolzano	Autonomous Province of Bolzano
P.A. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli-V.G	Friuli-Venezia Giulia
Emilia-R.	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria
Marche	Marche
Lazio	Lazio
Abruzzo	Abruzzo
Molise	Molise
Campania	Campania
Puglia	Apulia
Basilicata	Basilicata
Calabria	Calabria
Sicilia	Sicily
Sardegna	Sardinia

2.875	2 875
11.257	11 257
118	118
441	441
76	76
1.941	1 941
3.706	3 706
16.712	16 712
992	992
2.439	2 439
257	257
1.702	1 702
352	352
5.024	5 024
42	42
1.829	1 829
1.101	1 101
6.596	6 596
166	166
2.839	2 839
12	12
505	505
14	14
551	551
74	74
1.725	1 725
-	-
781	781
-	-
174	174
-	-
212	212
-	-
591	591
-	-
275	275
-	-
432	432
-	-
397	397
-	-
644	644
TLR 2018	DH 2018
Potenziale tecnico TLR	Technical potential of DH

Figure 103: Map of technical potential of district heating per municipality



0 GWh	0 GWh
1 - 10 GWh	1–10 GWh

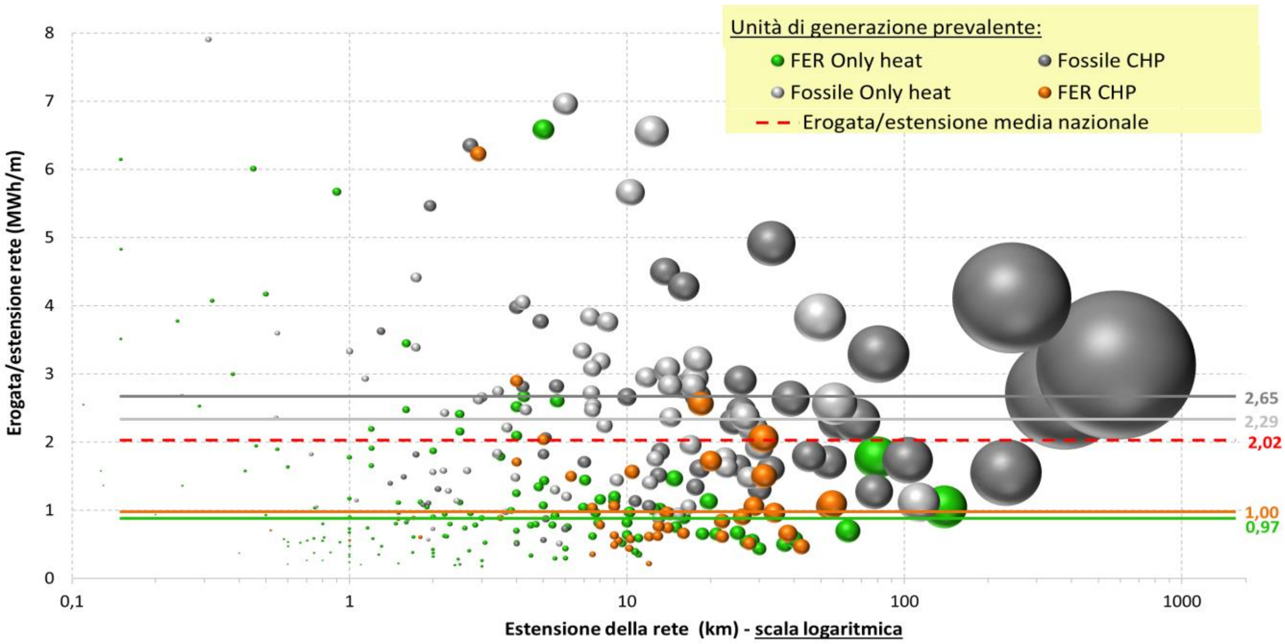
10 - 100 GWh	10–100 GWh
100 - 1.000 GWh	100–1 000 GWh
> 1.000 GWh	> 1 000 GWh

7.2.1 Linear heat density

The Linear Heat Density (LHD) is the ratio of the annual heat delivered to the total length of the DH piping and network, and makes it possible to estimate, from the heat demand that can be connected to a DH network, the length of piping that needs to be constructed.

Italian district heating networks have an average linear density of 2 MWh/m. Networks predominantly supplied by fossil fuels are generally larger and have higher linear density values (on average 2.65 MWh/m with CHP). The many small mountain networks have much lower average linear heat density values (1 MWh/m). For more details, please refer to Section 3.2.6, where a more detailed description of this parameter in Italian networks is provided.

Figure 104: Bubble graph illustrating the linear heat density of Italian networks (ordinates) as a function of the linear extent of the network (abscissae), energy supplied (bubble width) and primary power source (bubble colour)



Unità di generazione prevalente:	Principal generation unit:
FER Only heat	Renewables Heat only
Fossile Only heat	Fossil fuels Heat only
Fossile CHP	Fossil fuels CHP
FER CHP	Renewables CHP
Erogata/estensione media nazionale	National average supply/size
0	0
1	1
2	2
3	3
4	4

5	5
6	6
7	7
8	8
0,1	0.1
1	1
10	10
100	100
1000	1 000
2,65	2.65
2,29	2.29
2,02	2.02
1,00	1.00
0,97	0.97
Erogata/estensione rete (MWh/m)	Network supply/size (MWh/m)
Estensione della rate (km) - scala logaritmica	Length of network (km) – logarithmic scale

The theoretical value of linear heat density can also be calculated for built-up areas without a district heating network, by using the calculation methodology suggested by Persson[33]:

$LHD = e \cdot q \cdot w$

where:

LHD: linear heat density

e: plot ratio, i.e. the ratio of the usable area to the land area in a given territory

q: specific heat demand relative to floor area

w: 'effective width' ratio of the land area served by the network and network length, calculated on the basis of the empirical formula provided by the same author $w = 61{,}8 \cdot e^{-0{,}15}$

Linear density is one of the variables with the greatest impact on distribution costs, which decrease as this parameter increases. Where distribution costs are higher, stand-alone or central heating technologies installed in individual buildings are the most cost-effective solutions. A decision was therefore made to use linear heat density as a parameter to select the most suitable parts (i.e. the census zones) of built-up areas to be connected to district heating. Specifically, the LHD value was calculated for each census zone in areas not served by district heating networks, in order to then select for the subsequent stages of the analysis only those zones with values greater than:

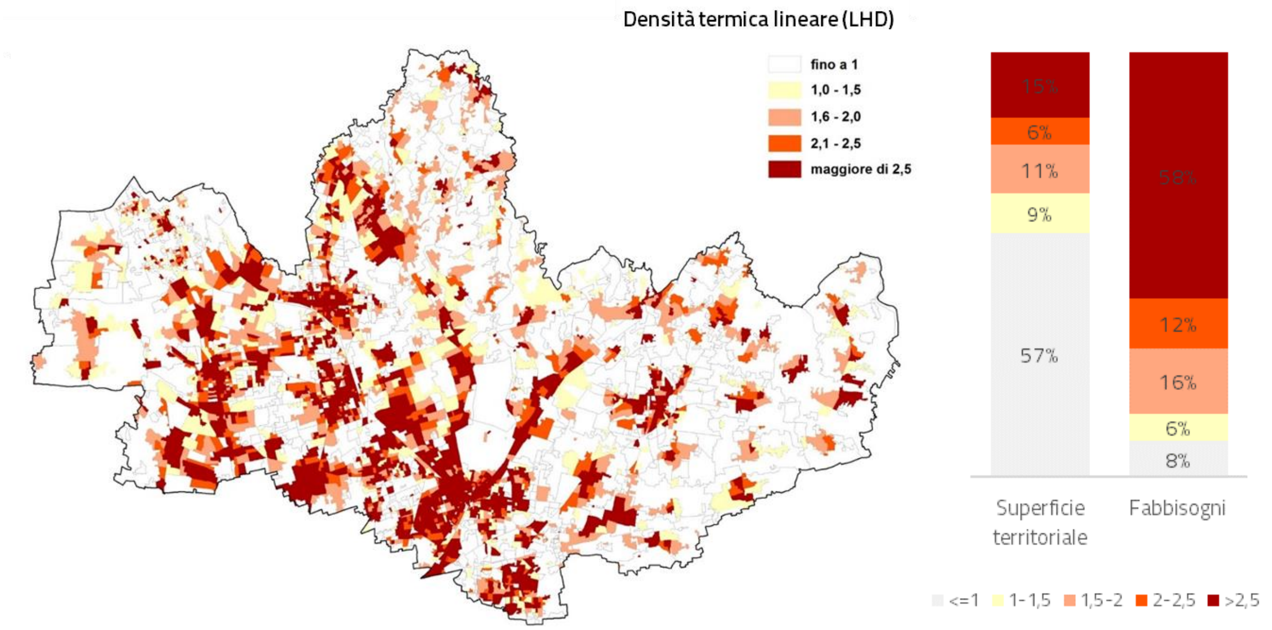
- 2 MWh/m, in areas with natural gas supply without significant renewable sources of thermal energy available;

[33] Urban Persson 'Realise the potential! Cost effective and energy efficient district heating in European urban areas', 2011.

- 1 MWh/m, in areas where (through the analyses described in Chapter 6) potential has been identified for exploitation of waste heat, geothermal energy or biomass, since the local availability of particularly valuable or low-cost sources that are difficult to use without a DH network may in some cases justify the creation of such a network, even in areas with low heat density. In addition to these areas, all areas without natural gas supply have also been taken into consideration, including those where no significant renewable energy sources were found, in which district heating could reduce the infrastructure gap.

As an example, to demonstrate the impact that selecting census zones based on linear heat density has on the technical potential of district heating, reference is made to the case involving the Province of Monza and Brianza, where the areas with a linear heat density lower than 1 represent a good 57% of the provincial land area, but only 8% of heat demand.

Figure 105: Grouping of census zones in the Province of Monza and Brianza on the basis of linear heat density



Densità termica lineare (LHD)	Linear heat density (LHD)
fino a 1	up to 1
1,0 - 1,5	1.0–1.5
1,6 - 2,0	1.6–2.0
2,1 - 2,5	2.1–2.5
maggiore di 2,5	greater than 2.5
15%	15%
6%	6%
11%	11%
9%	9%
57%	57%
Superficie territoriale	Land area
58%	58%

12%	12%
16%	16%
6%	6%
8%	8%
Fabbisogni	Demand
<=1	<=1
1-1,5	1–1.5
1,5-2	1.5–2
2-2,5	2–2.5
>2,5	>2.5

7.3 Technical potential of district heating supply

By comparing the local availability of the heat generation resources described in Chapter 6 and the technical potential of the district heating demand described in the previous section, the maximum technical potential of the district heating supply was assessed for each technology and for each municipality, without economic considerations.

The following table summarises the main results obtained nationally for the different technological sources considered when calculating the technical potential of the supply.

The sum of the technical supply potentials in this step of the analysis is higher than that of the technical demand potential (57 TWh) because a given municipality might contain several sources and technologies that could be technically developed to meet a given demand, which will be selected in the subsequent analysis of the economic potential.

Table 60: Summary of technical supply potentials for sources of district heating technology

Technology	Typical capacity
Recovery of waste heat	5.7 TWh
Geothermal energy (high, medium)	3.4 TWh
Biomass	3.3 TWh
Heat pumps	11.3 TWh
Solar power	3.7 TWh
Gas CHP	48.0 TWh
Gas boiler	13.3 TWh
LPG boiler	0.7 TWh

There is a description below of the maximum demand that can be met by each generation technology using district heating systems and the criteria used to define it.

7.3.1 Waste heat

The waste heat estimated for thermal power plants, incinerators and industrial plants, described in Chapter 6, is potentially recoverable heat that does not take into account seasonal factors, demand for district heating in the area local to the plants, or economic considerations.

In order to evaluate the quantity of waste heat that can actually be dispatched via district heating networks (technical potential for supply of WH via district heating), a matching algorithm has been developed for the total waste heat recoverable from each plant in the winter season and the district heating demand (technical potential of DH demand) in the five neighbouring municipalities within a maximum radius of 15 km. The waste heat resource is in some cases clustered in certain geographical areas (thermal power stations, industrial districts) which does not always correspond in terms of location with urban centres having a sufficiently high district heating demand to be able to absorb it (e.g. rural areas, climate zones A-B-C).

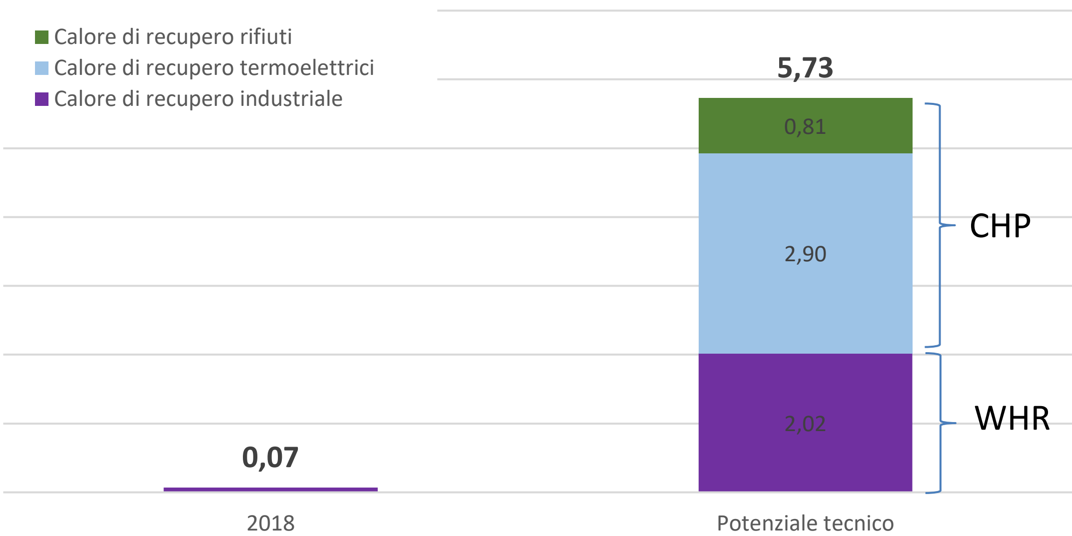
In municipalities with several waste heat plants and thus with a supply of heat in excess of demand, the plants to be activated were chosen on the basis of an economic order of merit, i.e. activating those plants with minimum costs for recovering heat as a priority.

By matching the supply and demand for waste heat, as well as quantifying the heat that could potentially be transported in the DH networks, the length of the pre-insulated transport pipes needed to connect to the DH distribution network was estimated.

Of the 67 TWh of heat recoverable from priority stationary installations, 38 TWh are likely to be recovered during the winter seasons (26 TWh in climate zones D-E-F). Of this 38 TWh, only 6 TWh could be dispatched to the municipalities local to the plants.

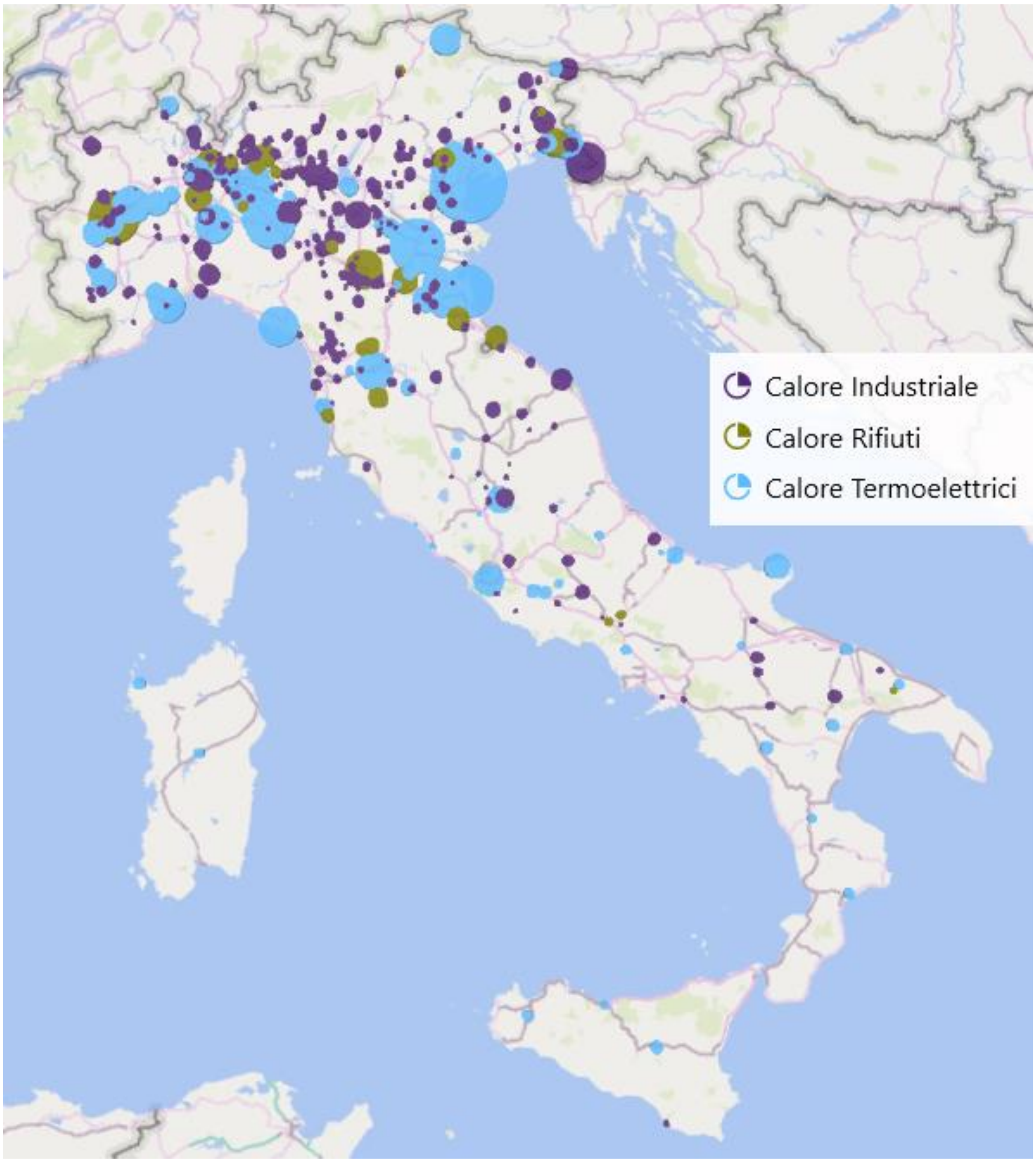
Based on the regulatory definition of waste heat (Section 6.1), only 2 TWh of the almost 6 TWh of recoverable heat, obtained from industrial installations, are accounted for in the final results as recovered waste heat, while the remaining 4 TWh, recovered from gas and waste-fuelled thermal power plants are to be considered as additional CHP heat production, from gas and waste.

Figure 106: Heat recovery in district heating networks in 2018 and technical potential



Calore di recupero rifiuti	Recovered waste heat
0.07	**0.07**
2018	2018
5.73	**5.73**
0.81	0.81
2.90	2.90
2.02	2.02
CHP	CHP
WHR	WHR
Potenziale tecnico	Technical potential

Figure 107: Technical potential map of heat recovery in district heating networks from industrial, thermal power and waste plants



Calore Industriale	Industrial heat
Calore Rifiuti	Waste heat
Calore Termoelettrici	Thermoelectric heat

7.3.2 Geothermal energy

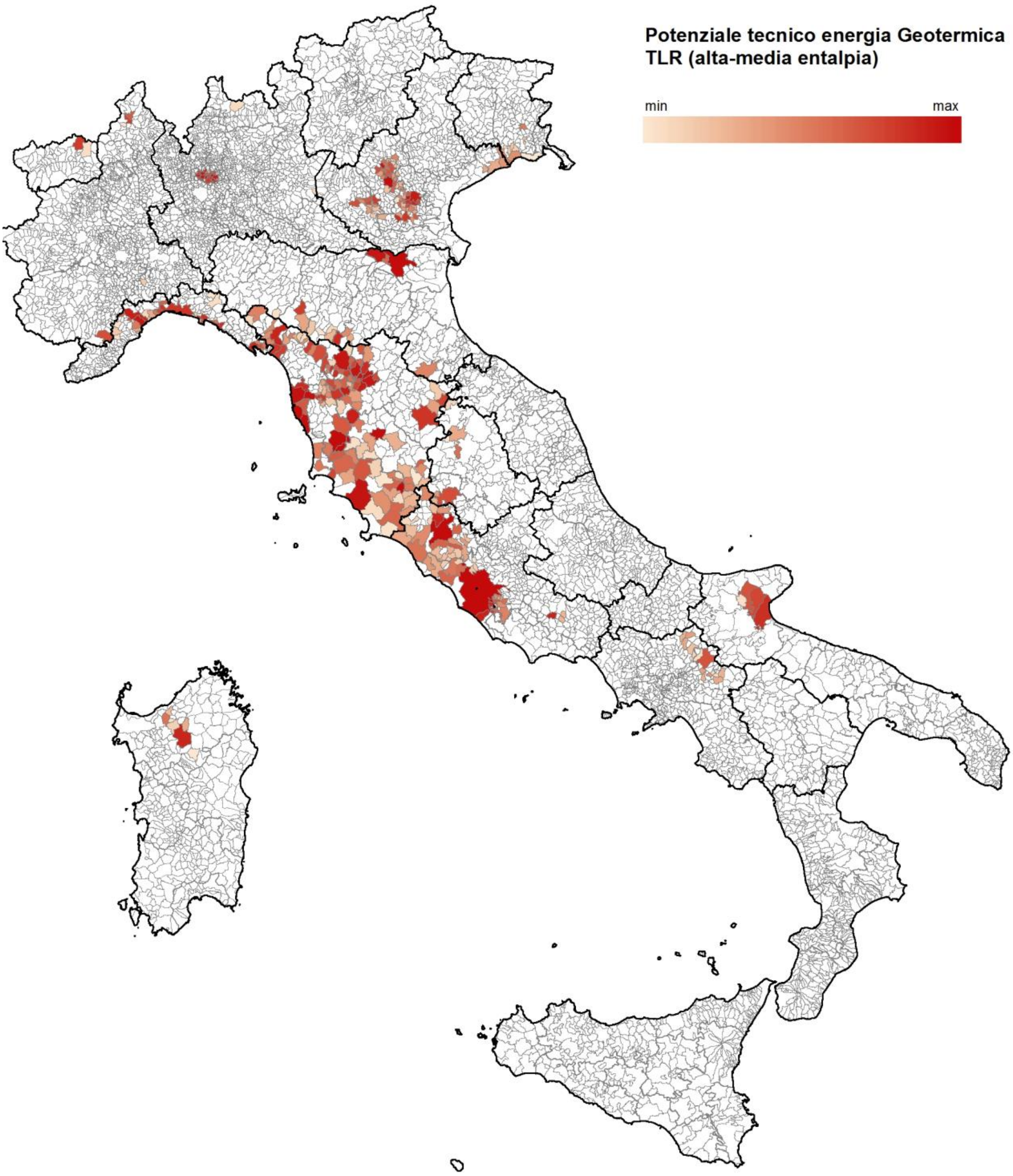
The technical potential of the energy that can be produced from geothermal sources for use in district heating systems was evaluated on the basis of the grouping of municipalities according to geothermal potential as described in Section 6.2, applying the following calculation criteria:

1. **Municipalities with high geothermal potential:** for these municipalities, the technical potential of geothermal corresponds to the district heating demand in these municipalities.

2. **Municipalities with medium geothermal potential:** the thermal energy that can be produced from geothermal sources, as estimated using the parametric function referred to in Section 6.2, was offset against existing geothermal uses and compared with the municipal district heating demand, taking the lower of the two values.
3. **Municipalities with low geothermal potential:** the estimated potential for production of geothermal heat was considered as part of the technical potential of heat pumps, which assumes that heat pumps can meet 20% of the district heating demand for each municipality, and the results of which are reported in Section 7.3.4.

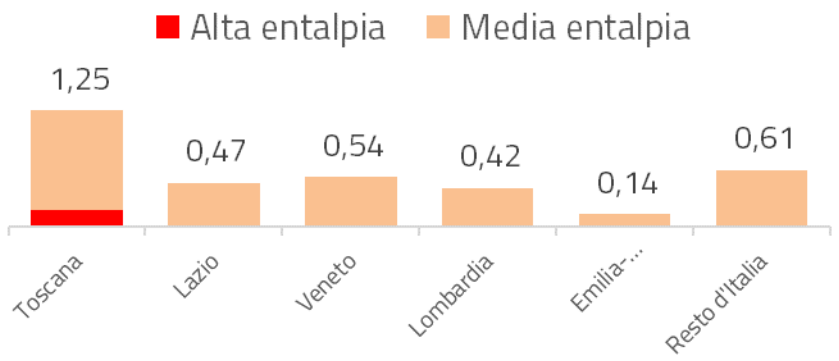
The technical potential for geothermal district heating totals 3.4 TWh, and is predominantly found in the Regions of Tuscany, Lazio and Veneto.

Figure 108: Map of technical potential for district heating from geothermal sources



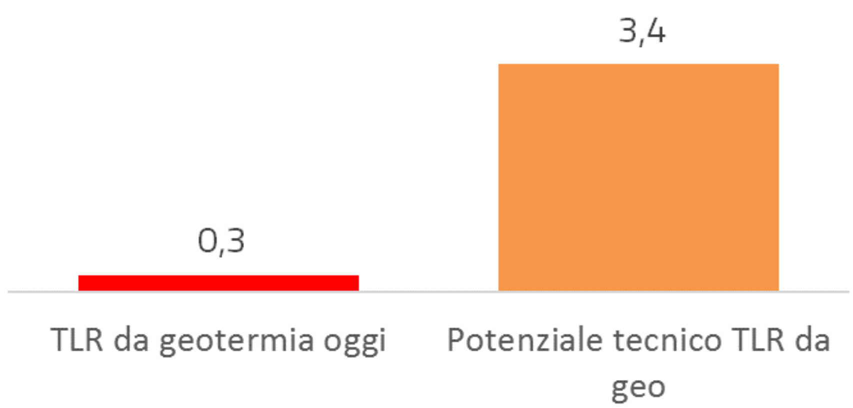
Potenziale tecnico energia Geotermica TLR (alta-media entalpia)	Technical potential of geothermal energy for DH purposes (high-medium enthalpy)
min	min
max	max

Figure 109: Technical potential for district heating from geothermal sources, broken down by Region



Alta entalpia	High enthalpy
Media entalpia	Medium enthalpy
1,25	1.25
0,47	0.47
0,54	0.54
0,42	0.42
0,14	0.14
0,61	0.61
Toscana	Tuscany
Lazio	Lazio
Veneto	Veneto
Lombardia	Lombardy
Emilia-...	Emilia-Romagna
Resto d’Italia	Rest of ITALY

Figure 110: Comparison between district heating from geothermal sources in 2018 and the technical potential (TWh)



0,3	0.3
TLR da geotermia oggi	DH from geothermal sources today
3,4	3.4
Potenziale tecnico TLR da geo	Technical potential for DH from geothermal sources

7.3.3 Biomass

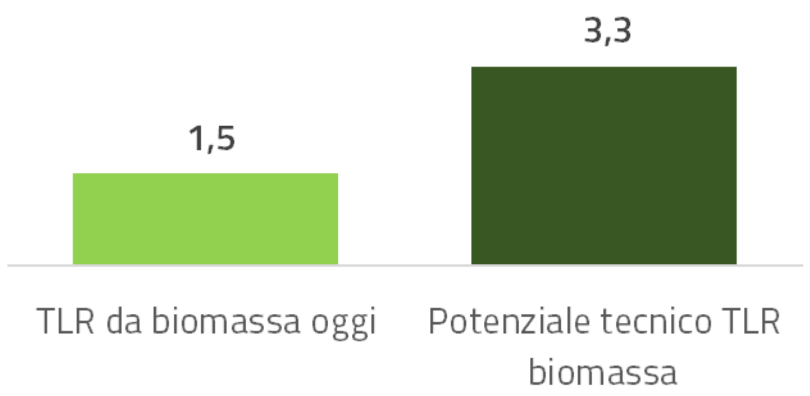
The technical potential of the energy that can be produced from biomass for use in district heating systems was evaluated on the basis of the grouping of municipalities most suitable for the use of this source that was carried out based on the IAVB index (described in Section 6.3), in order to identify those municipalities in which the exploitation and use of biomass seems more sustainable due to the availability of forest resources, existing infrastructures and geomorphological conditions which make it unlikely that air quality problems will arise.

The technical potential for biomass-fuelled district heating was therefore estimated to be equal to the district heating demand of the municipalities in the group indexed as most suitable for biomass use (IAVB>2.25). The potential for biomass-fuelled district heating totals more than 3 TWh, with a greater concentration in Alpine areas (Trentino-Alto Adige and Lombardy above all), which already have these infrastructures, as well as some potential in smaller districts scattered along the Apennine ridge.

Figure 111: Map of technical potential for district heating from biomass

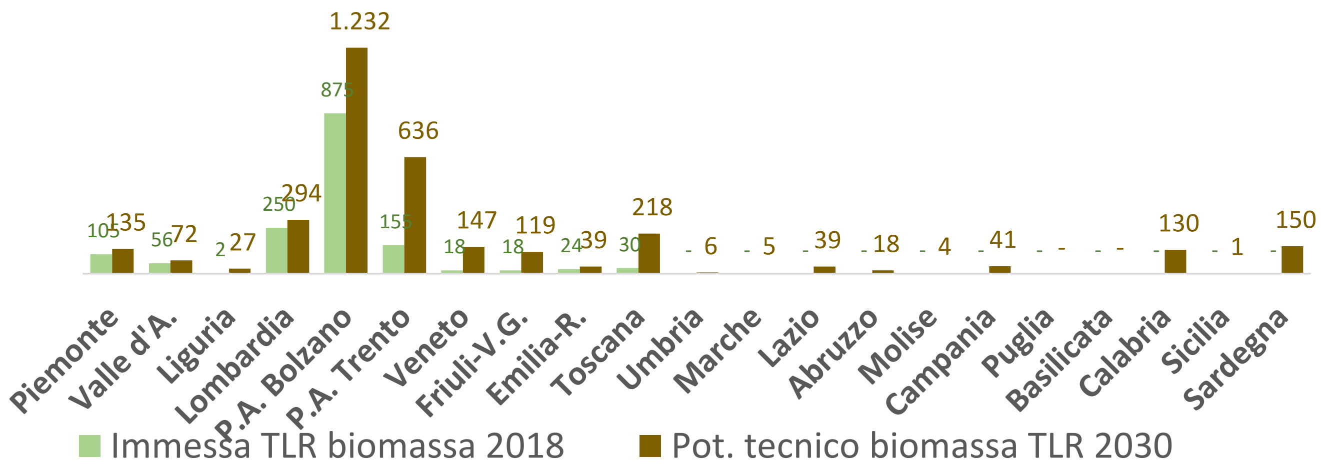
Potenziale tecnico TLR biomassa	Technical potential for biomass-fuelled district heating
min	min
max	max

Figure 112: Comparison between district heating from biomass in 2018 and the technical potential (TWh)



1,5	**1.5**
TLR da biomassa oggi	DH from biomass today
3,3	**3.3**
Potenziale tecnico TLR biomassa	Technical potential for biomass-fuelled district heating

Figure 113: Technical potential for district heating from biomass sources, broken down by Region/Autonomous Province (TWh)



Piemonte	Piedmont
Valle d'A.	Valle d'Aosta
Liguria	Liguria
Lombardia	Lombardy
P.A. Bolzano	Autonomous Province of Bolzano
P.A. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli-V.G.	Friuli-Venezia Giulia
Emilia-R.	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria
Marche	Marche

Lazio	Lazio
Abruzzo	Abruzzo
Molise	Molise
Campania	Campania
Puglia	Apulia
Basilicata	Basilicata
Calabria	Calabria
Sicilia	Sicily
Sardegna	Sardinia
105	105
135	135
56	56
72	72
2	2
27	27
250	250
294	294
875	875
1.232	1 232
155	155
636	636
18	18
147	147
18	18
119	119
25	25
39	39
30	30
218	218
6	6
5	5
39	39
18	18
4	4
41	41
130	130
1	1
150	150
Immessa TLR biomassa 2018	Biomass district heating input in 2018
Pot. tecnico biomassa TLR 2030	Technical potential for biomass-fuelled district heating in 2030

7.3.4 Other sources

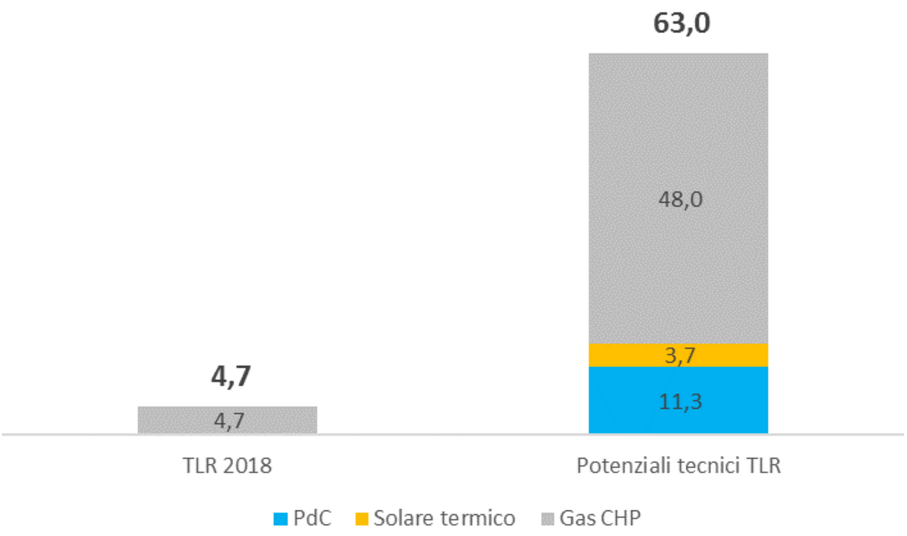
The technical potential of the other sources that could contribute to supplying the DH networks is less constrained by local energy resources and has thus been evaluated on the basis of the assumptions set out below.

Table 61: Technical potential of other sources that can help to supply DH networks

Other sources	Assumptions for calculating technical potential
Heat pumps	20% of district heating demand
Solar power	The lower value between the solar energy that can be obtained from 1/1 000th of the administrative area and 10% of the district heating demand
CHP gas	90% of district heating demand of municipalities with natural gas supply
Gas boiler	25% of district heating demand of municipalities with natural gas supply
Oil boilers	25% of district heating demand of municipalities without natural gas supply

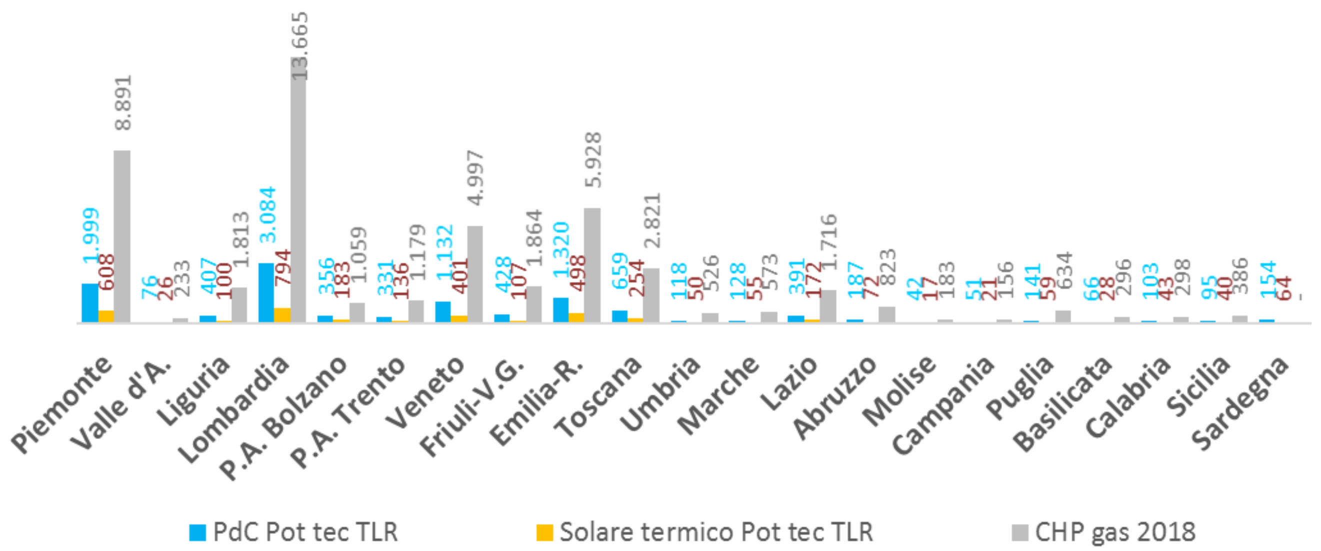
Based on these assumptions, a technical potential of 48 TWh is obtained for gas-fired CHP for district heating, 11 TWh for thermal energy that could be produced by heat pumps using different technologies (including geothermal heat pumps) and a technical potential of almost 4 TWh for solar power.

Figure 114: Technical potential for district heating from gas-fired CHP, heat pumps and solar power (TWh)



4,7	**4.7**
4,7	4.7
TLR 2018	DH 2018
63,0	**63.0**
48,0	48.0
3,7	3.7
11,3	11.3
Potenziali tecnici TLR	Technical potential of DH
PdC	Heat pumps
Solare termico	Solar power
Gas CHP	Gas CHP

Figure 115: Technical potential for district heating from gas-fired CHP, heat pumps and solar power (TWh) by Region/Autonomous Province



Piemonte	Piedmont
Valle d'A.	Valle d'Aosta
Liguria	Liguria
Lombardia	Lombardy
P.A. Bolzano	Autonomous Province of Bolzano
P.A. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli-V.G.	Friuli-Venezia Giulia
Emilia-R.	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria
Marche	Marche
Lazio	Lazio
Abruzzo	Abruzzo
Molise	Molise
Campania	Campania
Puglia	Apulia
Basilicata	Basilicata
Calabria	Calabria
Sicilia	Sicily
Sardegna	Sardinia
1.999	1 999
608	608
8.891	8 891
76	76
26	26
233	233
407	407
100	100
1.813	1 813
3.084	3 084
794	794

13.665	13 665
356	356
183	183
1.059	1 059
331	331
136	136
1.179	1 179
1.132	1 132
401	401
4.997	4 997
428	428
107	107
1.864	1 864
1.320	1 320
498	498
5.928	5 928
659	659
254	254
2.821	2 821
118	118
50	50
526	526
128	128
55	55
573	573
391	391
172	172
1.716	1 716
187	187
72	72
823	823
42	42
17	17
183	183
51	51
21	21
156	156
141	141
59	59
634	634
66	66
28	28
296	296
103	103
43	43
298	298
95	95
40	40
386	386

154	154
64	64
PdC Pot tecTLR	Heat pump tech. pot. DH
Solare termico Pot tec TLR	Solar power tech. pot. DH
CHP gas 2018	CHP gas 2018

7.4 Economic analysis of district heating

In order to determine the economic potential for developing district heating systems, it was necessary to conduct an economic analysis of the costs of district heating systems and of the alternative individual heating solutions.

In order to assess the costs of district heating, a maximum estimate was made for the DH infrastructure that would need to be constructed to meet district heating demand, defining the main technical parameters thereof, which would be used to evaluate the investment and operating costs of the networks.

7.4.1 Costs of generating heat using individual technologies

The costs of generating heat using individual solutions are a very important benchmark for district heating systems which need to offer competitive tariffs in order to attract new users with stand-alone or centralised heating systems that are not connected to the network.
The unit generation costs of different technologies have been calculated with reference to single-family users where more robust and homogeneous cost data is available and which can in any case be considered sufficiently representative of the unit generation costs of centralised systems[34].
The generation costs were therefore calculated on the basis of the current market value of the technologies (obtained by GSE for incentive applications), the existing benefits for investors (tax deductions) and the current final prices of energy products consumed for heat production.

Table 62: Costs of individual heat generation technologies

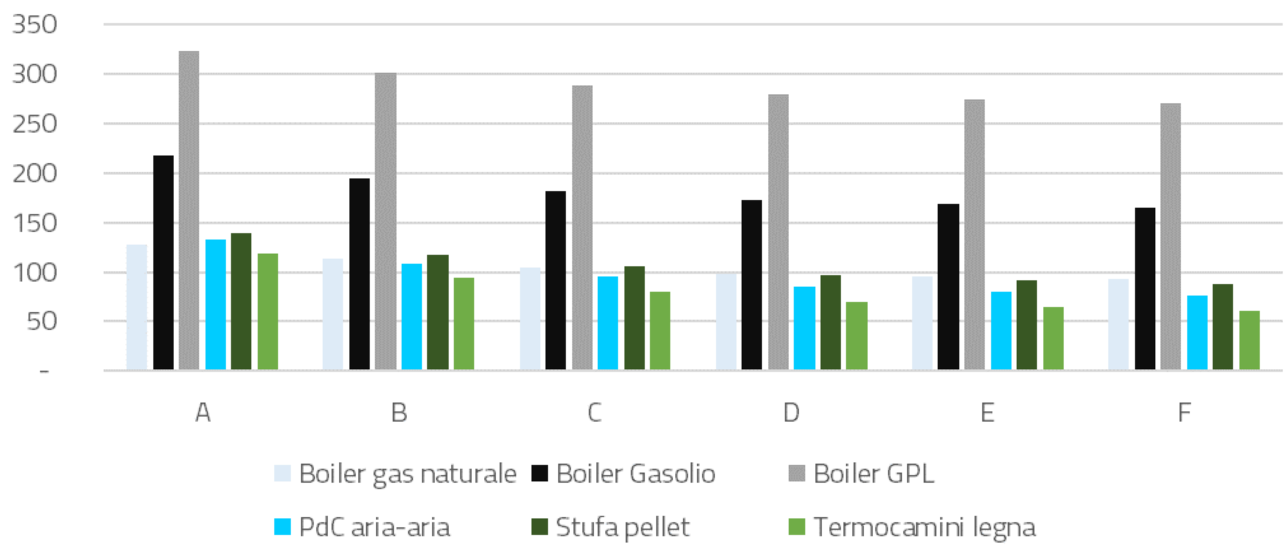
Technology	Plant cost [€]	O&M cost [€/year]	Useful life [y]	Efficiency [%]	Cost of energy consumed [€/MWh]
Gas boiler	1 400	70	15	95%	80
Diesel boiler	1 400	70	15	85%	129
LPG boiler	1 400	70	15	90%	233
Heat pumps	4 500	70	15	3.50	219

[34] Theoretically lower due to economies of scale and cost sharing between owners, but in some cases partly offset by less prudent management, greater distribution losses and higher management costs (for example accounting).

Pellet stove	2 700	70	15	80%	61
Wood-burning fireplaces	3 200	70	15	80%	38

Unit generation costs vary significantly on a geographical basis, depending on the climate zones that determine energy needs and hours of operation. In the warmer parts of the country, the shorter winter season has a serious impact on the competitiveness of technologies with higher investment costs, even if they in some cases offer better energy performance and lower operating costs.

Figure 116: LCOH (levelised cost of heat) for different individual technologies by climate zone (€/MWh)



350	350
300	300
250	250
200	200
150	150
100	100
50	50
A	A
-	-
B	B
C	C
D	D
E	E
F	F
Boiler gas naturale	Natural gas boiler
PdC aria-aria	Air-to-air heat pump
Boiler Gasolio	Diesel boiler
Stufa pellet	Pellet stove
Boiler GPL	LPG boiler
Termocamini legna	Wood-burning fireplaces

7.4.2 Costs of heat distribution for DH

Based on the incremental technical potential of each municipality, i.e. the technical potential minus the energy already supplied by existing infrastructures, estimates were drawn up regarding the size of the new district heating infrastructures needed to transport the heat to new users, and the associated investment and operational costs, which are composed of several components, were calculated as follows:

$CAPEX_{DH\ infr} = C_{tub} + C_{ss} + C_{acc}$

$OPEX_{DH\ infr} = C_{o\&m\ netw} + C_{pump}$

C_{tub}: investment cost of pipes

C_{ss}: investment cost of substations

C_{acc}: investment cost of accessories

$C_{o\&m\ netw}$: cost of operating and maintaining the network

C_{pump}: pumping costs

The different cost components set out above have been calculated on the basis of an extensive survey of the literature data in the district heating sector and the operating data of existing DH networks, and also with the help of a number of parametric formulas developed for Italy by the Polytechnic University of Milan in collaboration with AIRU.

The largest portion of the heat distribution costs is represented by the investment costs for constructing and laying the pipes needed to transport the heat. The specific cost of constructing the networks (€/km) is closely linked to the diameter of the pipeline to be laid and has been assessed using the following parametric formula (source HeatRoadMap Europe 2019):

$C_{tub}\ [€] = L_{incr}\ Cl_{in}$

$Cl_{in}\ [€/m] = C_1 + C_2\ D_m$

Cl_{in} specific cost per unit of length

C_1 and C_2 are two cost parameters that can be obtained from the following table as a function of the level of housing density in the area in question, evaluated using the plot ratio variable (ratio of usable area to the land area in a given territory)[35].

Table 63: Cost components C1 and C2 as a function of plot ratio

Urban area	Plot ratio E [%]	C1 [€/m]	C2 [€/m²]
Inner city areas	>0.5	286	2 022

[35] Urban Persson 'Realise the potential! Cost effective and energy efficient district heating in European urban areas', 2011.

Outer city areas	0.3-0.5	214	1 725
Park areas	<0.3	151	1 378

D_m: average pipe diameter

The average diameter of the pipes was evaluated using the following parametric formula (source: Heat Roadmap Europe[36]):

D_m *[m] = 0.0486 LN (LHD) + 0.0007*

LHD: linear heat density

The incremental length of the network to which the linear costs apply was calculated using the ratio of incremental technical potential to the linear heat density (LHD) characteristic of the municipality, assessed as follows:

- for municipalities that already have district heating, the linear density value recorded on the networks was used (ratio of annual energy supplied to network length);
- for municipalities without district heating networks, the average theoretical linear density (calculated using the Persson formula, see Section 7.2.1) of the census zones of the municipality with characteristics favourable to district heating was used.

As regards the cost per unit of power of utility substations, the parametric formula for calculating the costs per unit of power of substations developed by the Polytechnic University of Milan on the basis of AIRU data was used.

C_Q *[€/kW] = 2 389* $Q^{0.715}$ *with 25 <* C_Q *< 145*

Q: average substation power

The average power of the substations was calculated for municipalities with district heating on the basis of data collected by GSE for statistical monitoring of the DH sector, while the sector average was used for municipalities without district heating.
Ancillary costs (inclusive of connecting pipework, 'special' components such as inspection pits, connections, etc.) and design costs were considered to be 20% of the total network investment costs.
As regards operating costs, reference was made to the network operating costs provided in the JRC guidelines[37] of

- 250 €/TJ for the operation and maintenance of the network;
- 1.5 €/kW for the operation and maintenance of substations.

Consumption for pumping has been drawn from the electricity consumption of the district heating networks in operation, setting a benchmark for electricity consumption for pumping of 2.6% of the thermal energy fed into

[36] https://www.sciencedirect.com/science/article/pii/S0360544219306097#fig2
[37] JRC 'Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level', 2015

the network, to which the final price of electricity in Italy of 140.8 €/MWh (final price without VAT applicable to the 2-20 GWh consumption range) has been applied, obtained from Eurostat statistics.

For municipalities with district heating, the network losses were considered to be the same as those recorded in networks operating in those municipalities (source: GSE DH statistics for 2018), while for municipalities without district heating the sector average of 17% was used.

Useful life was considered to be 30 years for networks and 15 years for utility substations. The discount rate of the investment in the networks was set at 5%. The average network costs calculated for incremental technical potential are summarised in the following table, expressed as specific distribution cost, i.e. the cost per unit of heat supplied by the network.

Table 64: DH distribution costs broken down into main components

Specific cost of pipelines [€/MWh]	Specific cost of substations [€/MWh]	Specific cost of accessories [€/MWh]	Operative cost of pumping [€/MWh]	Network O&M costs [€/MWh]	Total distribution cost [€/MWh]
8.1	5.2	2.3	3.7	2.4	**21.7**

7.4.3 Costs of generating heat for district heating

The costs of generating heat to supply district heating networks were worked out by creating a catalogue of heat generation technologies. To this end, a series of cost data from a variety of sources was obtained and processed: the costs reported to the GSE by operators as part of applications for incentives, data relating to technology costs acquired from RSE studies, data obtained by trade associations through consultation and data from sector literature.
Although an attempt has been made to estimate costs that are as representative as possible of reality in Italy, the strong dependence on site-specific conditions and the fact that the data are not always exhaustive means that these economic data must be considered as indicative and not always representative of all applications, which in some cases may differ significantly from what is set out below:

Table 65: Catalogue of costs of the main technologies used to produce heat to be fed into district heating networks

Technology	Typical capacity	Details of technology considered	Investment costs [€/kW]	O&M [€/kW year]	useful life [years]
Biomass boilers	0.5–5 MW	Biomass boiler	400	16	15
Biomass ORC	0.5–5 MW	ORC	5 500	300	15
Solar power[38]	>500 m^2	Forced circulation solar system	400	4	20

[38] Investment and O&M costs are expressed for this technology in €/m^2 instead of €/kW.

Industrial WH[39]	0.5–40 MW	GVR, Exchangers, heat pumps and DH connection	1 000	20	20
WH-CHP incinerators[8]	0.5–40 MW	CHP retrofit interventions + DH connection	400	10	20
Thermoelectric WH-CHP[8]	0.5–70 MW	CHP retrofit interventions + DH connection	650	15	20
CHP new gases	5 MW	ICE CHP	700	30	15
Gas boiler	0.5–5 MW	Gas boiler	125	9	15
Oil boilers	0.5–5 MW	LPG boiler	125	9	15
High-enthalpy geothermal	0.5–5 MW	Open-loop geothermal	580	23	20
Medium-enthalpy geothermal	0.5–5 MW	Closed-loop geothermal	1 100	44	20
Heat pumps (Hydro, geo)	0.5–5 MW	Water-to-water and extraction heat pumps	500	10	15

In addition to the costs for constructing and managing the system mentioned above, the costs of energy carriers must also be taken into account, for which the values shown in the table below were used.

Table 66: Commodity prices used in the economic analysis of DH networks

Energy carrier	Type of price	Source (year)	Value (2019) [€/MWh]
Natural gas	Final price excl. VAT + gen. ele. ancillary costs	Eurostat (2019) 100-1 000 PJ	25.1
Light fuel oil	Final price excl. VAT	MISE (Light fuel oil – 2019)	106.6
Wood chips	Final price excl. VAT	AIEL (average 2013-2017)	19.6
Waste	Final price excl. VAT	hp in other production chain	-
Electricity	Final price excl. VAT	Eurostat (2019) 2 000-20 000 MWh	140.8

The technical parameters used to simulate plant operation and calculate energy input and output are average values taken from the operating data of HE CHP plants connected to district heating networks and indicative conventional efficiencies for boilers and heat pumps.

Table 67: List of technical parameters by technology

[39] Investment and O&M costs include the average connection costs needed to connect the industrial site to the urban centre as a result of matching supply and demand.

Technology	H/E	$\eta_{el\ CHP}$(%)	$\eta_{el\ no\ CHP}$ (%)	Echp/E	η_H
ICE large capacity	0.94	40%	40%	96%	
ICE small capacity	1.37	33%	33%	94%	
ORC biomass	4.17	15%	15%	43%	
CCGT	0.94	41%	58%	38%	
Waste	3.2	19%	30%	36%	
Gas boiler					92%
Oil boiler					85%
Biomass boiler					85%
Heat pumps					3.5

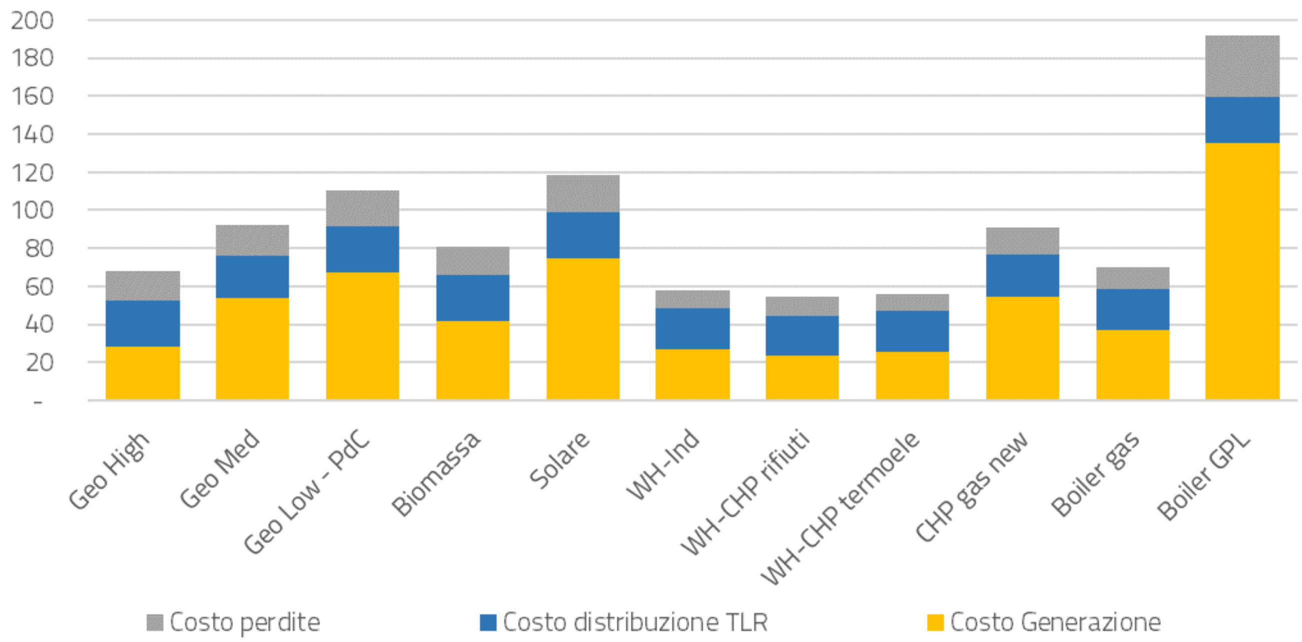
The total costs of heat sold via DH can ultimately be broken down into three components:

- *generation*: the cost of generating heat due to the costs of investment, O&M and the commodities consumed in heat generation plants. For cogeneration plants to be built from scratch, in order to divide the costs between thermal and electrical output, the cost attributable to heat production was calculated as the difference between the total costs of the plant and the economic valuation of electrical output at current wholesale market prices. For waste heat recovery plants, the investment and O&M costs have been attributed to heat production only, plus any costs for electricity consumption for heat pumps and pumping and, in the case of thermal power plants, the loss of revenue due to the reduced electricity generation[40];
- *distribution*: the costs of the construction and operational management of transport infrastructure;
- *network losses*: to which some additional generation and distribution costs can be attributed, compared to those necessary to meet heat demand.

Generation costs are generally lower than for individual solutions, in particular due to lower energy carrier costs, which are also significantly impacted by pricing and tax policies. This margin is partly offset and, in some cases, exceeded by infrastructure costs and higher losses.
All costs are highly variable and site specific: they tend to decrease in colder climate zones where the increase in operating hours reduces the impact of investment costs, and with increased urbanisation, where more heat is distributed along the same pipework length.

[40] It is assumed that retrofitting work to increase waste heat takes place mainly in the country's large power plants, generally CCGT or steam plants, and that the plants operate at the same level of consumption. Consequently, the increase in heat recovery from spillage or back pressure results in a loss of electricity production, which can be assessed using the factor β set at 20% on the basis of the operating data recorded in HE CHP plants.

Figure 117: LCOH (levelised cost of heat) for different technologies (€/MWh)



200	200
180	180
160	160
140	140
120	120
100	100
80	80
60	60
40	40
20	20
-	-
Geo High	Geo high
Geo Med	Geo med
Geo Low - PdC	Geo low – heat pump
Biomassa	Biomass
Solare	Solar power
WH - Ind	WH – ind.
WH - CHP rifiuti	WH – CHP waste
WH - CHP termoele	WH – CHP thermoele.
CHP gas new	CHP new gases
Boiler gas	Gas boiler
Boiler GPL	LPG boiler
Costo perdite	Cost of losses
Costo distribuzione TLR	DH distribution cost
Costo Generazione	Generation cost

On the basis of the unit costs of heat generation, the mix of sources capable of meeting the incremental district heating demand for each municipality at minimum cost was selected on economic merit. In municipalities where the supply of sources exceeded demand, the most expensive technologies were thus not taken into account in the business plan for the potential DH network.

Based on the incremental district heating demand met by each technology, the thermal capacity to be installed to produce the required energy was calculated taking into account network losses and the equivalent hours of operation, assumed to be equal to the heating hours set out in Presidential Decree No 412 of 26 August 1993 for the different climate zones. For each municipality, the basic thermal power needed to meet heat demand was always supplemented by an additional and reserve thermal capacity from gas or oil boilers (depending on whether or not the municipality has a gas supply), the amount of which was calculated using a peak factor of 1.3 times the average thermal capacity.

In order to meet the efficiency requirements of the district heating networks, it is assumed that the heat generated by the integration boilers could not exceed 25% of the thermal energy fed into DH networks. Electricity production was defined on the basis of the technology-specific H/E ratio and, in the case of waste heat recovered from thermal power plants or waste, the lost electricity production associated with increased recovered heat was taken into account, based on a factor β of 20%.

On the basis of what has been described, the main parameters that characterise the DH network and the plants for supplying it (length of networks, pipe diameter, plant capacity, mix of technologies) have been calculated, and can also be used to determine the investment costs and all the energy inputs and outputs used to formulate the management costs which are taken into account when determining the cash flows, on the basis of which the economic potential described in Section 7.5 was established.

7.4.4 Revenue from energy sales and DH incentives

In addition to the costs described above, revenue was also assessed for each potential network that could be developed for each municipality. Revenue is derived from the sale of the heat and electricity produced by the plants, which were valued as follows:

- it was assumed that electricity would be sold wholesale at a price in line with current market values (Single National Price in 2019: 53 €/MWh);
- it was assumed that heat would be retailed at a price linked to the heat generation costs of the individual solution (95 €/MWh, which corresponds to the LCOH for a gas boiler in zone E with 95% efficiency, and to a fuel cost commensurate with the final price of gas, including taxes, in 2019).

All existing policies supporting the sector have also been considered in the financial analysis:

- tax credit: granting of a tax credit of 21.94 €/MWh for each unit of heat supplied from geothermal or biomass sources. The value of the benefit was incorporated in the sale price to the end user;
- reduced excise duties on natural gas: on gas consumed for heat production in district heating networks mostly fuelled by CHP, excise duties were considered for electricity production rather than civil production;
- VAT reduced to 10% on the sale of heat:
- tax deductions for constructing utility substations;

- o White Certificates: the issuing of Energy Efficiency Certificates for electricity and heat production in cogeneration mode was assessed according to the rules set out in the Ministerial Decree of 5 September 2011; in the case of heat produced from renewables, the certificates issued were assessed in accordance with Decree Law No 34/2019 and the related operational clarifications published by GSE, assuming a market price of White Certificates of EUR 260 in both cases.

7.5 Economic and financial potential of district heating

After characterising the technical and economic parameters for the development of efficient district heating infrastructure, the analysis turned to assessment of the cost-effectiveness of the proposed projects from an investment point of view, going on to determine the economic and financial potential of district heating under current market and regulatory conditions. The assessment of the economic potential of the system, which identifies a way of developing district heating which ensures that the energy and climate targets set out in the INECP are reached while minimising the overall system costs, can be found in Chapter 9.

7.5.1 Methodology and interpretation of results

The economic and financial analysis, carried out on a municipal scale, verified the economic feasibility of the investments, assessing the costs and revenue arising from development and operation of the network and power stations for a potential investor, assuming the sale price to the final customer to be in line with the marginal cost of heat production, which is taken to be equal to the cost of generation by a natural gas boiler.

The economic feasibility of the initiatives was analysed on the basis of the Net Present Value (NPV) of each network, covering an assessment period of 30 years.

A weighted average cost of capital (WACC) of 5% was used to calculate the NPV. The financial and economic potential was obtained by limiting the technical potential to initiatives with a positive NPV. Moreover, a cost-effectiveness percentage was also established for each initiative based on the internal rate of return (IRR). For projects with an IRR greater than 15%, the entire technical potential identified was assumed to be cost effective. For projects with an IRR below the minimum acceptability threshold (hurdle rate), the economic potential was considered to be nil. The hurdle rate was set at 7%. In cases with an IRR between the hurdle rate and the 15% threshold, the share of cost-effectiveness was determined in a proportional manner.

Since the revenues from district heating networks have been set on the basis of the costs of generating heat in the residential sector with conventional solutions, the assessment of the cost-effectiveness for investors can be used at least partly to assess cost-effectiveness for final users[41].

The results of the analysis must be interpreted as providing an overview and are useful for identifying the most cost effective initiatives through a comparative assessment. The assessment of individual investments requires specific feasibility assessments that factor in the features of each investment and site-specific aspects that cannot be considered adequately by large-scale analysis.

The assessment of the economic potential of DH was supplemented by an assessment of the environmental benefits, such as reducing greenhouse gas emissions and primary energy savings, linked to its development.

7.5.2 Economic and financial potential of DH – the results

The economic and financial potential of efficient DH under current market and regulatory conditions is estimated at 21 TWh of delivered thermal energy. This potential represents double the quantity of energy currently delivered to the networks (11.2 TWh incremental potential), an extension of DH networks of around 3 700 km (+77% compared to 2018) and an increase in the municipal volume connected to the network of 340 mln m^3 (+93% compared to 2018).

Regarding technologies that minimise supply costs for investors, district heating potential is mainly driven by HE CHP gas technologies which account for 11 TWh, or 52%, of this potential, an increase of 40% on the current share. This HE CHP gas potential also includes 1.6 TWh (about 15%) of useful heat recovered through retrofits and changes in configuration to increase the share of cogenerated energy produced by existing plants that currently dissipate this energy as waste heat[42]. From a financial and economic point of view, the use of gas boilers continues to offer rather competitive generation costs due to the reduced costs of plant investment and the favourable gas prices granted in the district heating sector when working in conjunction with HE CHP plants[43]. This technology accounts for 23% of the networks' economic potential (levels in line with the current 24%), thus almost covering the restriction imposed for non-CHP network efficiency requirements, assumed to be 25%[44].

Bioenergy used in district heating can continue to play an important role in the sector, increasing its contribution from 2 TWh to 3 TWh. In particular, biomass is economically favoured in mountainous areas, especially where there

[41] This consideration is only partly valid, as district heating does not compete with all efficient heat supply technologies (for example heat pumps and photovoltaics), but rather only conventional ones.

[42] Mostly at the capacitor at temperatures close to the ambient temperature, as they are designed to maximise electricity production.

[43] For cogeneration district heating, if the energy and electrical capacity are at least 10% of the total energy and thermal capacity, all fuel that is not subject to excise duty on electricity, including that used in integration/back-up boilers, is subject to industrial excise duty rather than civil excise duty.

[44] for the purposes of the study, a stricter maximum development threshold for fossil fuel boilers was applied than is currently envisioned for efficient district heating. This value can be as high as 49% in cases where the district heating is partly fuelled by renewables or waste heat.

is no natural gas supply[45], also thanks to the tax credit measure that helps to improve the economic results of this solution in locations with low population density and higher infrastructure costs. The thermal generation costs of biomass plants with heat production alone were lower than those of cogeneration plants (ORC technology) and consequently development is more focused on this type of technology than the other, which has undergone considerable development in the past, including because of rather profitable incentives in the electrical sector. The increase in the use of biomass for heat production alone was achieved in particular by limiting the development thereof to areas most suitable for this type of technology (due to availability of resources, geomorphology that limits air quality problems, etc.), and could be accomplished without further felling of forest biomass when replacing inefficient individual biomass systems.

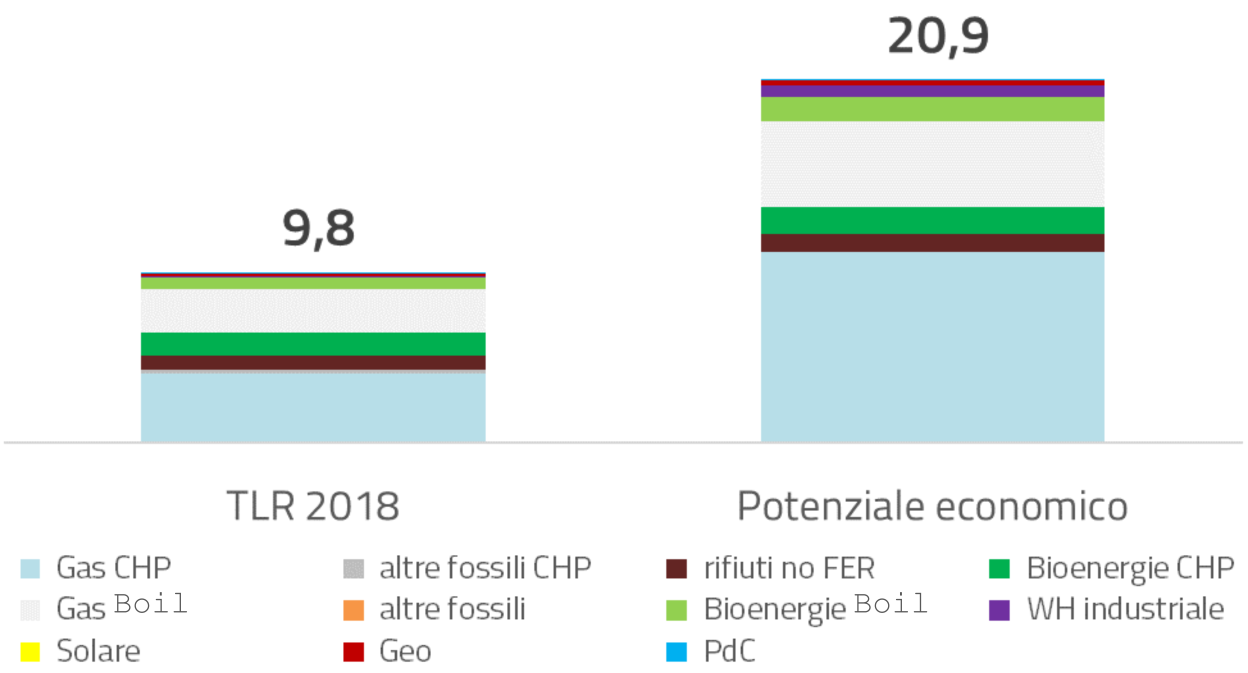
Regarding increased heat recovery, as well as the 1.6 TWh of recovered heat credited to gas CHP potential, an additional 0.4 TWh of heat can be recovered by increasing cogeneration in waste incineration plants[46] and 0.7 TWh of industrial waste heat can be recovered by heat exchangers, GVRs and heat pumps from the process waste heat estimated to be dissipated currently. The numbers of these types of heat recovery measures are therefore highly relevant. The economic viability of individual recovery projects, in addition to the possibility of matching supply and demand, is determined by the cost of the different recovery technologies, the length of connections required to link to the DH network and the amount of recoverable heat.

Medium- and high-enthalpy geothermal energy increases from 0.2 TWh to 0.3 TWh: only a small share of its potential can be developed, because in several areas with geothermal potential, the overall costs of a district heating system remain high. Solar power and heat pumps (including low-enthalpy geothermal and hydrothermal pumps) have not demonstrated any appreciable financial potential, on the basis of current costs and support measures, as other solutions meeting the efficiency requirements of DH networks involve lower costs and are preferred. Heat pumps and solar power in any case remain key solutions for decarbonising the heating sector, mainly with individual systems, as better described in Chapter 9.

From a geographical point of view, 95% of the economic potential of district heating is confirmed to be located in northern Italy, in line with the current share and a more significant majority than for technical potential, which also showed considerable scope for development along the Apennine ridge and in the big urban centres of central Italy in zone D. The economic and financial potential is highly concentrated in two Regions, Lombardy and Piedmont, 60% of the national total. The most significant growth margins for district heating are found in Lombardy (32% of the incremental economic potential), Piedmont (19%), Veneto and Emilia-Romagna (both 11%) and the Autonomous Province of Trento (9%).

[45] This is also due to the lack of competition with gas CHP solutions.
[46] 0.2 TWh was credited to bioenergy CHP and 0.2 TWh to non-renewable waste CHP.

Figure 118: Energy supplied by district heating in 2018 and its economic and financial potential by 2030 [TWh]



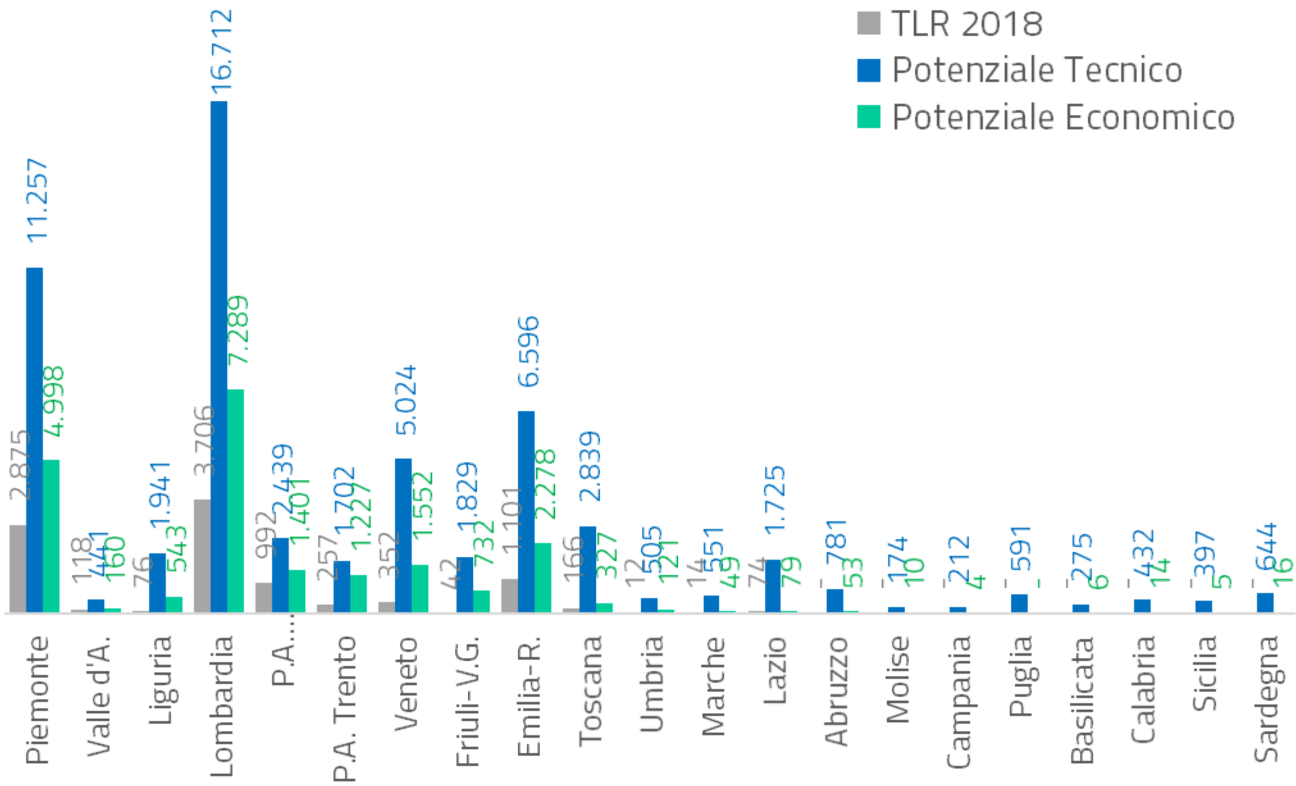
9,8	**9.8**
TLR 2018	DH 2018
Gas CHP	Gas CHP
Gas Boil	Gas boiler
Solare	Solar power
altre fossili CHP	Other fossil fuels CHP
altre fossili	Other fossil fuels
Geo	Geo
20,9	**20.9**
Potenziale economico	Economic potential
rifiuti no FER	Non-renewable waste
Bioenergie Boil	Bioenergy boiler
PdC	Heat pumps
Bioenergie CHP	Bioenergy CHP
WH industriale	Industrial WH

Table 68: Energy supplied by district heating in 2018 and its economic and financial potential by 2030 [TWh]

Technology	DH supplied 2018 [TWh]	DH supplied Economic and financial potential [TWh]
Natural gas CHP	4.0	11.0

Natural gas boiler	2.5	4.9
Bioenergy CHP and boiler	2.0	3.0
Non-renewable waste CHP	0.8	1.0
Other fossil fuels CHP and boiler	0.3	-
Direct-use geothermal	0.2	0.3
Industrial waste heat	0.1	0.7
Heat pumps	0.0	0.0
Solar power	0.0	0.0
Total DH	**9.8**	**20.9**

Figure 119: Energy supplied by district heating in 2018 and technical and economic and financial potential by 2030, broken down by Region/Autonomous Province [TWh]

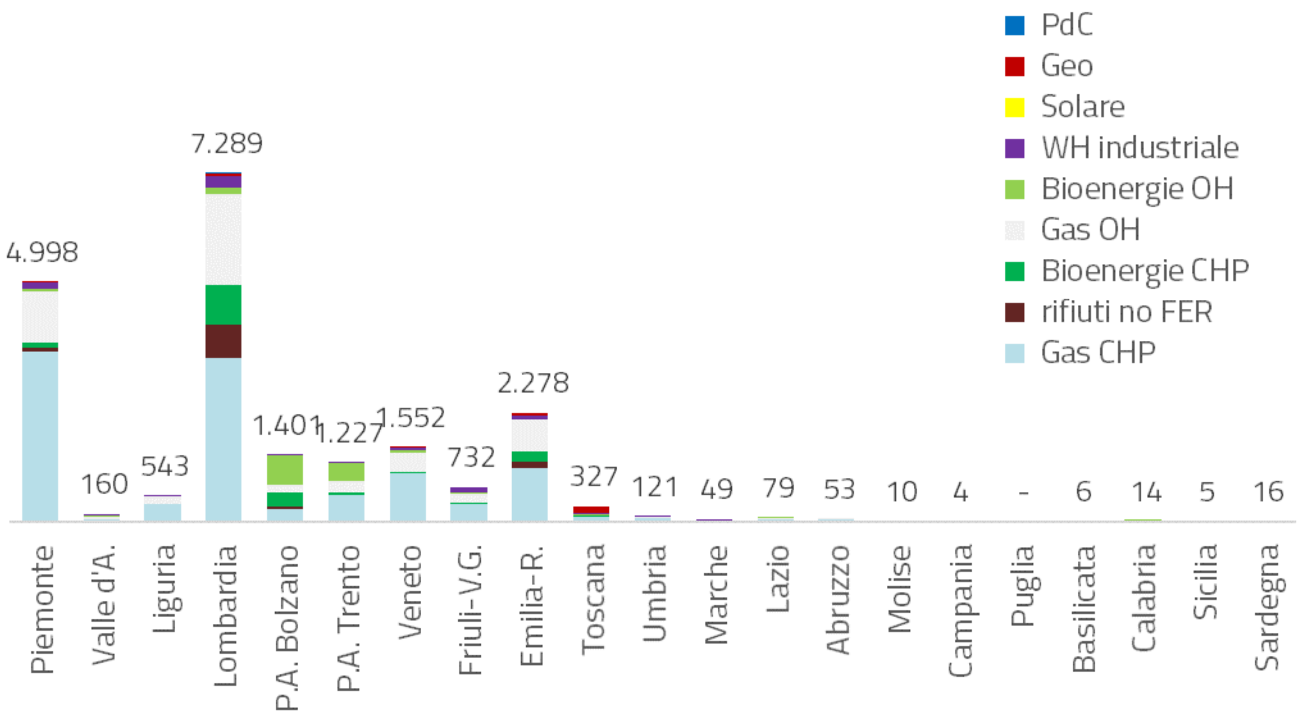


Piemonte	Piedmont
Valle d'A.	Valle d’Aosta
Liguria	Liguria
Lombardia	Lombardy
P.A.....	Autonomous Province of Bolzano
P.A. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli-V.G.	Friuli-Venezia Giulia
Emilia-R.	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria

Marche	Marche
Lazio	Lazio
Abruzzo	Abruzzo
Molise	Molise
Campania	Campania
Puglia	Apulia
Basilicata	Basilicata
Calabria	Calabria
Sicilia	Sicily
Sardegna	Sardinia
2.875	2 875
11.257	11 257
4.998	4 998
118	118
441	441
160	160
76	76
1.941	1 941
543	543
3.706	3 706
16.712	16 712
7.289	7 289
992	992
2.439	2 439
1.401	1 401
257	257
1.702	1 702
1.227	1 227
352	352
5.024	5 024
1.552	1 552
42	42
1.829	1 829
732	732
1.101	1 101
6.596	6 596
2.278	2 278
166	166
2.839	2 839
327	327
12	12
505	505
121	121
14	14
551	551
49	49
74	74
1.725	1 725
79	79

-	-
781	781
53	53
-	-
174	174
10	10
-	-
212	212
4	4
-	-
591	591
-	-
-	-
275	275
6	6
-	-
432	432
14	14
-	-
397	397
5	5
-	-
644	644
16	16
TLR 2018	DH 2018
Potenziale Tecnico	Technical potential
Potenziale Economico	Economic potential

Figure 120: Economic and financial potential by Region/Autonomous Province and by technology [TWh]



Piemonte	Piedmont
Valle d'A.	Valle d'Aosta
Liguria	Liguria
Lombardia	Lombardy
P.A. Bolzano	Autonomous Province of Bolzano
P.A. Trento	Autonomous Province of Trento
Veneto	Veneto
Friuli-V.G.	Friuli-Venezia Giulia
Emilia-R.	Emilia-Romagna
Toscana	Tuscany
Umbria	Umbria
Marche	Marche
Lazio	Lazio
Abruzzo	Abruzzo
Molise	Molise
Campania	Campania
Puglia	Apulia
Basilicata	Basilicata
Calabria	Calabria
Sicilia	Sicily
Sardegna	Sardinia
4.998	4 998
160	160
543	543
7.289	7 289
1.401	1 401

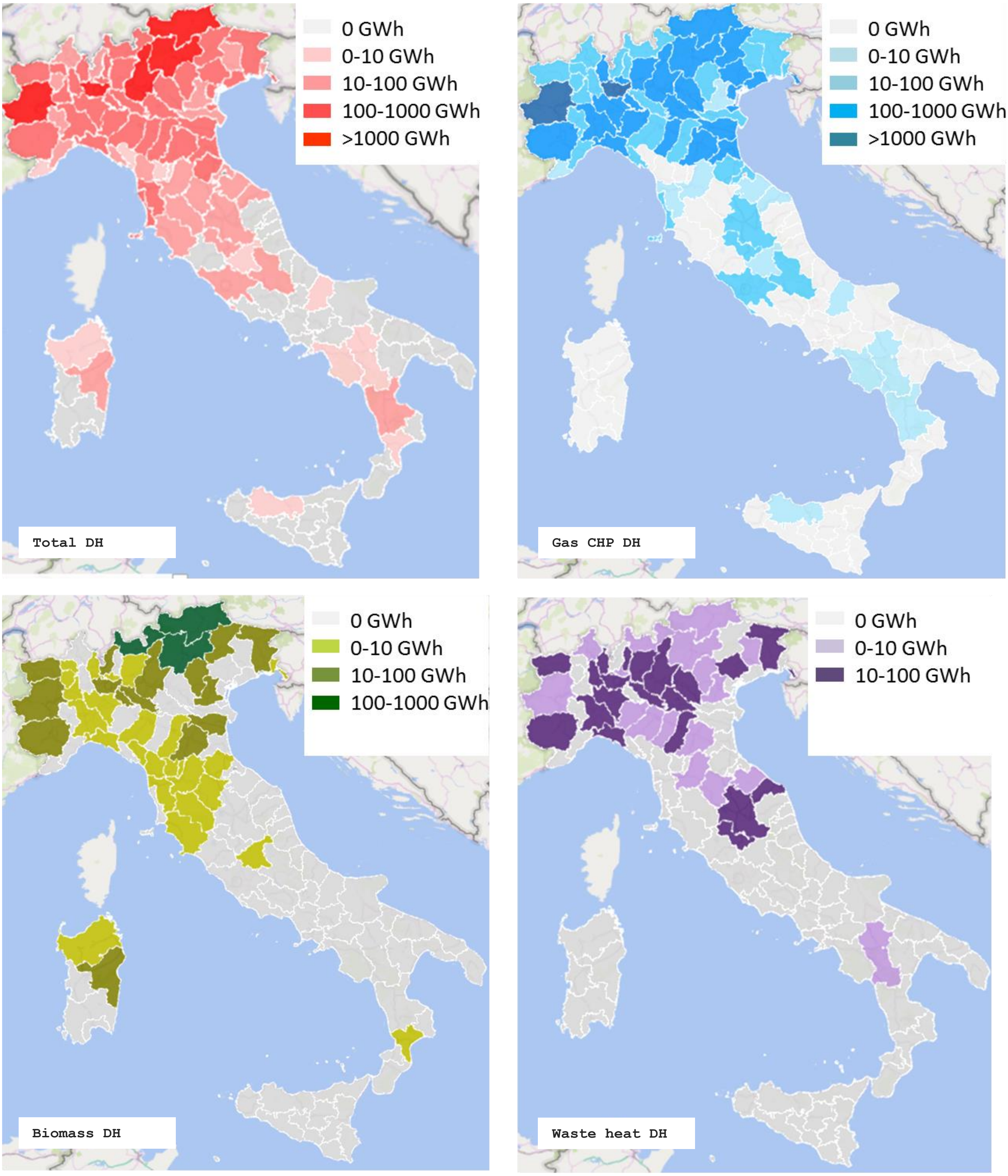
1.227	1 227
1.552	1 552
732	732
2.278	2 278
327	327
121	121
49	49
79	79
53	53
10	10
4	4
-	-
6	6
14	14
5	5
16	16
PdC	Heat pumps
Geo	Geo
Solare	Solar power
WH industriale	Industrial WH
Bioenergie OH	Bioenergy HO
Gas OH	Gas HO
Bioenergie CHP	Bioenergy CHP
rifiuti no FER	Non-renewable waste
Gas CHP	Gas CHP

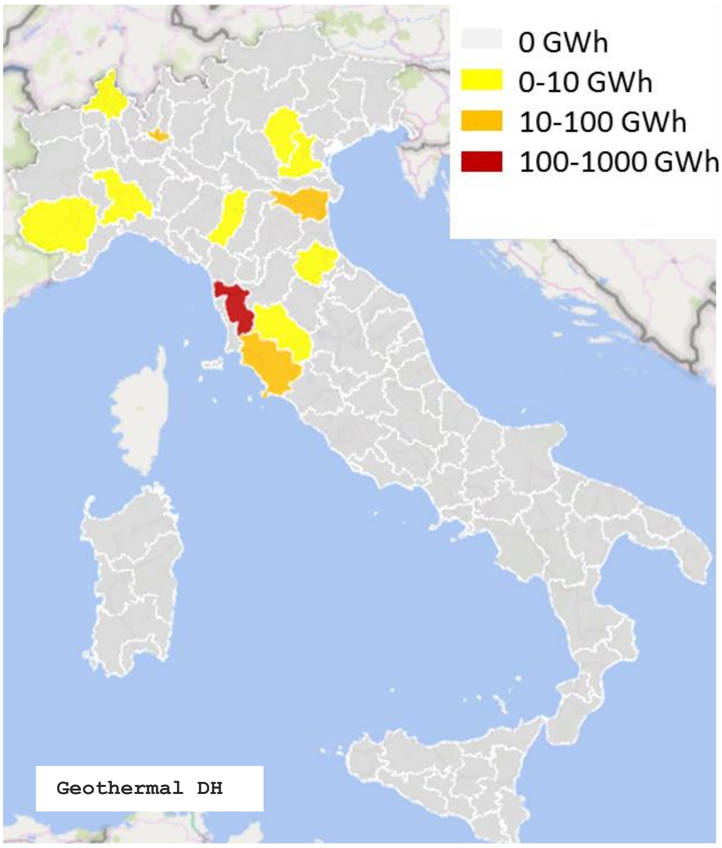
Table 69: Energy supplied by district heating in 2018 and economic and financial potential broken down by technology for each Region/Autonomous Province

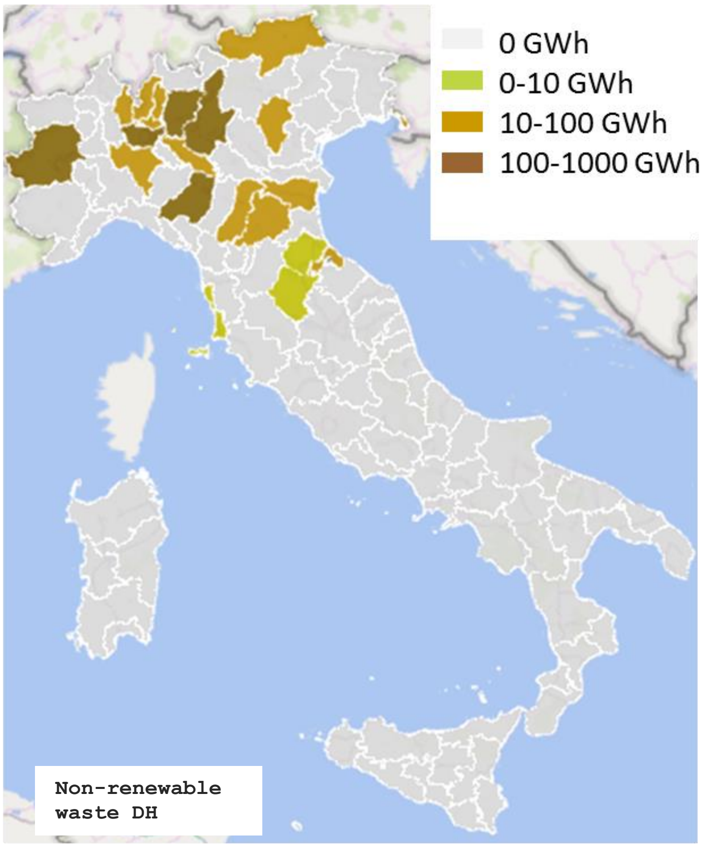
	Energy supplied by DH in 2018 [GWh]	Total technical potential of DH [GWh]	Economic and financial potential by technology						
			DH gas CHP [GWh]	DH biomass [GWh]	DH non-renewable waste [GWh]	DH waste heat [GWh]	DH biomass [GWh]	Other economic potential of DH (gas boiler)	Total DH [GWh]
Piedmont	2 875	11 257	3 553	179	73	117	6	1 069	4 998
Valle d'Aosta	118	441	48	49	-	17	-	45	160
Liguria	76	1 941	366	1	-	19	-	157	543

Lombardy	3 706	16 712	3 411	977	712	237	43	1 908	7 289
Autonomous Province of Bolzano	992	2 439	279	928	30	0	-	164	1 401
Autonomous Province of Trento	257	1 702	565	411	-	1	-	250	1 227
Veneto	352	5 024	1 005	80	9	41	7	411	1 552
Friuli-Venezia Giulia	42	1 829	362	58	20	111	-	181	732
Emilia-Romagna	1 101	6 596	1 115	216	148	64	68	668	2 278
Tuscany	166	2 839	100	41	7	10	154	15	327
Umbria	12	505	76	-	-	28	-	17	121
Marche	14	551	12	-	-	19	-	19	49
Lazio	74	1 725	42	2	-	-	-	35	79
Abruzzo	-	781	40	-	-	-	-	13	53
Molise	-	174	7	-	-	-	-	2	10
Campania	-	212	3	-	-	-	-	0	4
Apulia	-	591	-	-	-	-	-	-	-
Basilicata	-	275	2	-	-	3	-	1	6
Calabria	-	432	9	2	-	-	-	3	14
Sicily	-	397	4	-	-	-	-	1	5
Sardinia	-	644	-	16	-	-	-	-	16
Italy	**9 787**	**57 068**	**10 999**	**2 961**	**999**	**666**	**277**	**4 961**	**20 862**

Figure 121: Provincial maps of DH economic and financial potential with details of supply technologies: top left total DH, top right gas CHP DH, bottom left biomass DH, bottom right waste heat DH, on the left on the following page geothermal DH, on the right on the following page non-renewable waste DH. The potential also includes existing development.

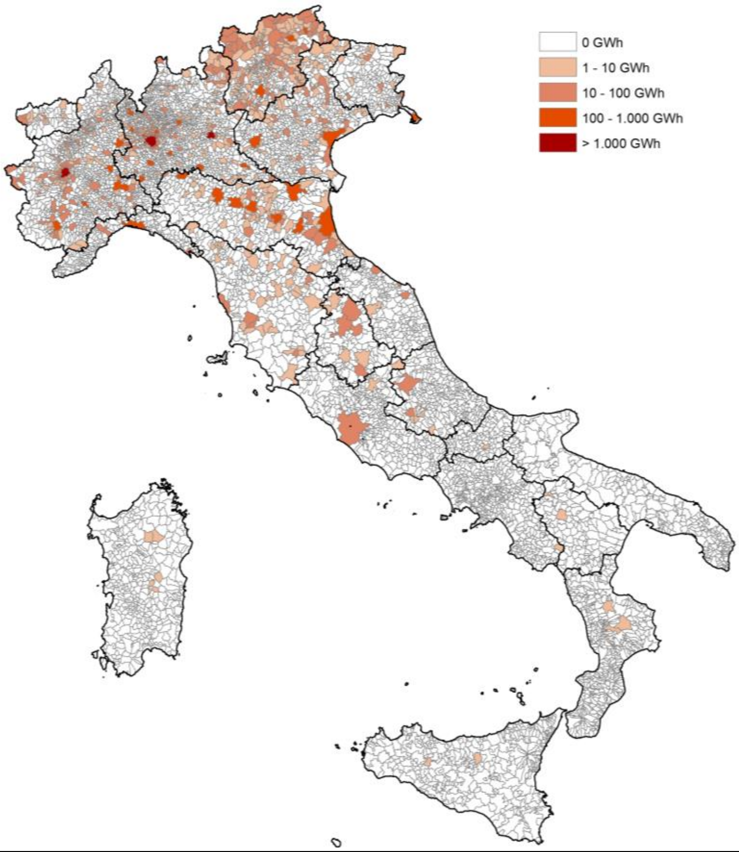



0 GWh
0-10 GWh
10-100 GWh
100-1000 GWh
Geothermal DH


0 GWh
0-10 GWh
10-100 GWh
100-1000 GWh
Non-renewable waste DH

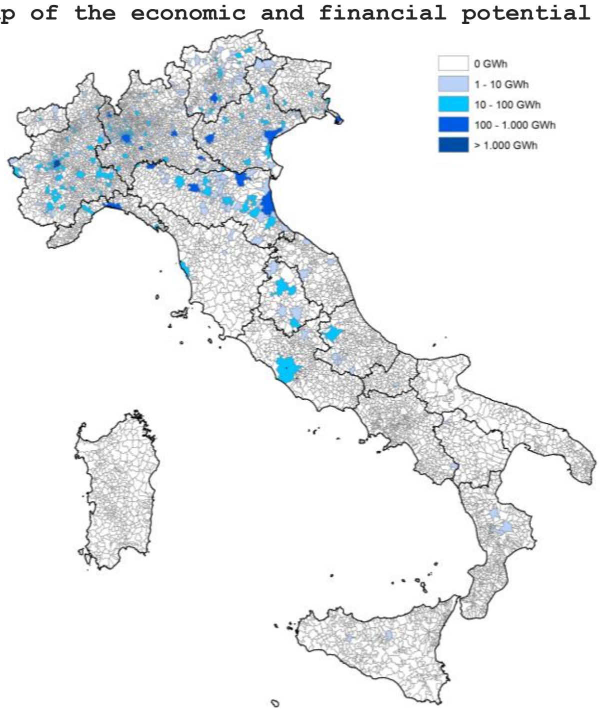
0 GWh	0 GWh
0-10 GWh	0–10 GWh
10-100 GWh	10–100 GWh
100-1000 GWh	100–1000 GWh
>1000 GWh	> 1 000 GWh
TLR totale	Total DH
0 GWh	0 GWh
0-10 GWh	0–10 GWh
10-100 GWh	10–100 GWh
100-1000 GWh	100–1000 GWh
>1000 GWh	> 1 000 GWh
TLR gas CHP	Gas CHP DH
0 GWh	0 GWh
0-10 GWh	0–10 GWh
10-100 GWh	10–100 GWh
100-1000 GWh	100–1000 GWh
TLR biomasse	Biomass DH
0 GWh	0 GWh
0-10 GWh	0–10 GWh
10-100 GWh	10–100 GWh
TLR calore di scarto	Waste heat DH
0 GWh	0 GWh
0-10 GWh	0–10 GWh
10-100 GWh	10–100 GWh
100-1000 GWh	100–1000 GWh
TLR geotermia	Geothermal DH
0 GWh	0 GWh
0-10 GWh	0–10 GWh
10-100 GWh	10–100 GWh
100-1000 GWh	100–1000 GWh
TLR rifiuti nonFER	Non-renewable waste DH

Figure 122: Municipal map of economic and financial potential of DH



0 GWh	0 GWh
0 - 10 GWh	0–10 GWh
10 - 100 GWh	10–100 GWh
100 - 1.000 GWh	100–1 000 GWh
> 1.000 GWh	> 1 000 GWh

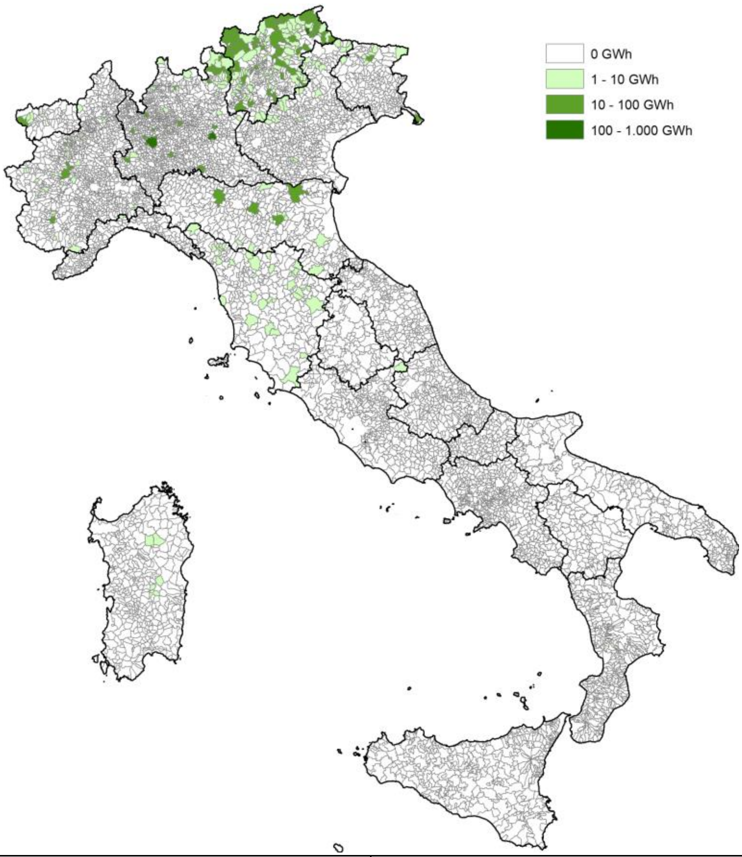
Figure 123: Municipal map of the economic and financial potential of DH fuelled by gas CHP



0 GWh	0 GWh

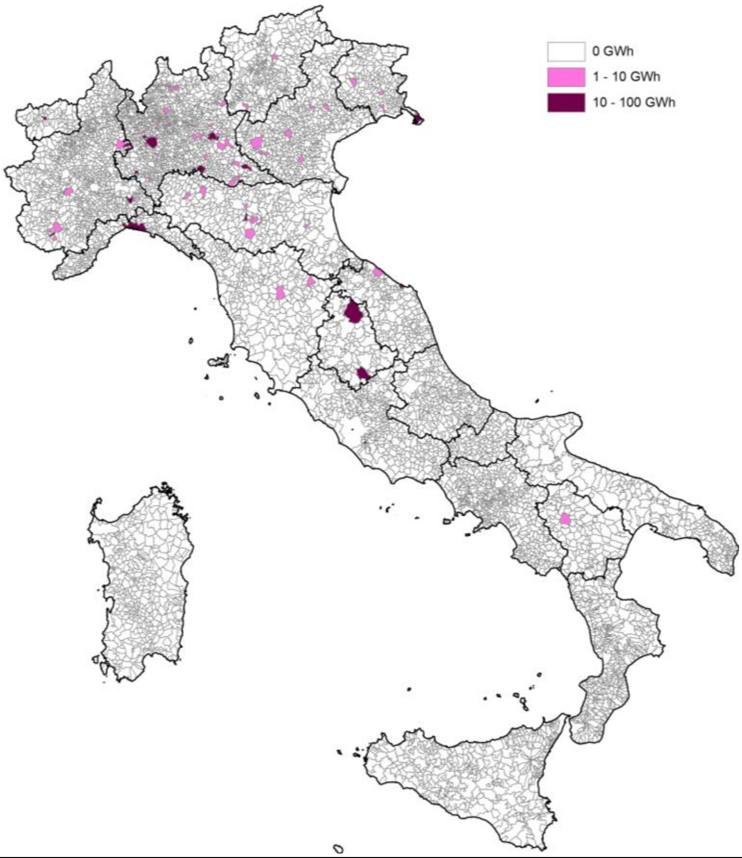
0 -10 GWh	0–10 GWh
10 - 100 GWh	10–100 GWh
100 - 1.000 GWh	100–1 000 GWh
> 1.000 GWh	> 1 000 GWh

Figure 124: Municipal map of the economic and financial potential of DH fuelled by biomass



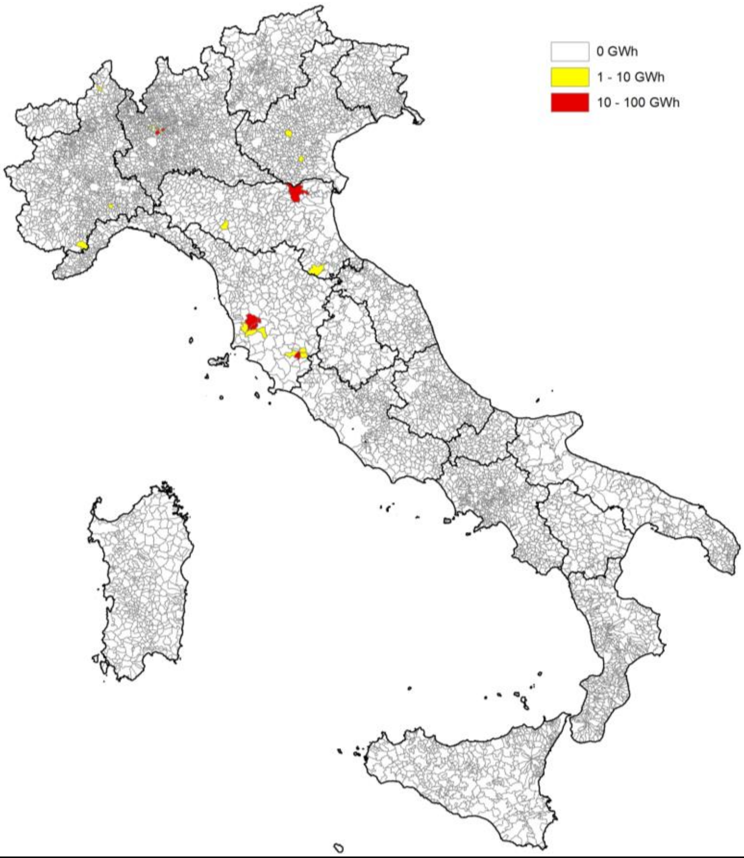
0 GWh	0 GWh
0 - 10 GWh	0–10 GWh
10 - 100 GWh	10–100 GWh
100 - 1.000 GWh	100–1 000 GWh

Figure 125: Municipal map of the economic and financial potential of district heating fuelled by waste heat recovered from the industrial sector (not including CHP heat recovered from thermal power plants and incinerators).



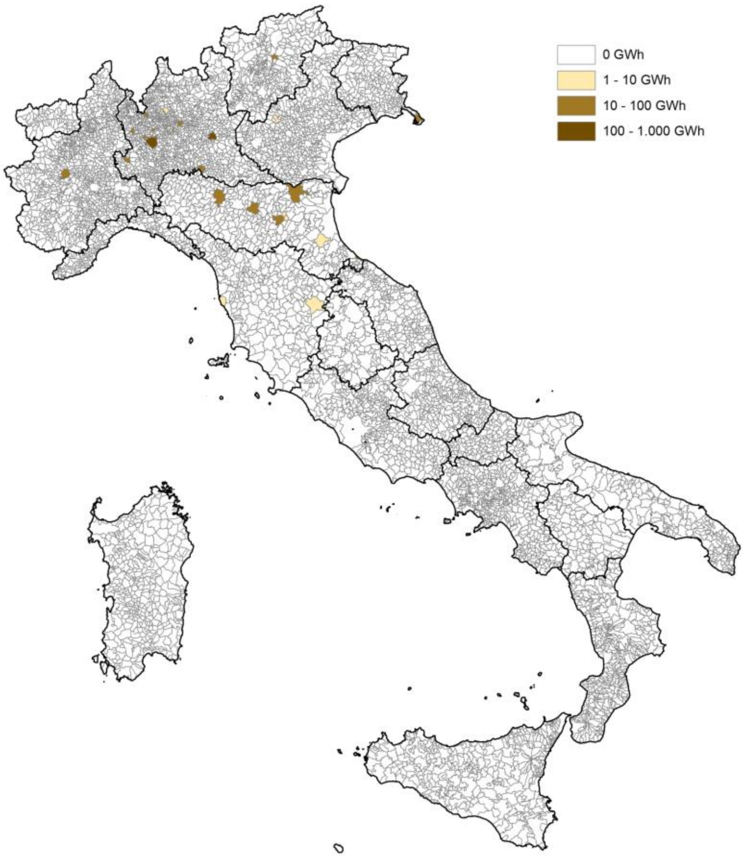
0 GWh	0 GWh
0 - 10 GWh	0–10 GWh
10 - 100 GWh	10–100 GWh

Figure 126: Municipal map of the economic and financial potential of DH fuelled by geothermal energy



0 GWh	0 GWh
0 - 10 GWh	0–10 GWh
10 - 100 GWh	10–100 GWh

Figure 127: Municipal map of the economic and financial potential of DH fuelled by non-renewable waste



0 GWh	0 GWh
0 - 10 GWh	0–10 GWh
10 - 100 GWh	10–100 GWh
100 - 1.000 GWh	100–1 000 GWh

7.5.3 Environmental benefits

The environmental benefits linked to the development of the economic and financial potential of district heating were assessed in terms of primary fossil energy savings and greenhouse gas emissions prevented.
For this assessment, an energy and emissions balance was drawn up between the incremental development of DH identified by the economic and financial potential and the counterfactual solution, represented by separate gas-fired heat and electricity production, taking the following technological features into account:

- district heating: energy consumption from the different energy carriers used in DH networks according to the economic and financial potential (gas, waste, biomass, electrical consumption from pumping, etc.) was calculated for each network, using the average efficiencies of the plants obtained from the operating data from the HE CHP-DH plants available in Section 7.4.3.
- Counterfactual: gas boiler consumption to produce the same heat as delivered by DH (η: 95%) and gas consumption to produce the same electricity as that produced by DH cogeneration plants using a non-cogeneration CCGT (η_{el}: 50%).

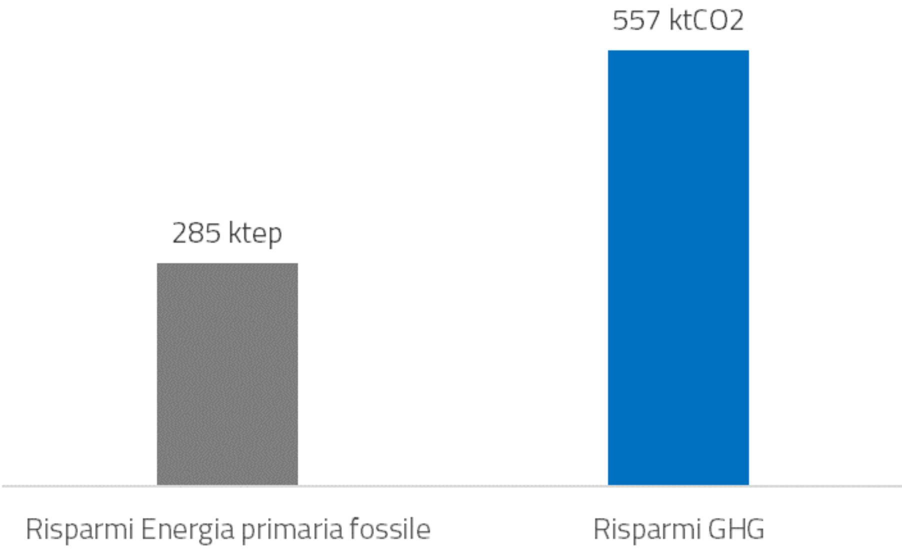
The greenhouse gas emission factors used to calculate the emissions associated with the energy carriers are shown below:

Table 70: Emission factors adopted to estimate emissions

Carrier	Other sectors	CO_{2eq} [t/MWh]
Electricity	CCGT gas	0.391
Natural gas	Thermoelectric	0.207
Biomass	Thermoelectric	0.006
Waste	Incinerator	0.176
Natural gas	Civil boiler	0.207

On the basis of the methodology described above, it has been estimated that the incremental development of the networks relative to the economic and financial potential would permit 0.3 Mtoe of primary fossil energy to be saved and 0.6 $MtCO_2$ of emissions to be prevented compared to the counterfactual scenario of separate gas-fired production, which represents the predominant marginal technology.

Figure 128: Primary fossil energy and greenhouse gas savings attributable to economic and financial potential



285 ktep	285 ktoe
557 ktco2	557 $ktco_2$
Risparmi Energia primaria fossile	Primary fossil energy savings
Risparmi GHG	GHG savings

7.6Network efficiency potential

7.6.1 Reduction of network losses

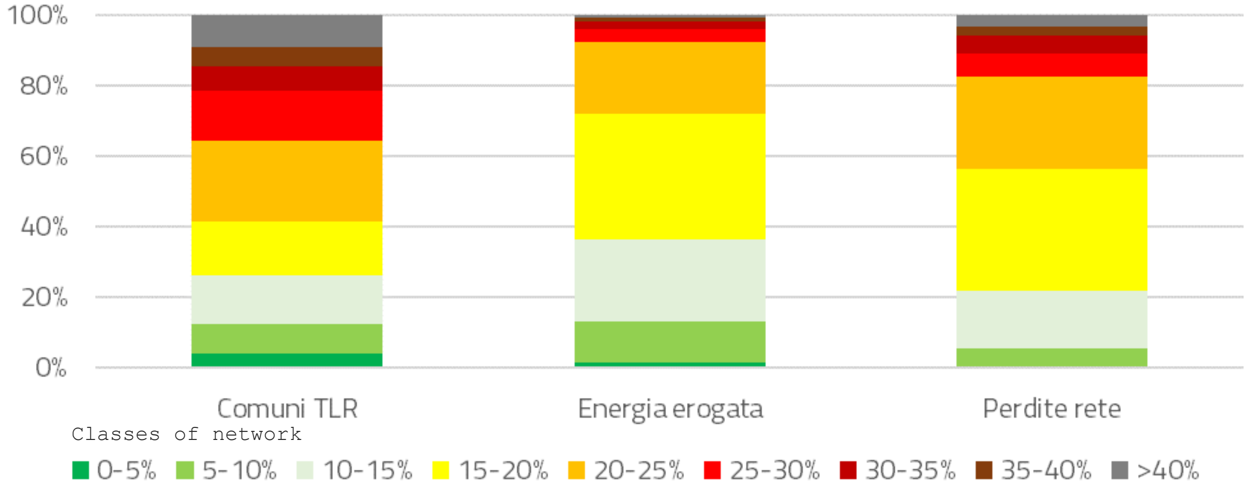
In 2018, heat losses during heat distribution by district heating networks amounted to 2.01 TWh, or 17% of the heat fed into the networks. The JRC guidelines[47] state that 'for well designed and maintained DH networks, the average annual losses do not exceed 10% of the heat supplied to the network, for older and neglected networks they can reach 20% or more'. The losses depend on many factors, including the seasonal profile of heat demand, in respect of which Italy does not appear to be in an advantageous position (short winters with substantial peaks). Currently, setting a target of 10% for losses seems very challenging based on the national situation, both on the basis of the performance of existing networks and on the basis of the opinions collected by trade associations, which have emphasised that a numerical target for network losses is difficult to predict and apply and must take the development of the networks and a number of their characteristics into account, including the temperature of the delivery and return fluid, linear heat density and the degree of network saturation. One of the most promising ways of limiting losses requires the implementation of 4th generation DH networks, alongside a high level of building efficiency also aimed at reducing heat emission temperatures.

An analysis of the distribution of losses in municipalities with district heating shows that only ¼ of the networks in operation have losses of less than 15%. If the analysis is carried out on the basis of the energy supplied,

[47] JRC 'Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level', 2015.

it can be seen that 36% of the energy delivered is supplied with losses of less than 15%, from which it can be deduced that large urban networks tend to have lower losses.

Figure 129: Analysis of loss distribution by class



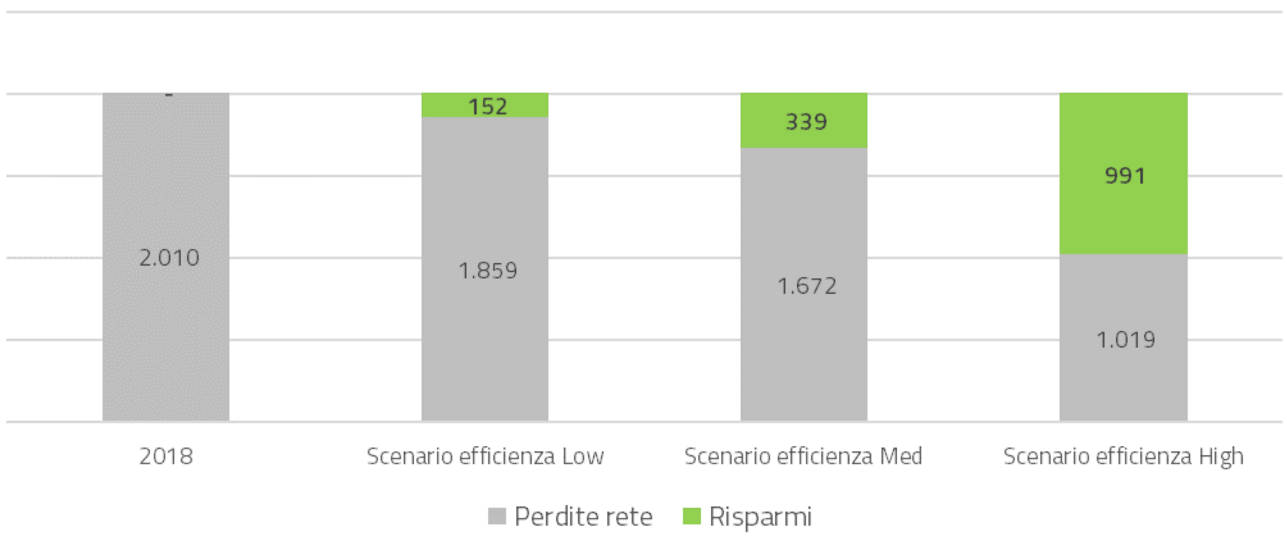
Comuni TLR	DH municipalities
Energia erogata	Energy delivered
Perdite rete	Network losses

A number of network efficiency scenarios have been drawn up by setting decreasing loss caps in order to quantitatively estimate theoretical margins of energy savings achievable with scenarios having an increasing degree of ambition.

- low scenario: cap network losses at 20%;
- medium scenario: cap network losses at 15%;
- high scenario: cap network losses at 10%.

Based on these scenarios, a range of savings relating to the reduction of network losses between 150 GWh and 1 TWh can be assumed, for the same energy supplied.

Figure 130: Network losses and savings achievable in different efficiency scenarios (GWh)



Scenario efficienza Low	Low efficiency scenario
Scenario efficienza Med	Medium efficiency scenario
Scenario efficienza High	High efficiency scenario
Perdite rete	Network losses
	Savings

7.6.2 4th generation district heating networks and low-temperature heating plants

4th generation district heating involves the distribution of heat via hot water at temperatures of 55-60°C, allowing easier incorporation of renewable energy sources and local waste heat recovery, and a reduction in network losses.
In traditional DH networks, heat can be directly recovered primarily at T >100°C: this limits or makes difficult the use of renewable sources and low-temperature waste heat which, in order to be recovered, need an increase in temperature with a reduction in energy performance and an increase in costs. Compared to traditional DH, 4th generation DH also has advantages in terms of investment costs (polyethylene and polypropylene pipes can be used, with a high level of prefabrication, including joints, which considerably reduces the cost of materials[48]), space required and installation.
The implementation of 4th generation networks is closely linked to the temperature levels of the heating systems of connected users. Low-temperature civil heating systems (radiators) have undoubted advantages in terms of efficiency, as they increase both generation and distribution efficiency. However, regulation is more difficult due to greater thermal inertia in this type of system, which favours continuous use during the cold season. Homes occupied by people who spend most of the day out of the house may not be suitable for this type of use, although the pandemic is expected to increase smart working.

[48] Source: Polimi 'Assessment of the potential for deployment of efficient district heating in Italy' 2020.

While there is no doubt that, for new neighbourhoods and buildings, introducing a 4th generation DH network with low-temperature heating systems could be one of the most beneficial solutions due to its high level of sustainability and compatibility with renewable energy sources, for existing neighbourhoods its implementation, however virtuous, could be more complex due to technical and economic difficulties that could arise when adapting the existing buildings and systems. These difficulties are far from insignificant in Italy, where less than 10% of buildings were constructed in the last decade (Section 2.1.2) and around 5% of buildings have radiator heating, according to estimates by trade associations.

Although Italy's energy and climate strategy foresees extensive retrofitting of the country's building stock, increasingly in the form of 'deep renovation', with significant initiatives to support it[49], it is realistic to expect that it will take time to adapt the entire building stock and that transitional phases will involve a certain degree of heterogeneity in the heating equipment in buildings. Taking this into account, one possibility for connecting buildings with traditional heating to 4th generation networks, which should not be overlooked, could be to install heat pumps at the user's premises solely to cover the temperature delta, the network temperature (55-60°C) and the operating temperature of the traditional heating system (80°C).

[49] e.g. Conto Termico (Heating Account) and tax deductions, especially the 110% Superbonus, which has recently been extended and is part of an important funding line within the National Recovery and Resilience Plan.

8 Technical and financial potential of CHP

8.1Methodology for analysing CHP potential

The potential for developing high-efficiency cogeneration has been assessed by analysing the characteristics of the demand for energy in the residential, service and industrial sectors as described in Chapters 1 and 2 and discussed in more depth below. This analysis has served to identify clusters, or subsectors, of typical users making up the various use sectors and to define both the unit energy demand of customers (electricity and heat) and each cluster's overall demand.

For every subsector of users identified, moreover, the HE CHP systems currently in operation have been analysed, to identify their current degree of penetration (in terms of energy supplied, installed capacity etc.), the characteristics of the installations (size, technology, fuels etc.) and technological performance (efficiency, hours of operation, share of cogenerated energy, share of self-consumed energy etc.).

Analysis of the existing demand and supply has made it possible to identify the users best placed to be served by CHP systems and to assess the amount of cogeneration capacity and energy that can truly be achieved at those users' premises. This has allowed identification of what has been classed as a theoretical maximum value, which we have defined as **technical potential** for cogeneration development, meaning the greatest share of heat demand which, based on technical constraints, can be met by CHP installations, regardless of any economic and financial considerations.

More specifically, the technical potential was assessed through the following steps:

1. Characterising the heat demand of the subsectors best suited for supply by a cogenerator, in light of certain indicators and technical constraints (amount of heat demand by customers, presence of installations already in commercial operation in the subsector, required temperature of the heat, heat/electricity ratio, installation constraints, etc.).

2. Identifying typical cases for each identified subsector, and determining the energy requirements thereof, as well as those of the entire target population for each typical case.

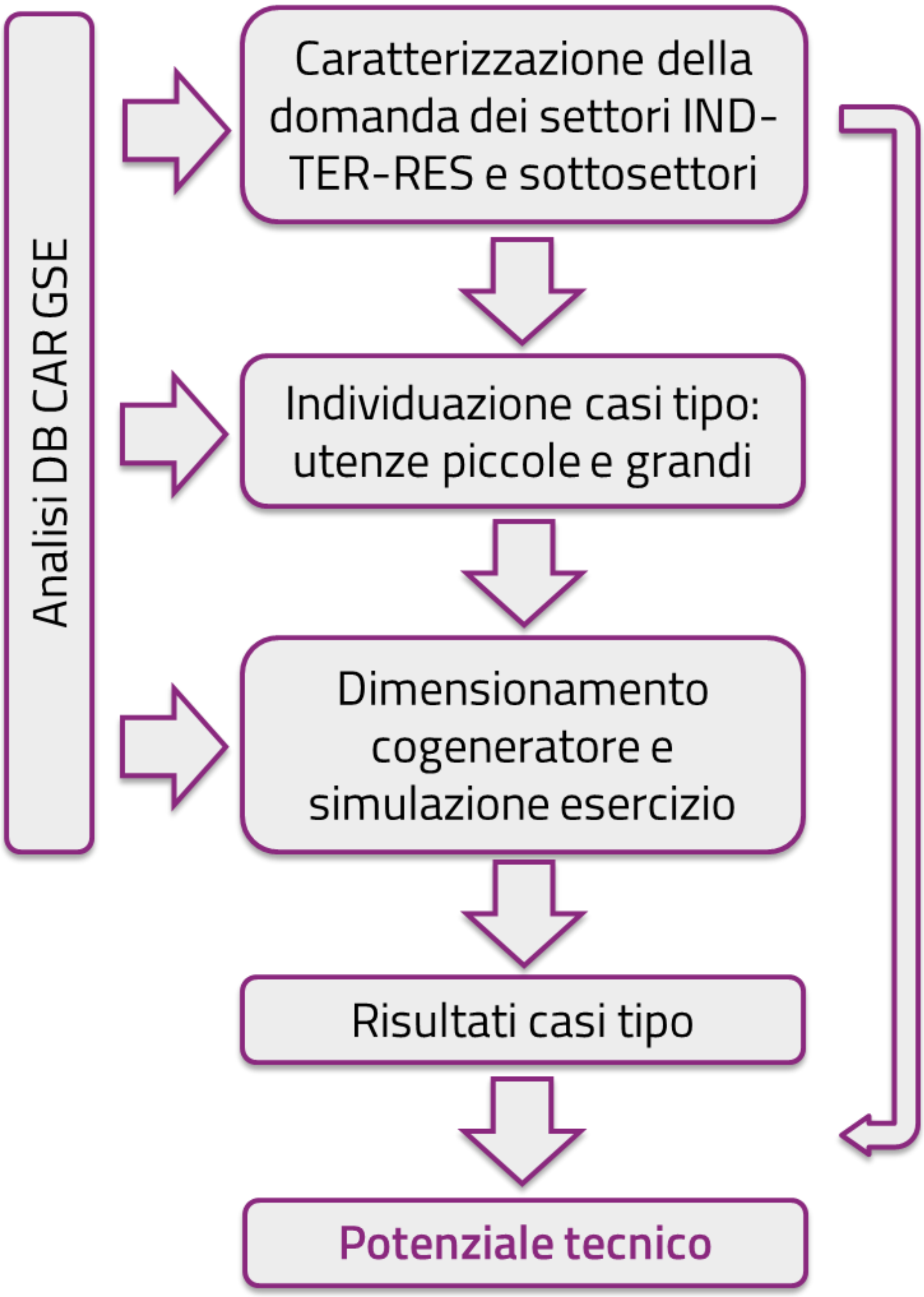
3. Establishing the size of the cogenerator and simulating its operating conditions at the typical user's premises in the subsector identified, by applying specific performance indicators obtained from existing installations serving similar users in terms of energy demand. This can be used to calculate the heat and electricity that can be cogenerated at the premises of the user of reference.

4. Estimating the maximum amount of cogenerated thermal energy and electricity technically obtainable in the subsectors to which the

simulated typical users belong, by extending the energy results obtained in the case study to the whole reference subsector.

Below is a schematic representation of the methodology for determining technical potential.

Figure 131: Methodology for calculating technical potential of HE CHP



Analisi DB CAR GSE	GSE analysis of HE CHP database
Caratterizzazione della domanda dei settori IND-TER-RES e sottosettori	Demand characterisation for the industrial, service and residential sectors, and for subsectors
Individuazione casi tipo: utenze piccole e grandi	Identifying typical cases: small-scale and large-scale users

Dimensionamento cogeneratore e simulazioneesercizio	Estimating the size of the cogenerator and simulating operation
Risultati casi tipo	Case type results
Potenziale tecnico	Technical potential

After assessing the parameters of the system in operation for each typical user and the associated technical potential of the subsector, the economic potential was assessed, estimating the economic and financial sustainability of operation of the proposed system, under the current legislation and in light of current market trends.

The economic projections have taken into account the current regulatory framework and market conditions, giving the appropriate value to each project:

- the prices of commodities have been calculated taking into account the current prices of raw materials and the various tariff schemes available according to type of customer and use of the energy produced by the cogenerator;
- the incentives and discounts offered by support schemes and facilities for self-producing CHP installations, according to size, use and other specific requirements (discount on excise duty, partial exemption from system charges for self-consumed energy, white certificates awarded according to the primary energy savings achieved, net metering system for HE CHP systems below 200 kW);
- the quantities of energy to which the values so calculated need to be applied;
- the technological costs of cogenerators (investment and maintenance) obtained from a market survey on the main suppliers of these technologies in Italy.

Subsequently, for each type of customer, a detailed business case was analysed to identify the cash flows and associated indicators of the economic and financial performance of the investment in the CHP system, comparing it with the sector's baseline scenario. Based on the economic indicators used (NPV, IRR, etc.) and assuming that typical customers' investment choices are aiming to obtain an energy supply for the lowest possible cost, the economic feasibility of the HE CHP systems was assessed, and thus their economic potential. A weighted average cost of capital (WACC) of 5% was used to calculate the NPV. The economic potential was obtained firstly by limiting the technical potential only to projects with positive NPV. Secondly, a share of feasibility was established for each initiative based on the internal rate of return (IRR). For projects with an IRR greater than 15%, the entire technical potential identified was assumed to be cost effective. For projects with an IRR below the minimum acceptability threshold (hurdle rate), the economic potential was considered to be nil. This minimum IRR threshold value was assumed to be 5% in the residential sector, while in the service and industrial sectors the minimum efficiency for activating potential was set at 7%. The economic potential of high-efficiency cogeneration was thus determined by multiplying the feasibility percentage by the technical potential described above.

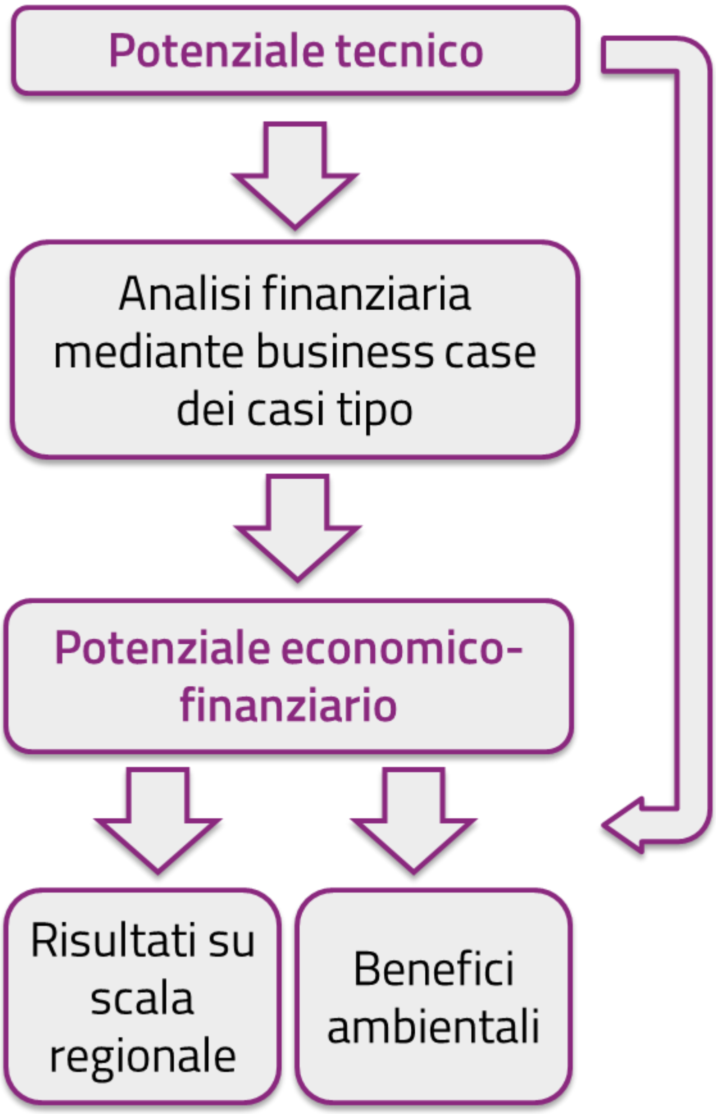
The technical and economic potential calculated using the methods described above were lastly compared with the statistical data for existing HE CHP in the various sectors to determine the potential increase. If the results of the potential calculated using the calculation model were lower than the data for existing HE CHP, the absolute potential was adjusted to take into account the existing situation.

The resulting economic potential should be interpreted as probabilistic, since the estimates, while having a rational basis, reflecting the current regulatory and market conditions and following the principles laid down in recent EU directives, completely ignore certain non-technical factors and barriers which are not purely economic (availability of funding, industrial and management policies, business alternatives, permits, etc.) and which can significantly alter (limit or indeed improve) the feasibility of the project.

The technical and economic potential for the development of HE CHP have been expressed in terms of the thermal and electrical capacity that can potentially be installed and the estimated output of thermal energy and electricity, for the purposes of comparison with the statistical-energy data on the HE CHP systems in operation in the various use sectors (industrial, services, residential) and to assess the incremental potential.

Below is a schematic representation of the methodology for determining economic and financial potential.

Figure 132: Methodology for calculating the economic and financial potential of HE CHP



Potenziale tecnico	Technical potential
Analisi finanziaria mediante business case dei casi tipo	Financial analysis through business case studies of typical cases
Potenziale economico-finanziario	Economic and financial potential
Risultati su scala regionale	Results on a regional scale
Benefici ambientali	Environmental benefits

The results of the technical and economic potential of HE CHP were also revised on a **regional scale** using a top-down approach. The potential calculated at national level was then distributed according to the regional demand for heat in each sector, checking whether the regional distribution of the sector potential calculated matched the high-efficiency cogeneration existing at regional level for that sector and correcting the potential figure when it was lower than that already achieved. The assessment of the technical and economic potential was accompanied by an assessment of the **environmental benefits**, such as savings on GHG emissions and primary energy savings, linked to the development of the potential of high-efficiency CHP.

The **primary energy savings** were calculated on the basis of the efficiency reference values of separate heat and power production, processed by GSE on the basis of the technologies assumed to have been replaced in the sectors[50], and the correction factors that take into account the network voltage and relationship between self-consumed energy and energy fed into the grid, which in turn leads to network losses (taken from Commission Delegated Regulation (EU) 2015/2402, which analysed and updated the loss factors for the national grid).

The **GHG emissions prevented** were calculated using the primary energy savings described above by applying the GHG emission factors of the prevailing marginal fuel, natural gas.

The primary energy and emissions savings were assessed for each typical user in each sector and were extended to the incremental technical and economic potential for development of HE CHP in that sector (where 'incremental' means the difference between the potential and the capacity and energy from HE CHP already achieved in the reference sector).

To assess the potential of CHP, GSE worked with RSE to characterise the energy demand of a number of subsectors, particular in the service sector.

8.2 Technology costs: investment and O&M

After characterising the energy demand of the typical users identified, the technology and size of the cogenerator were defined in each case, simulating the operating conditions. Information about the investment, operating and maintenance costs, and about the useful life of different technologies, was therefore needed for the economic analysis. As shown in Section 4.3.1, while in terms of existing capacity large combined cycle plants currently account for the largest share of existing cogeneration output, in terms of numbers internal combustion engines (ICE) largely predominate, especially looking at the trend of new installations in recent years.

[50]More specifically, the reference electrical efficiency for separate production was set at 53%. The reference thermal efficiency for separate heat production was 92%.

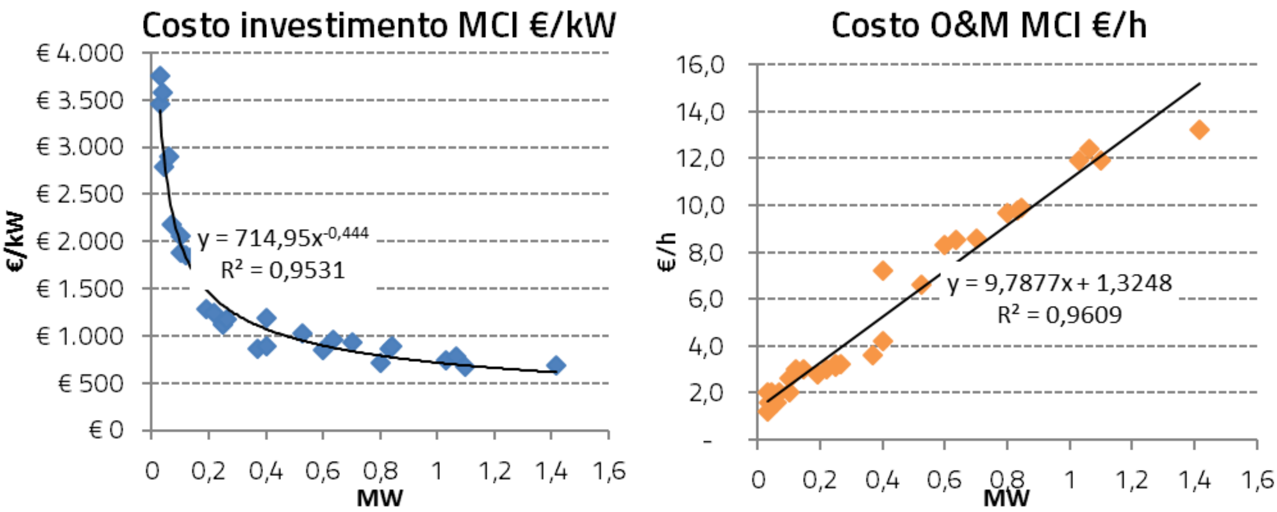
For this reason, an ad hoc examination of market costs was carried out for ICEs. The cost of investing in ICE cogenerators varies greatly depending on their size. Costs increase significantly as size decreases. A parametric curve obtained from the recognised cost data was implemented, with exponential fitting from 30 kW up to 500 kW, the most common capacity range in simulated cases, and linear interpolation for larger plants.

For maintenance purposes, the typical cost of full service contracts was applied, the value of which is set on the basis of the system's hours of operation. The maintenance cost per hour of operation offered by suppliers increases almost linearly in relation to the size of the plant. The useful life of the ICE plants was based on the manufacturer's data. For small plants (micro-HE CHP <20 kW), the useful life is estimated at 20 000 hours of operation, for medium-sized plants of 20-500 kW, it is estimated to be around 40 000 hours of operation, while for medium to large ICE plants (>500 kW), the useful life is estimated to be between 60 000 and 70 000 hours. Thus, useful life in calendar years depends both on size and use intensity (hours of operation) of the system and ranges in the different case studies from 6 to 15 years.

Table 71: Investment, O&M and useful life costs estimated for ICEs in simulations, for different electrical capacities

Capacity (MWe)	Investment cost (€/kW)	O&M (€/h)	Useful life (years)
0.001	6 000	1.33	20 000
0.005	3 163	1.37	20 000
0.01	3 163	1.42	20 000
0.02	3 163	1.52	20 000
0.03	3 163	1.62	40 000
0.05	2 704	1.81	40 000
0.1	1 987	2.30	40 000
0.2	1 461	3.28	40 000
0.5	973	3.28	40 000
0.8	828	6.22	40 000
1	732	9.15	60 000
4	698	11.11	60 000
5	687	12.00	60 000

Figure 133: Market survey of investment and O&M costs of ICEs and fitting curves



€/kW	€/kW
MW	MW
$y = 714{,}95x^{-0{,}444}$	$y = 714.95x^{-0.444}$
$R^2 = 0{,}9531$	$R^2 = 0.9531$
Costo investimento MCI €/kW	ICE investment cost €/kW

€/h	€/h
MW	MW
y = 9,7877 + 1,3248	y = 9.7877 + 1.3248
$R^2 = 0{,}9609$	$R^2 = 0.9609$
Costo O&M MCI €/h	ICE O&M cost €/h

For CCGT and GT plants, considered only in large companies in the most energy-intensive sectors, the following parameters were applied: investment costs of 1 000 €/kW_e, fixed maintenance costs of 4%-6% of investment costs and useful life of 75 000 hours and not exceeding 15 years.

Table 72: Investment, O&M and useful life costs estimated for combined cycle and gas turbine plants in the simulations

Technology	Investment cost (€/kW)	O&M (€/kW/year)	Useful life (hours)
CCGT	1 000	40	75 000
Gas turbine	1 000	60	75 000

In all applications, the existing boilers are also maintained after deployment of the CHP system, for backup purposes; therefore, their investment and maintenance costs and useful life have not been factored in.

8.3 Commodities and financial assumptions

Regarding commodities, the final consumer prices of the gas and electricity drawn by users were taken from Eurostat, using 2019 as the reference year[51]. Both domestic and non-domestic prices from this information source were considered, and applied to industrial and service users, with and without VAT. These prices are available by consumption band, so the different typical users have been allocated final electricity and gas prices based on their consumption.

Table 73: Final electricity and gas prices (excluding VAT) considered for the different consumption bands (source: Eurostat)

Electricity code	Min. band (MWh)	Max. band (MWh)	Price excluding VAT (€/MWh)	Gas code	Min. band (MWh)	Max. band (MWh)	Gas price (€/MWh)
D1	-	1.0	464	D1	0	5.6	104
D2	1.0	2.5	225	D2	5.6	55.6	72
D3	2.5	5.0	211	D3	55.6		63
D4	5.0	15.0	210				
D5	15.0		204				
I1	-	20	311	I1	0	277.8	60
I2	20	500	188	I2	277.8	2 777.8	46
I3	500	2 000	163	I3	2 777.8	27 778	32
I4	2 000	20 000	141	I4	27777.8	277 778	26
I5	20 000	85 000	114	I5	277 777.8	1 111 111	24
I6	85 000	150 000	92	I6	1 111 111		25
I7	150 000		76				

The HE CHP systems considered for SMEs are often below 200 kWe and thus it is assumed, where this is determined to be the case, that they access the net metering scheme. In these cases, the power produced by the cogenerator and exchanged with the grid is thus priced at an NM tariff calculated as the average of the NM tariffs applied to HE CHP systems in 2019 by GSE (around 80 €/MWh). If the power fed into the grid exceeds that drawn from the grid, not all of the feed-in energy is priced at the net metering tariff. The excess quantity is priced at the wholesale market price. The industrial sectors which are assumed to have installations with a capacity above 200 kW cannot access the NM scheme. Therefore, all the energy they feed into the grid is priced at wholesale market prices.

[51] 'Energy statistics - natural gas and electricity prices (from 2007 onwards) (nrg_pc) https://ec.europa.eu/eurostat/web/energy/data/database

The wholesale price of electricity taken as a reference for the calculations is the single national average price in 2019 on the day ahead market (PUN MGP 2019)[52], 52.3 €/MWh.

Self-consumed electricity is liable for excise duty on electricity, like consumed electricity. The amount of the excise duty on electricity varies according to the consumption band.

The price of the gas consumed by the CHP was obtained from the final price of gas described earlier, net of the rebate on excise duties for the production and self-production of electricity, in accordance with the current rules of the Customs Agency. A rebate on the excise duty is granted for the consumption of natural gas for electricity generation below the specific consumption threshold of 0.22 kWh/Nm3. On the other hand, consumption above the threshold and the consumption of gas by boilers are subject to the ordinary excise duty, in relation to which it is important to differentiate between duty for industrial uses and duty for civil uses, which is considerably higher.

The price of the energy efficiency certificates or white certificates (type II-HE CHP) was taken from GME's statistical data on the average prices of the centralised market for white certificates in 2019[53], and totals EUR 260 per energy efficiency certificate; this value is assumed to remain constant in the future.

8.4 Economic drivers of HE CHP

It may be relevant to anticipate the main economic drivers associated with HE CHP as indicated by the financial analysis; in the various cases simulated, the incorporation of HE CHP leads first of all to investment costs. In terms of operating costs, compared to the counterfactual situation considered, several variations are noted:

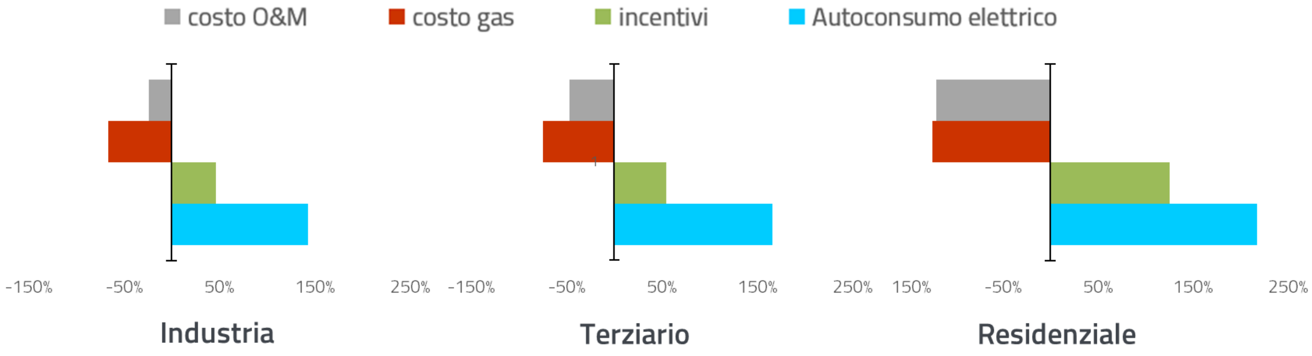
- **Self-consumption of electricity**: savings on electricity bills due to self-consumption of electricity;
- **Incentives**: white certificates, net metering, reduced gas excise duties
- **Gas cost**: increase in gas bill due to higher gas consumption by the cogenerator
- **O&M cost**: costs of operating and maintaining HE CHP plants

In the various simulated cases, the algebraic sum of these contributions constitutes the annual operating margin for HE CHP intervention compared to the counterfactual scenario. The figure below shows the percentage share of each of these contributions to the average annual operating margin recorded for the industrial, service and residential sectors. Savings on electricity bills due to self-consumption is in all cases the main economic driver, even compared to incentives, in particular in industry.

[52] In actual fact, a zone price is applied, but since this study is conducted at national level and the zone price spreads of the Italian electricity market are by now quite low, this aspect is deemed to be negligible.

[53] http://www.mercatoelettrico.org/It/Statistiche/TEE/StatisticheTEE.aspx

Figure 134: Percentage contributions of the main economic drivers to the annual operating margin in HE CHP business cases



costo O&M	O&M cost
costo gas	Gas code
incentivi	Incentives
Autoconsumo elettrico	Self-consumption of electricity
Industria	Industry
Terziario	Services
Residenziale	Residential

8.5 HE CHP potential in industry

Industry has traditionally been the sector of greatest interest for HE CHP, as is also evident from the analysis of existing development in Section 4.3.3, which shows that, as of 2018, 75% of HE CHP heat generated is delivered to industry.

The HE CHP potential for the industrial sector was calculated by characterising the heat demand for that sector. The analysis of existing plants was also used to identify the subsectors most relevant for HE CHP, and the energy demand of typical reference users within these subsectors was characterised. On the basis of a number of considerations and technical constraints, the proportion of heat demand that can be technically met by high-efficiency cogeneration has been determined; extending this result to the reference population of the typical user in question gives the technical potential. The economic and financial potential, in terms of the heat that can be produced using HE CHP and, consequently, the capacity that can be installed, has been calculated by means of an economic and financial analysis carried out on different application scenarios for cogeneration plants.

8.5.1 Characterisation of heat demand in the industrial sector

As described in detail in Sections 1.4 and 2.3, final consumption in the industrial sector and energy industries[54] in Italy in 2018 was 31.9 Mtoe.

[54] The analysis considers the consumption for energy purposes by processing industries as an integral part of the industrial sector. Consumption by the processing sector included consumption for energy purposes by the energy industries (such as refineries, coke ovens,

This consisted of 20.2 Mtoe of heat for industrial processes[55] (corresponding to an estimated requirement of 18.5 Mtoe) and 11.7 Mtoe for unavoidable electricity uses, including a marginal share of heat which, owing to process requirements, is supplied using electricity.

Heat demand is mainly covered by direct consumption of fossil fuels. The remainder, about 17%, is covered by derived heat, while power demand is mainly covered by drawing from the national grid.

In relation to subsectors, overall it is noted that the highest energy consumption in industry is by the refineries and the non-metallic mineral products sector, followed by chemicals and petrochemicals and by the steel industry.

The mechanical engineering, steel and chemical sectors account for the highest electricity consumption (collectively 40% of the total considered). The highest share of heat consumption is recorded in the refining and non-metallic mineral products sectors (19% and 17% respectively of the total).

In order to assess the technical potential of HE CHP, it was necessary to carry out in-depth characterisation of the demand for heat and power in the various subsectors, in greater detail than that provided by the industrial sectors shown in the national energy balances and published by Eurostat. To this end, the data on consumption by the industrial sectors shown in Eurostat's energy balances for 2018 has been broken down using ISTAT statistical data on individual industrial sectors relating to the energy expenditure of companies and to the number of companies by ATECO subsector and by company size (as measured by number of workers).

Thus, the overall demand for heat and power of each ATECO subsector has been estimated, as well as the demand of each ‘typical’ company identified by size class: micro-enterprises (0-10 workers), SMEs (10-50 workers), and medium and large enterprises (>50 workers).

The next step was to select the typical users on which to simulate the operation of a cogenerator; to this end, those industrial sectors were selected which have companies with a high demand for heat and power or which already have HE CHP systems in operation, as reported in GSE's database on HE CHP.

For each subsector selected, it was considered useful to consider two types of typical user: one representative of medium to large enterprises (MLE), likely to be of greater interest, and one representative of small and medium-sized enterprises (SME), which generally have lower demand. Micro-enterprises, on the other hand, have not been considered due to their low requirements.

Account has therefore been taken of the heat and power demand both of the typical users and of their reference populations, which constitutes, by design, a subset of the demand of the relevant subsector.

The heat and power demand in the above cases, and for the corresponding reference populations, are illustrated below. It should be noted that the

etc.) net of the consumption of raw materials. Demand was calculated from direct consumption, assuming conversion efficiency of 90%.

[55] The share of demand for space heating and cooking in this sector is negligible.

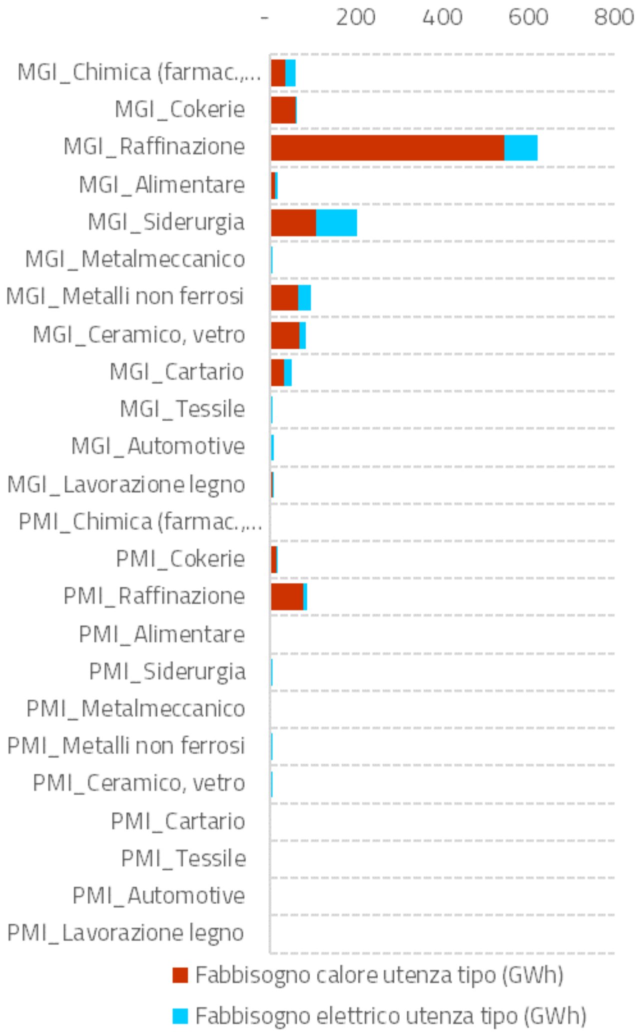
overall heat demand of the reference populations of the typical users totals around 177 TWh, which is more than 80% of the total heat demand in the industrial sector, reflecting the comprehensive range considered.

Table 74: Heat and power demand of the typical users chosen and the corresponding reference populations

typical user (*)	Heat demand of typical user (GWh)	Power demand of typical user (GWh)	Total heat demand of typical user sector (GWh)	Total power demand of typical user sector (GWh)
MLE_chemistry (pharma, plastics, etc.)	36	24	21 469	14 095
MLE_coke ovens	58	3	582	30
MLE_refineries	546	76	33 246	4 620
MLE_food	10	7	11 575	7 852
MLE_steel	107	96	17 691	15 899
MLE_mechanical engineering	3	3	9 747	11 839
MLE_non-ferrous metals	64	31	4 957	2 411
MLE_ceramics, glass	67	16	28 867	6 939
MLE_paper	31	18	12 667	7301
MLE_textiles	3	2	4 224	2 991
MLE_automotive	2	7	1 152	3 433
MLE_woodworking	5	5	614	728
SME_chemistry (pharma, plastics, etc.)	0	0	388	255
SME_coke ovens	15	1	291	15
SME_refineries	76	11	8 043	1 118
SME_food	1	0	3 890	2 639
SME_steel	1	1	524	471
SME_mechanical engineering	0	0	5 894	7 159
SME_non-ferrous metals	2	1	240	117
SME_ceramics, glass	3	1	5 872	1 411
SME_paper	1	0	1 457	840
Total			**176 775**	**95 187**

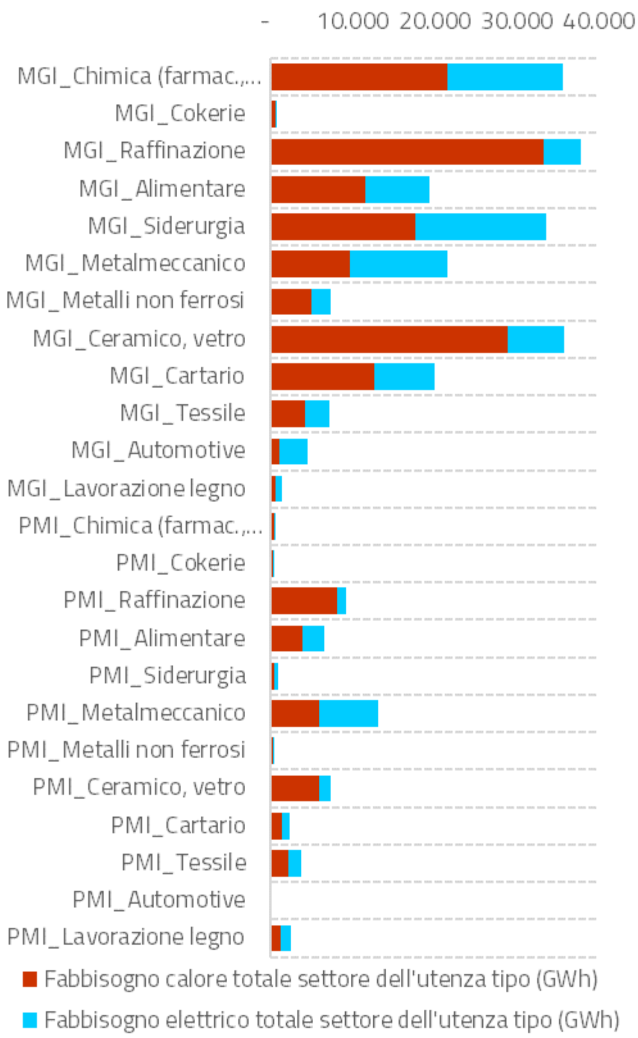
(*) For the purposes of this study, MLE: Medium to large enterprises >50 employees; SME: small and medium-sized enterprises, 10-50 employees

Figure 135: Heat and power demand of the typical users chosen and the corresponding reference populations



MGI_Chimica (farmac.,..	MLE_ chemistry (pharma, etc.)
MGI_Cokerie	MLE_coke ovens
MGI_Raffinazione	MLE_refineries
MGI_Alimentare	MLE_food
MGI_Siderurgia	MLE_steel
MGI_Metalmeccanico	MLE_mechanical engineering
MGI_Metalli non ferrosi	MLE_non-ferrous metals
MGI_Ceramico, vetro	MLE_ceramics, glass
MGI_Cartario	MLE_paper
MGI_Tessile	MLE_textiles
MGI_Automotive	MLE_automotive
MGI_Lavorazione legno	MLE_woodworking
PMI_Chimica (farmac.,...	SME_chemistry (pharma, etc.)
PMI_Cokerie	SME_coke ovens
PMI_Raffinazione	SME_refineries
PMI_Alimentare	SME_food
PMI_Siderurgia	SME_steel
PMI_Metalmeccanico	SME_mechanical engineering
PMI_Metalli non ferrosi	SME_non-ferrous metals

PMI_Ceramico, vetro	SME_ceramics, glass
PMI_Cartario	SME_paper
PMI_Tessile	SME_textiles
PMI_Automotive	SME_automotive
PMI_Lavorazione legno	SME_woodworking
Fabbisogno calore utenza tipo (GWh)	Heat demand of typical user (GWh)
Fabbisogno elettrico utenza tipo (GWh)	Power demand of typical user (GWh)



MGI_Chimica (farmac.,..	MLE_ chemistry (pharma, etc.)
MGI_Cokerie	MLE_coke ovens
MGI_Raffinazione	MLE_refineries
MGI_Alimentare	MLE_food
MGI_Siderurgia	MLE_steel
MGI_Metalmeccanico	MLE_mechanical engineering
MGI_Metalli non ferrosi	MLE_non-ferrous metals
MGI_Ceramico, vetro	MLE_ceramics, glass
MGI_Cartario	MLE_paper
MGI_Tessile	MLE_textiles
MGI_Automotive	MLE_automotive
MGI_Lavorazione legno	MLE_woodworking

PMI_Chimica (farmac.,...	SME_chemistry (pharma, etc.)
PMI_Cokerie	SME_coke ovens
PMI_Raffinazione	SME_refineries
PMI_Alimentare	SME_food
PMI_Siderurgia	SME_steel
PMI_Metalmeccanico	SME_mechanical engineering
PMI_Metalli non ferrosi	SME_non-ferrous metals
PMI_Ceramico, vetro	SME_ceramics, glass
PMI_Cartario	SME_paper
PMI_Tessile	SME_textiles
PMI_Automotive	SME_automotive
PMI_Lavorazione legno	SME_woodworking
Fabbisogno calore totale settore dell’utenza tipo (GWh)	Total heat demand of typical user sector (GWh)
Fabbisogno elettrico totale settore dell'utenza tipo (GWh)	Total power demand of typical user sector (GWh)

It should be noted that, in terms of the demand from individual typical users, the large refining industries have by far the greatest demand, followed by the steel industry and then, some way behind, by non-ferrous metals, ceramics and others. However, due to the number of companies surveyed in each subsector, in terms of reference populations the demand is more widely distributed, with high levels in the aforementioned subsectors and in the chemistry, paper and food sectors.

8.5.2 Technical potential in the industrial sector

Based on the demand in each typical case, bottom-up studies of production processes were conducted for each industrial sector. These identified the specific demand (per unit of product/turnover) and defined the share of heat demand that can be covered by CHP, given the technical constraints such as temperature[56].

This analysis was used to calculate the demand for heat and power from typical users in the various sectors which can be covered by CHP systems, with appropriate technical sizing.

After characterising the demand for heat and power from the typical users considered, the CHP system was chosen, its size estimated and its operating conditions simulated.

The choice of technology was oriented to the current market trends for the plants in operation, analysing GSE’s database on HE CHP. Analyses show that the technology most commonly used for the new installations is a gas ICE, except in cases of high capacity where GT or CCGT may be preferable.

The size of the cogenerators was determined on a case-by-case basis, taking into account the typical capacities of the existing plants in the sectors, as listed in the GSE CHP database, and considering the H/E ratio of the user, the typical operating hours of the plants and the share of heat that can be cogenerated.

In particular, the size of the HE CHP systems was chosen to maximise coverage of the heat and power demanded by the process. This involved:

[56] Gambini M. Vellini. M. ‘Illustration of the main industrial processes relevant to HE CHP’ 2015

- minimising the amount of electricity fed into the national grid, hence ensuring the plant had a maximum electrical capacity not exceeding that required by the process;
- maximising the heat made available by the cogenerator and, hence, fully exploiting the CHP system's maximum H/E to obtain the greatest efficiency in terms of HE CHP generation and primary energy savings.

This was done by calculating the ratio of average electrical and heat capacity of the $H/E_{user-chp}$ process which could be met by cogeneration and comparing it with the $(H/E)_{cog}$ ratio of the specific cogeneration technology. If the result is:

$$\left(\frac{H}{E}\right)_{utenza-chp} > \left(\frac{H}{E}\right)_{cog}$$

this means that the CHP technology chosen is able to supply the electricity required by the process but not the heat. In this case, the cogenerator is sized to cover the electricity required by the process, while auxiliary boilers are used to meet the heat capacity required by the process.

On the other hand, if the result is:

$$\left(\frac{H}{E}\right)_{utenza-chp} < \left(\frac{H}{E}\right)_{cog}$$

this means that the CHP technology chosen is able to supply the heat required by the process but not the electricity. In this case, the cogenerator is sized to cover the heat demand of the process, while the electricity shortfall not met by the CHP system is drawn from the national grid.

Applying this criterion, it is possible to size the cogenerator (calculation of electrical capacity, of CHP rated output and of the fuel’s heat output) and any fuel heat outputs associated with the production of heat by auxiliary systems and the electrical power drawn from the grid.

The operating conditions were simulated using the specific performance indicators taken from operating data of similar users from an energy demand point of view, processed by the HE CHP database, for each subsector. In particular, the hours of operation (in HE CHP and electricity-only mode), the electric and thermal efficiency, the share of self-consumption, etc. were estimated. It has been assumed that the cogenerator will be installed at a demand point receiving its electricity from the national grid and heat from a gas boiler with efficiency in line with the market baseline (90% efficiency), to be maintained after installation of the cogenerator to serve as a backup boiler.

Table 75: Technical parameters and energy outputs of HE CHP systems under the operating conditions assumed for the industrial sector

Case study	MLE_chemistry (pharma, plastics, etc.)	MLE_coke ovens	MLE_refineries	MLE_food	MLE_steel	MLE_mechanical engineering	MLE_non-ferrous metals	MLE_ceramics, glass
HE CHP technology	ICE	ICE	CCGT	ICE	ICE	ICE	ICE	GT
System capacity	1-10 MW	1-10 MW	10-100 MW	1-10 MW	1-10 MW	0.1-1 MW	1-10 MW	1-10 MW
Electrical capacity (MW)	4.6	1.1	21.1	1.1	1.8	0.3	1.1	1.5
Thermal capacity (MW)	4.1	1.0	30.4	1.0	1.7	0.4	1.0	2.3
HE CHP electrical efficiency (%)	40%	38%	35%	40%	40%	35%	40%	30%
HE CHP thermal efficiency (%)	35%	37%	47%	36%	37%	45%	37%	47%
Self-consumption (%)	94%	92%	50%	92%	73%	59%	73%	94%
CHP electricity share (%)	80%	60%	80%	81%	84%	96%	84%	73%
Equivalent hours of electricity	5 395	4 661	4 507	5 121	4 463	3 353	4 463	5 935
Share of heat that can be cogenerated (%)	50%	15%	36%	40%	6%	50%	6%	15%
Cogenerated heat (MWh)	17 786	2 893	109 212	4 173	6 394	1 286	3 862	10 117
HE CHP electricity (MWh)	20 092	2 967	75 878	4 585	6 839	964	4 131	6 384
Total electricity produced (MWh)	25 260	4 943	95 222	5 677	8 116	1 002	4 902	8 769
Self-consumed electricity (MWh)	23 511	2 967	47 598	5 246	5 951	591	3 594	8 252
Electricity drawn from the grid (MWh)	-	-	28 280	1 831	89 824	2 532	27 718	7 960
Consumption of back-up boiler (MWh)	20 028	61 415	485 340	6 955	111 310	1 428	67 233	63 700
Consumption of HE CHP system (MWh)	49 794	7 813	219 317	11 527	17 123	2 747	10 343	21 309

Total CHP system consumption (MWh)	62 602	13 016	273 53 7	14 273	20 321	2 853	12 274	29 272

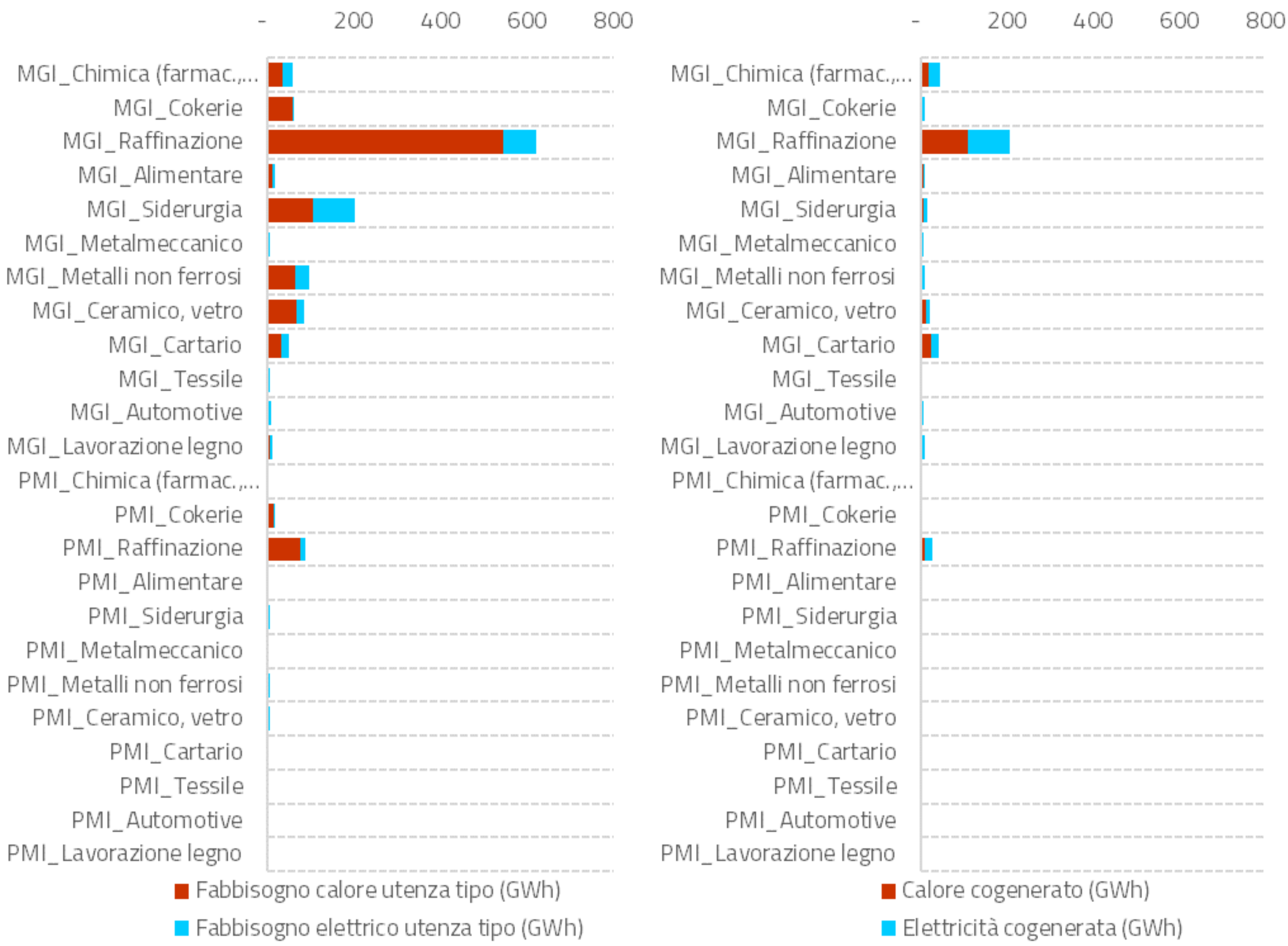
Case study	MLE_paper	MLE_textiles	MLE_automotive	MLE_woodworking	SME_chemistry (pharma, plastics, etc.)	SME_coke ovens	SME_refineries	SME_food
HE CHP technology	ICE	ICE	ICE	ICE	ICE	ICE	ICE	ICE
System capacity	1-10 MW	0.1-1 MW	0.1-1 MW	1-10 MW	0.02-0.1 MW	0.1-1 MW	1-10 MW	0.02-0.1 MW
Electrical capacity (MW)	2.9	0.3	0.4	1.4	0.03	0.3	2.7	0.05
Thermal capacity (MW)	4.8	0.3	0.3	1.4	0.04	0.3	2.4	0.07
HE CHP electrical efficiency (%)	33%	39%	42%	38%	36%	38%	39%	34%
HE CHP thermal efficiency (%)	50%	38%	33%	37%	42%	37%	36%	47%
Self-consumption (%)	77%	97%	96%	100%	85%	92%	100%	86%
CHP electricity share (%)	90%	80%	71%	43%	85%	60%	68%	84%
Equivalent hours of electricity	5 577	4 046	4 924	4 281	4 563	4 661	5 866	4 037
Share of heat that can be cogenerated (%)	77%	30%	50%	55%	50%	15%	36%	40%
Cogenerated heat (MWh)	23 906	987	1 185	2 503	155	723	9 594	233
HE CHP electricity (MWh)	14 647	1 007	1 474	2 622	129	742	10 566	159
Total electricity produced (MWh)	16 260	1 263	2 087	6 155	152	1 236	15 648	190
Self-consumed electricity (MWh)	12 448	1 220	1 999	5 394	130	742	10 566	163
Electricity drawn from the grid (MWh)	5 447	1 111	5 064	-	75	-	-	232
Consumption of back-up boiler (MWh)	7 934	2 560	1 317	2 275	175	15 354	73 822	389

Consumption of HE CHP system (MWh)	44 990	2 588	3 524	6 825	357	1 953	26 849	472
Total CHP system consumption (MWh)	49 998	3 247	4 987	16 022	421	3 254	39 762	563

Case study	SME_steel	SME_mechanical engineering	SME_non-ferrous metals	SME_ceramics, glass	SME_paper	SME_textiles	SME_automotive	SME_woodworking
HE CHP technology	ICE	ICE	ICE	GT	ICE	ICE	ICE	ICE
System capacity	0.02-0.1 MW	0.02-0.1 MW	0.1-1 MW	0.02-0.1 MW	0.1-1 MW	0.02-0.1 MW	0.001-0.02 MW	0.1-1 MW
Electrical capacity (MW)	0.060	0.028	0.102	0.063	0.106	0.022	0.005	0.191
Thermal capacity (MW)	0.071	0.043	0.122	0.100	0.165	0.027	0.004	0.183
HE CHP electrical efficiency (%)	34%	33%	34%	37%	35%	35%	42%	38%
HE CHP thermal efficiency (%)	41%	49%	41%	40%	53%	43%	33%	37%
Self-consumption (%)	100%	69%	100%	79%	49%	77%	96%	100%
CHP electricity share (%)	39%	98%	39%	79%	100%	90%	71%	43%
Equivalent hours of electricity	2 630	3 314	2 630	5 179	2 654	2 841	4 924	4 281
Share of heat that can be cogenerated (%)	6%	50%	6%	15%	77%	30%	50%	55%
Cogenerated heat (MWh)	74	140	126	407	438	70	15	333
HE CHP electricity (MWh)	62	91	105	257	281	57	19	349
Total electricity produced (MWh)	157	93	268	326	281	63	27	819
Self-consumed electricity (MWh)	157	64	268	256	138	49	26	718
Electricity drawn from the grid (MWh)	950	275	754	396	189	116	66	-
Consumption of back-up boiler (MWh)	1 287	155	2 195	2 560	145	181	17	303

Consumption of HE CHP system (MWh)	181	272	309	699	813	160	46	908
Total CHP system consumption (MWh)	460	279	785	883	813	178	65	2 132

Figure 136: Energy demand of typical users with indication of cogenerated heat and electricity



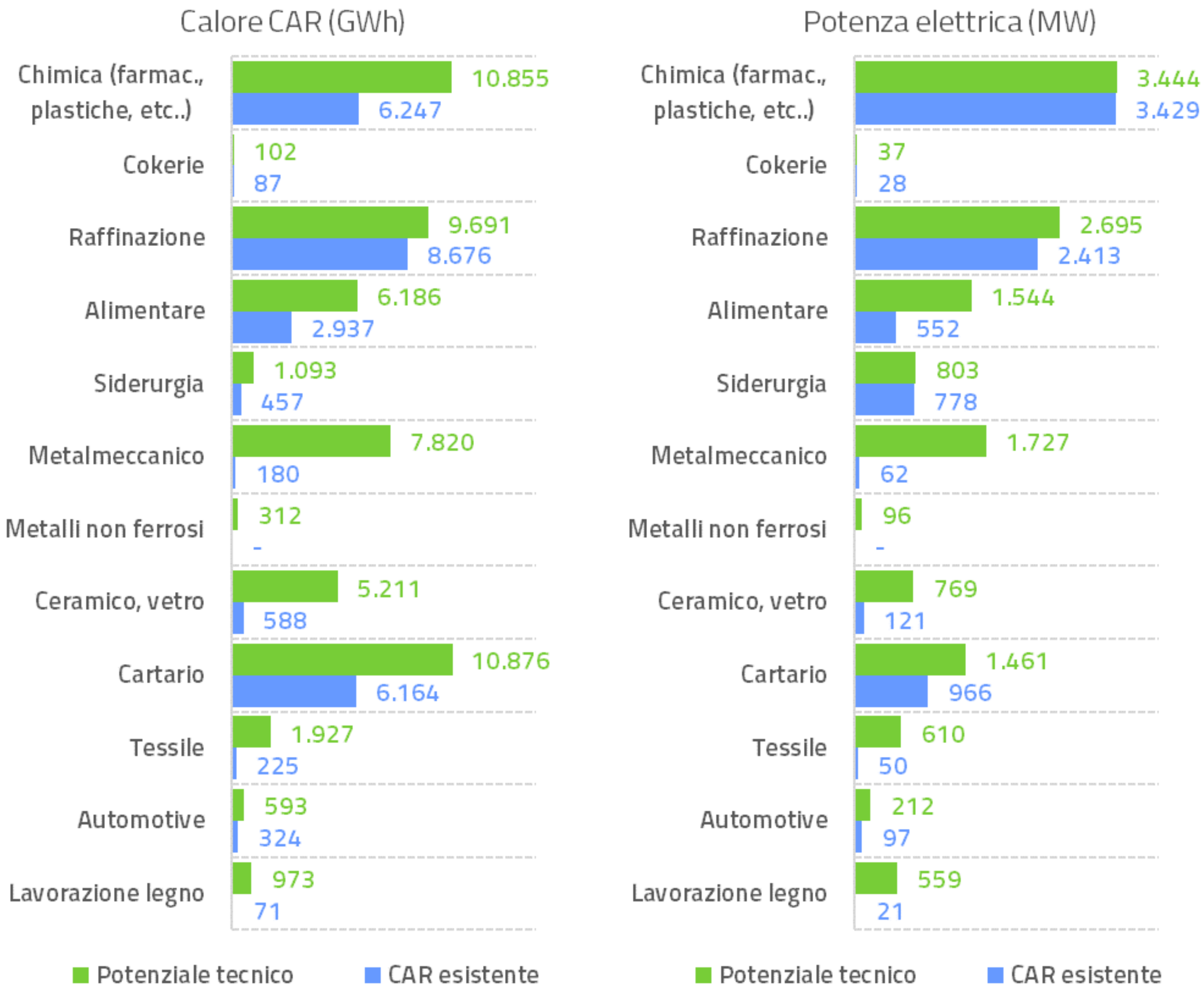
MGI_Chimica (farmac.,..	MLE_ chemistry (pharma, etc.)
MGI_Cokerie	MLE_coke ovens
MGI_Raffinazione	MLE_refineries
MGI_Alimentare	MLE_food
MGI_Siderurgia	MLE_steel
MGI_Metalmeccanico	MLE_mechanical engineering
MGI_Metalli non ferrosi	MLE_non-ferrous metals
MGI_Ceramico, vetro	MLE_ceramics, glass
MGI_Cartario	MLE_paper
MGI_Tessile	MLE_textiles
MGI_Automotive	MLE_automotive
MGI_Lavorazione legno	MLE_woodworking
PMI_Chimica (farmac.,...	SME_chemistry (pharma, etc.)
PMI_Cokerie	SME_coke ovens

PMI_Raffinazione	SME_refineries
PMI_Alimentare	SME_food
PMI_Siderurgia	SME_steel
PMI_Metalmeccanico	SME_mechanical engineering
PMI_Metalli non ferrosi	SME_non-ferrous metals
PMI_Ceramico, vetro	SME_ceramics, glass
PMI_Cartario	SME_paper
PMI_Tessile	SME_textiles
PMI_Automotive	SME_automotive
PMI_Lavorazione legno	SME_woodworking
Fabbisogno calore utenza tipo (GWh)	Heat demand of typical user (GWh)
Fabbisogno elettrico utenza tipo (GWh)	Power demand of typical user (GWh)

MGI_Chimica (farmac.,..	MLE_ chemistry (pharma, etc.)
MGI_Cokerie	MLE_coke ovens
MGI_Raffinazione	MLE_refineries
MGI_Alimentare	MLE_food
MGI_Siderurgia	MLE_steel
MGI_Metalmeccanico	MLE_mechanical engineering
MGI_Metalli non ferrosi	MLE_non-ferrous metals
MGI_Ceramico, vetro	MLE_ceramics, glass
MGI_Cartario	MLE_paper
MGI_Tessile	MLE_textiles
MGI_Automotive	MLE_automotive
MGI_Lavorazione legno	MLE_woodworking
PMI_Chimica (farmac.,...	SME_chemistry (pharma, etc.)
PMI_Cokerie	SME_coke ovens
PMI_Raffinazione	SME_refineries
PMI_Alimentare	SME_food
PMI_Siderurgia	SME_steel
PMI_Metalmeccanico	SME_mechanical engineering
PMI_Metalli non ferrosi	SME_non-ferrous metals
PMI_Ceramico, vetro	SME_ceramics, glass
PMI_Cartario	SME_paper
PMI_Tessile	SME_textiles
PMI_Automotive	SME_automotive
PMI_Lavorazione legno	SME_woodworking
Calore cogenerato (GWh)	Cogenerated heat (GWh)
Elettricità cogenerata (GWh)	Cogenerated electricity (GWh)

By extending the energy outputs obtained in the case study to the entire reference subsector, it is possible to estimate the technical potential; these values represent, on the basis of the assumptions made, the theoretical maximum amount of cogenerated heat and electricity technically obtainable in the industrial subsectors that can be supplied by a cogenerator, without considering economic and financial factors, which are discussed later.

Figure 137: Technical potential and existing HE CHP in the service sector. HE CHP heat (GWh) and electrical capacity (MW)

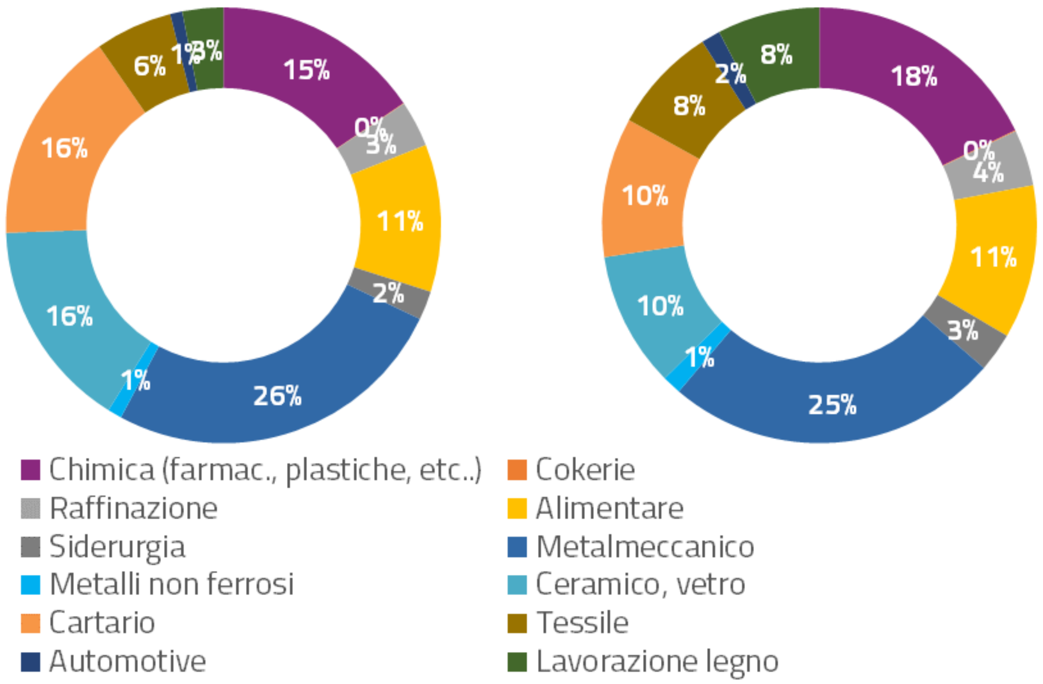


Calore CAR (GWh)	HE CHP heat (GWh)
Chimica (farmac., plastiche, etc..)	Chemistry (pharma, plastics, etc.)
Cokerie	Coke ovens
Raffinazione	Refineries
Alimentare	Food
Siderurgia	Steel industry
Metalmeccanico	Mechanical engineering
Metalli non ferrosi	Non-ferrous metals
Ceramico, vetro	Ceramics, glass
Cartario	Paper
Tessile	Textiles
Automotive	Automotive
Lavorazione legno	Woodworking
Potenziale tecnico	Technical potential
CAR esistente	Existing HE CHP

Potenza elettrica (MW)	Electrical capacity (MW)
Chimica (farmac., plastiche, etc..)	Chemistry (pharma, plastics, etc.)
Cokerie	Coke ovens

Raffinazione	Refineries
Alimentare	Food
Siderurgia	Steel industry
Metalmeccanico	Mechanical engineering
Metalli non ferrosi	Non-ferrous metals
Ceramico, vetro	Ceramics, glass
Cartario	Paper
Tessile	Textiles
Automotive	Automotive
Lavorazione legno	Woodworking
Potenziale tecnico	Technical potential
	Existing HE CHP

Figure 138: Incremental technical potential in industry. Distribution of HE CHP heat (GWh) and electrical capacity (MW)



Chimica (farmac., plastiche, etc..)	Chemistry (pharma, plastics, etc.)
Cokerie	Coke ovens
Raffinazione	Refineries
Alimentare	Food
Siderurgia	Steel industry
Metalmeccanico	Mechanical engineering
Metalli non ferrosi	Non-ferrous metals
Ceramico, vetro	Ceramics, glass
Cartario	Paper
Tessile	Textiles
Automotive	Automotive
Lavorazione legno	Woodworking

The paper and basic chemicals sectors have the greatest technical potential for HE CHP heat (11 TWh), followed by the refining sector. This is followed by mechanical engineering (7.8 TWh), food (6.2 TWh), ceramics (5.2 TWh) and then the other industries.

Overall, the industrial sector is associated with a technical potential of 55 638 GWh of heat, corresponding to a capacity of 13 957 MW.

However, it is important to interpret these results in the light of the existing HE CHP, inferring the incremental potential. Some particularly energy-intensive industrial sectors, such as refineries, appear to have largely already exhausted their technical development potential. The subsectors with the greatest growth potential are mechanical engineering (7.6 TWh), paper (4.7 TWh), ceramics (4.6 TWh), basic chemicals (4.6 TWh) and food (3.2 TWh).

Overall, the incremental potential of industry is 29 680 GWh of heat, which corresponds to a capacity of 6 790 MW. It should be noted that the incremental electrical capacity has not been calculated as the difference between the technical potential and the existing capacity, as this could lead to it being significantly underestimated; there are in fact several existing cases which have high capacity but few hours of use, while for new plants the average operating hours in the sector with the specific simulated technology were taken into account. Therefore, the incremental heat and electricity were calculated first and these were then used to determine the capacity of the plants needed to generate them, under simulated conditions.

8.5.3 Economic potential in the industrial sector

As described in detail in the methodology, a detailed business case was thus simulated for each typical user, considering the possible cost components, such as investment costs, O&M costs and fuel costs, including electricity drawn from the grid, as well as revenues from incentives and the possible sale of energy under the current regulatory conditions. The cash flows were compared with the baseline scenario for the sector, in which heat is assumed to be generated by a gas boiler, obtaining the relevant economic and financial performance indicators for investment in the cogeneration plant. As stated, the project IRR was used to determine the percentage of the technical potential that could be implemented, which translates into economic potential.

The economic potential results for different typical users in industry are shown below.

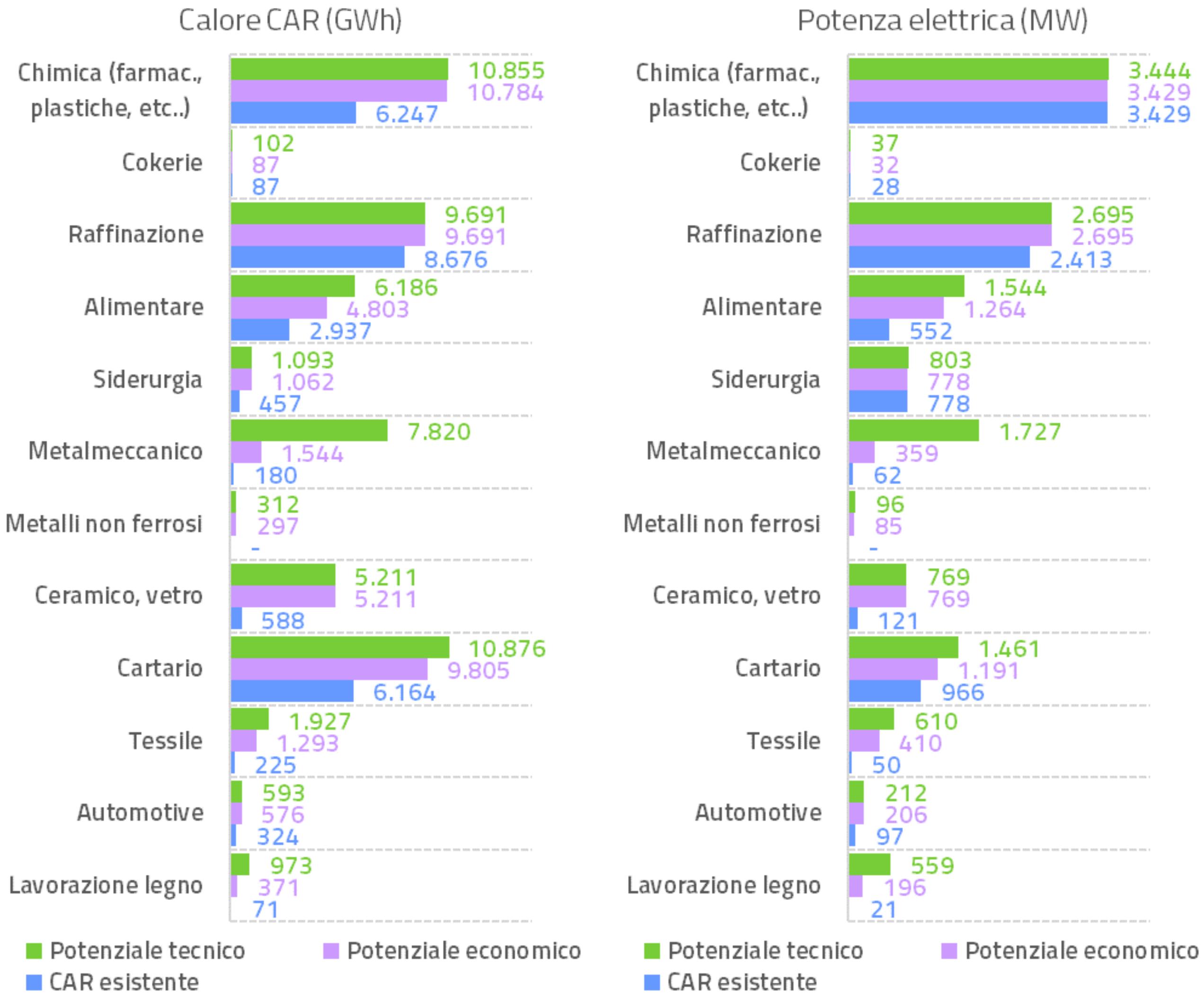
Table 76: Main costs and revenues of economic simulations and financial outputs in industry

Case study	MLE_chemistry (pharma, plastics, etc.)	MLE_coke ovens	MLE_refineries	MLE_food	MLE_steel	MLE_mechanical engineering	MLE_non-ferrous metals	MLE_ceramics, glass
CHP investment cost (mln EUR)	3.2	0.8	21.1	0.8	1.3	0.4	0.8	1.5
Annual CHP O&M cost (mln EUR)	0.3	0.1	0.8	0.1	0.1	0.0	0.1	0.1
CHP fuel cost (mln EUR)	1.6	0.3	6.5	0.4	0.5	0.1	0.3	0.8
Fuel cost for back-up boiler (mln EUR)	0.5	1.6	11.8	0.2	2.9	0.0	1.8	1.7
Cost of electricity drawn from the grid (mln EUR)	-	-	3.2	0.3	8.3	0.4	3.1	1.1
Revenues from feed-in energy (mln EUR)	0.1	0.1	2.5	0.0	0.1	0.0	0.1	0.0
Revenues from exchanged energy (mln EUR)	-	-	-	-	-	-	-	-
Revenues from white certificates (mln EUR)	0.5	0.1	2.0	0.1	0.2	0.0	0.1	0.1
Ex-ante backup boiler fuel cost (mln €)	1.1	1.7	14.8	0.4	3.1	0.1	1.9	2.0
Ex-ante cost of electricity drawn from the grid (mln €)	2.7	0.4	8.6	1.0	8.8	0.4	3.6	2.3
NPV (mln €)	6.4	0.8	18.7	1.9	1.3	0.0	1.2	3.0
IRR	>15%	>15%	>15%	>15%	>15%	10%	>15%	>15%
Discounted time for return on investment (years)	2.0	3.8	4.7	1.9	3.9	7.1	3.0	2.2

Case study	MLE_paper	MLE_textiles	MLE_automotive	MLE_woodworking	SME_chemistry (pharma, plastics, etc.)	SME_coke ovens	SME_refineries	SME_food
CHP investment cost (mln EUR)	2.1	0.4	0.4	1.0	0.1	0.3	1.9	0.1
Annual CHP O&M cost (mln EUR)	0.2	0.0	0.0	0.1	0.0	0.0	0.2	0.0
CHP fuel cost (mln EUR)	1.3	0.1	0.2	0.5	0.0	0.1	1.0	0.0
Fuel cost for back-up boiler (mln EUR)	0.2	0.1	0.0	0.1	0.0	0.5	1.9	0.0
Cost of electricity drawn from the grid (mln EUR)	0.8	0.2	0.7	-	0.0	-	-	0.0
Revenues from feed-in energy (mln EUR)	0.2	0.0	0.0	0.0	-	0.0	0.3	-
Revenues from exchanged energy (mln EUR)	-	-	-	-	0.0	-	-	0.0
Revenues from white certificates (mln EUR)	0.5	0.0	0.0	0.1	0.0	0.0	0.3	0.0
Ex-ante backup boiler fuel cost (mln €)	0.9	0.1	0.1	0.2	0.0	0.5	2.2	0.0
Ex-ante cost of electricity drawn from the grid (mln €)	2.5	0.3	1.0	0.8	0.0	0.1	1.5	0.1
NPV (mln €)	6.4	0.1	0.2	1.1	<0	<0	3.4	<0
IRR	>15%	>15%	>15%	>15%	Not cost-effective	1%	>15%	Not cost-effective
Discounted time for return on investment (years)	1.4	4.5	3.1	3.8		7.7	2.1	

Case study	SME_steel	SME_mechanical engineering	SME_Non-ferrous metals	SME_ceramics, glass	SME_paper	SME_Textiles	SME_Automotive	SME_woodworking
CHP investment cost (mln EUR)	0.1	0.1	0.2	0.1	0.2	0.1	0.0	0.3
Annual CHP O&M cost (mln EUR)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHP fuel cost (mln EUR)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Fuel cost for back-up boiler (mln EUR)	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Cost of electricity drawn from the grid (mln EUR)	0.2	0.1	0.1	0.1	0.0	0.0	0.0	-
Revenues from feed-in energy (mln EUR)	-	-	-	-	-	-	-	0.0
Revenues from exchanged energy (mln EUR)	-	0.0	-	0.0	0.0	0.0	0.0	-
Revenues from white certificates (mln EUR)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ex-ante backup boiler fuel cost (mln €)	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Ex-ante cost of electricity drawn from the grid (mln €)	0.2	0.1	0.2	0.1	0.1	0.0	0.0	0.1
NPV (mln €)	<0	<0	<0	0.2	<0	<0	<0	<0
IRR	Not cost-effective	Not cost-effective	Not cost-effective	>15%	3%	Not cost-effective	Not cost-effective	Not cost-effective
Discounted time for return on investment (years)				1.8	13.4	<0		

Figure 139: Technical potential, economic potential and existing HE CHP in the service sector. HE CHP heat (GWh) and electrical capacity (MW)

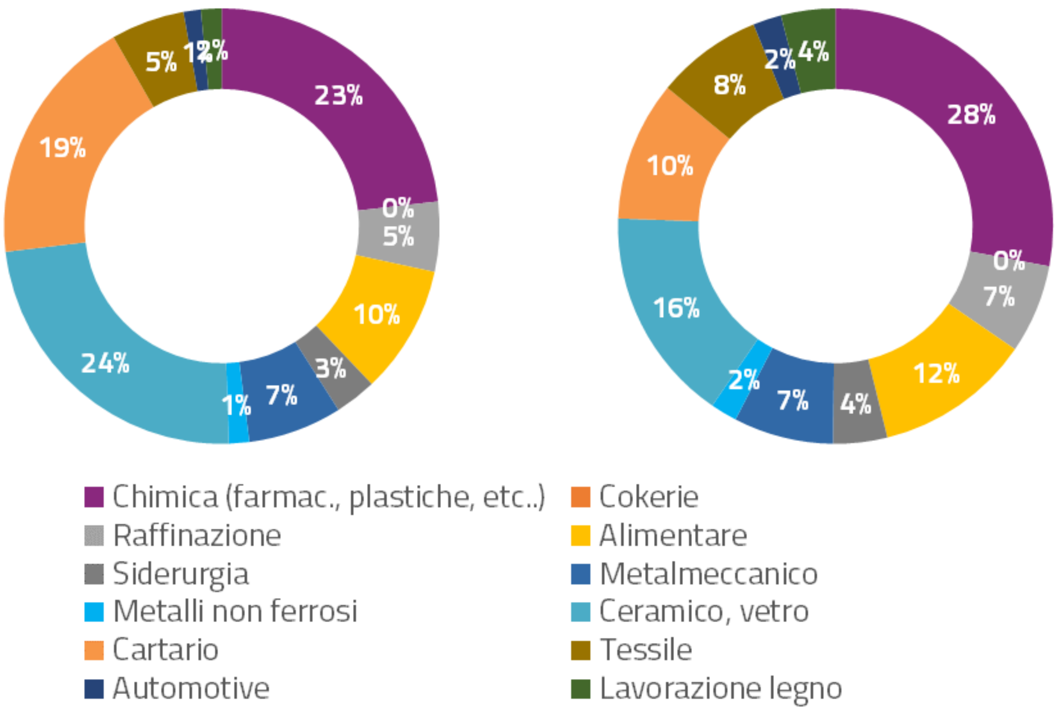


Calore CAR (GWh)	HE CHP heat (GWh)
Chimica (farmac., plastiche, etc..)	Chemistry (pharma, plastics, etc.)
Cokerie	Coke ovens
Raffinazione	Refineries
Alimentare	Food
Siderurgia	Steel industry
Metalmeccanico	Mechanical engineering
Metalli non ferrosi	Non-ferrous metals
Ceramico, vetro	Ceramics, glass
Cartario	Paper
Tessile	Textiles
Automotive	Automotive
Lavorazione legno	Woodworking
Potenziale tecnico	Technical potential
Potenziale economico	Economic potential
CAR esistente	Existing HE CHP

Potenza elettrica (MW)	Electrical capacity (MW)

Chimica (farmac., plastiche, etc..)	Chemistry (pharma, plastics, etc.)
Cokerie	Coke ovens
Raffinazione	Refineries
Alimentare	Food
Siderurgia	Steel industry
Metalmeccanico	Mechanical engineering
Metalli non ferrosi	Non-ferrous metals
Ceramico, vetro	Ceramics, glass
Cartario	Paper
Tessile	Textiles
Automotive	Automotive
Lavorazione legno	Woodworking
Potenziale tecnico	Technical potential
Potenziale economico	Economic potential
CAR esistente	Existing HE CHP

Figure 140: Incremental economic potential in the service sector. Distribution of HE CHP heat (GWh) and electrical capacity (MW)



Chimica (farmac., plastiche, etc..)	Chemistry (pharma, plastics, etc.)
Cokerie	Coke ovens
Raffinazione	Refineries
Alimentare	Food
Siderurgia	Steel industry
Metalmeccanico	Mechanical engineering
Metalli non ferrosi	Non-ferrous metals
Ceramico, vetro	Ceramics, glass
Cartario	Paper
Tessile	Textiles
Automotive	Automotive
Lavorazione legno	Woodworking

Overall, the industrial sector is associated with an economic potential of **45 523 GWh** of heat, corresponding to a capacity of **11 415 MW**. This potential is around 1.7 times greater than the current installed capacity, and thus still identifies significant growth margins, from a financial point of view, in different sectors of industry.

The chemical (10.8 TWh) and paper (9.8 TWh) sectors have the greatest economic potential for HE CHP heat, followed by the refining sector (9.7 TWh). This is followed by ceramics (5.2 TWh) and food (4.8 TWh).

In comparison to existing development, at energy-intensive users such as refineries, the high economic potential seems largely to be already exploited by the plants currently in operation. The sectors with the greatest incremental potential are ceramics (4.6 TWh), basic chemicals (4.5 TWh) and paper (around 3.6 TWh), followed by food (1.9 TWh) and mechanical engineering (1.4 TWh).

Overall, the incremental potential of industry is 19 566 GWh of heat, which corresponds to a capacity of 4 272 MW. For the reasons already mentioned under technical potential, the incremental electrical capacity was not calculated simply as the difference between the capacity of the economic potential and the existing capacity.

The economic analysis of the cash flows generated over the useful life of the CHP investment showed no or limited profitability in some of the subsectors with relevant incremental technical potential, such as mechanics, woodworking, some textiles sectors (yarns, weaving, other textile industries), especially as regards SMEs.

8.6HE CHP potential in the service sector

The HE CHP potential for the service sector was calculated by characterising the heat demand for that sector. The subsectors most relevant for HE CHP were identified, and the energy demand of typical reference users within these subsectors was defined. On the basis of a number of considerations and technical constraints, the proportion of heat demand that can be technically met by high-efficiency cogeneration has been determined; extending this result to the reference population of the typical user in question gives the technical potential. The economic and financial potential, in terms of the heat that can be produced using HE CHP and, consequently, the capacity that can be installed, has been calculated by means of an economic and financial analysis carried out on different application scenarios for cogeneration plants.

8.6.1 Characterisation of heat demand in the service sector

As described in more detail in Sections 1.3 and 2.2 of the analysis of energy demand in the service sector, in 2018, consumption in end uses in the service sector totalled 19.1 Mtoe; electricity accounted for 43% of consumption, followed by gas (38%) and renewables (14%). As regards heating and DHW, heat demand in the service sector totalled 11.2 Mtoe (130.5 TWh).

The majority of the heating and DHW needs within the service sector can be attributed to trade (53%), divided among a very large number of users;

followed by healthcare (9%), offices and sports facilities (7%) and then by other subsectors.

Based on an analysis of the existing HE CHP plants in the service sector, and on the basis of technical considerations relating to the size and profile of the heat and power demand, in the present study a number of typical users, belonging to certain subsectors, were selected as being of significant interest for HE CHP, and, in particular:

- **hospitals**: large healthcare facilities with a floor area greater than 5 000 m^2 were considered;
- **hotels**: 4- and 5-star hotels, which, due to the services they offer, have greater specific needs, were considered, as well as large hotels (floor area of more than 3 000 m^2);
- **swimming pools and sports centres**: large facilities with a floor area greater than 2 000 m^2 and typically with a swimming pool, for which the heat demand is not only high but also fairly constant throughout the year, were considered;
- **shopping centres**: large-scale retail establishments, which due to their large size could potentially use HE CHP, were considered;
- **schools**: large schools, with a floor area greater than 2 000 m^2, were considered;
- **universities and research centres**: facilities which are not particularly energy-intensive but which, because of their large size (often due to there being several buildings belonging to the same establishment) have complex needs that could potentially be met by HE CHP;
- **offices**: large office buildings with a floor area greater than 2 000 m^2.

Users most likely to benefit from HE CHP generally have high heat demand and, at the same time, high levels of electricity consumption, such as hospitals, sports centres and hotels. In particular, priority was given to those sports centres with a swimming pool, as they are particularly energy-intensive and have very high heat demand throughout the whole year[57]. As these users tend to have high heat demand throughout the year, and not only during the winter months, the operating hours of the cogenerator substantially increase and, by contrast, the time for return on the investment decreases. In addition, the climate factor has far less of an impact in these cases than in the residential sector.

The heat and power demand of the aforementioned typical users was characterised on the basis of studies from the sector literature[58], and specific processing carried out by GSE, including on the basis of area and consumption parameters taken from measures incentivised under the Conto Termico; for each user, therefore, specific requirements per unit of land

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[57] These considerations are in line with the results of a number of studies in the sector (see, for example: R. Loschi 'Cogeneration: application in the service sector in Italy', M. Vio 'Cogeneration plants', etc.).

[58] RSE study – Consumption in the service sector: hotels and large-scale retail trade, 2015. RdS 15000305.
RSE study – HE CHP potential 2015. RdS 15008445.
RSE study – HE CHP potential 2015. RdS 14009625.
RSE study – Energy consumption by public bodies Rds 14009243.
RSE study – A. Gelmini, F. Bazzocchi 'GDPint – an application for the technical and economic evaluation of energy districts', McTer presentation, Milan, 28 June 2012.
Aprea et al. 'Energy retrofitting of a swimming pool', AICARR Journal, September 2014 (a real case of HE CHP application is described in detail).

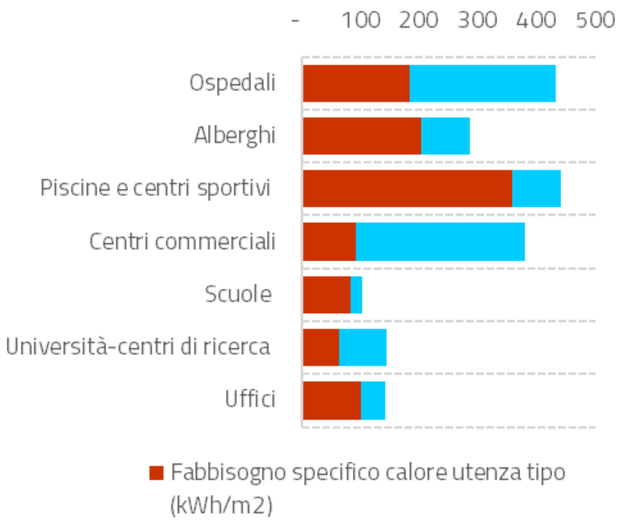
area were identified, and at the same time the number of users of this type, the average area and the total area thereof were estimated. The heat and power demand of the typical users and of their reference populations, which constitutes, by design, a subset of the demand of the relevant subsector, were thus determined.

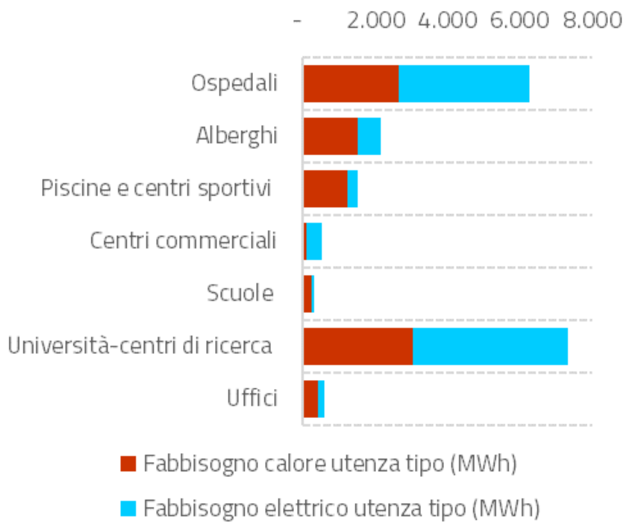
The heat and power demand in the above cases, and for the corresponding reference populations, are illustrated below. It should be noted that the overall heat demand of the reference populations of the typical users totals around 29 TWh, equivalent to 22% of the total heat demand in the service sector.

Table 77: Heat and power demand of the typical users chosen and the corresponding reference populations

typical user	Specific heat demand of typical user (kWh/m^2)	Specific power demand of typical user (kWh/m^2)	Heat demand of typical user (MWh)	Power demand of typical user (MWh)	Total heat demand of typical user sector (MWh)	Total power demand of typical user sector (MWh)
Hospitals	184	249	2 664	3 593	6 461 239	8 716 112
Hotels	203	84	1 512	626	4 313 149	1 786 491
Swimming pools and sports facilities	360	82	1 240	282	4 855 279	1 103 936
Shopping centres	92	28	96	419	2 571 224	8 913 725
Schools	84	20	241	57	3 661 586	774 440
Universities and research centres	63	81	3 027	4 300	1 396 314	1 785 548
Offices	102	42	429	175	5 692 421	2 325 911
Total					**28 951 211**	**25 406 163**

Figure 141: Heat and power demand of the typical users chosen and the corresponding reference populations





Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres
Scuole	Schools
Università-centri di ricerca	Universities and research centres
Uffici	Offices
Fabbisogno specifico calore utenza tipo (kWh/m2)	Specific heat demand of typical user (kWh/m^2)

Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres
Scuole	Schools
Università-centri di ricerca	Universities and research centres
Uffici	Offices
Fdbbisogno calore utenza tipo (MWh)	Heat demand of typical user (MWh)
Fabbisogno elettrico utenza tipo (MWh)	Power demand of typical user (MWh)

It should be noted that, in terms of the demand from individual typical users, universities and research centres and hospitals have the greatest demand; hospitals also have the highest overall consumption, followed by shopping centres and offices.

8.6.2 Technical potential in the service sector

After characterising the demand for heat and power from the typical users considered, the CHP system was chosen, its size estimated and its operating conditions simulated.

The choice of reference technology followed the current market trend in these sectors, in which use of internal combustion engines powered by natural gas is widespread (almost exclusive).

The size of the cogenerators was determined on a case-by-case basis, taking into account the typical capacities of the existing plants in the sectors, as listed in the GSE CHP database, and considering the H/E ratio of the user, the typical operating hours of the plants and the share of heat that can be cogenerated according to several case studies analysed by RSE.

The operating conditions were simulated using the specific performance indicators taken from operating data of similar users from an energy demand point of view, processed by the HE CHP database, for each subsector. In particular, the hours of operation (in HE CHP and electricity-only mode), the electric and thermal efficiency, the share of self-consumption, etc. were estimated. It has been assumed that the cogenerator will be installed at a demand point receiving its electricity from the national grid and heat from a gas boiler with efficiency in line with the market baseline (90% efficiency), to be maintained after installation of the cogenerator to serve as a backup boiler.

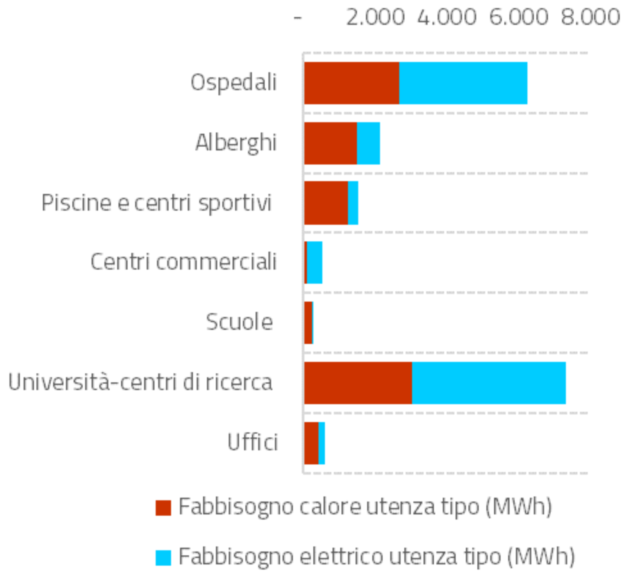
As shown by the results of the simulations, only a share of the user’s heat demand would be covered by the HE CHP system. Most of the share of heat demand which cannot be covered by the cogenerator is due to peaks in demand, the non-simultaneous presence of electrical and thermal loads and a heat-power ratio that is not always favourable for CHP applications, and is highly dependent on the specific area of reference. Although there are solutions, such as hot water tanks and electrical batteries, to distribute the thermal and electrical load over time, costs and space constraints hinder their deployment.

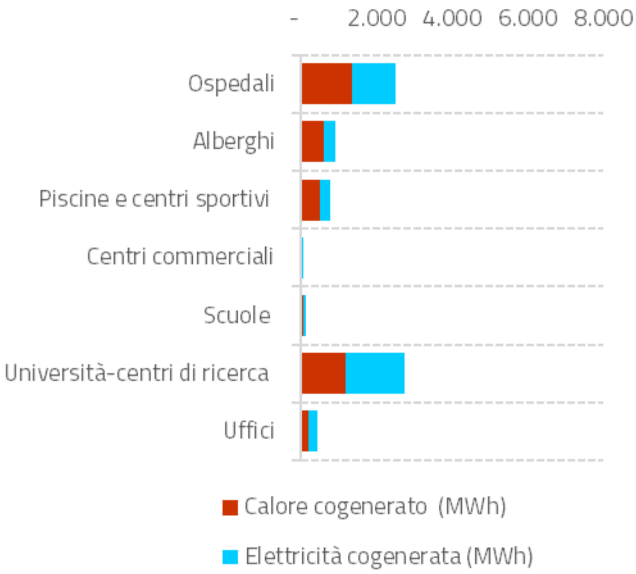
Table 78: Technical parameters and energy outputs of HE CHP systems under the operating conditions assumed for the service sector

Case study	Hospitals	Hotels	Swimming pools and sports facilities	Shopping centres	Schools	Universities and research centres	Offices
HE CHP technology	ICE gas	ICE gas	ICE gas	ICE gas	ICE gas	ICE gas	ICE gas
System capacity	0.1-1 MW	0.02-0.1 MW	0.02-0.1 MW	0.001-0.02 MW	0.02-0.1 MW	0.1-1 MW	0.02-0.1 MW
Electrical capacity (MW)	0.255	0.069	0.098	0.009	0.027	0.527	0.080
Thermal capacity (MW)	0.340	0.139	0.182	0.016	0.049	0.519	0.096
HE CHP electrical efficiency (%)	35%	29%	31%	32%	31%	38%	35%
HE CHP thermal efficiency (%)	45%	58%	57%	57%	56%	37%	41%
Self-consumption (%)	96%	93%	69%	84%	62%	53%	94%
CHP electricity share (%)	93%	100%	100%	92%	100%	79%	76%
Equivalent hours of electricity	4 382	4 550	2 896	2 293	1 954	2 954	2 889
Share of heat that can be cogenerated (%)	52%	42%	81%	36%	40%	0.4	50%
Cogenerated heat (MWh)	1 385	630	526	34	97	1 211	212
HE CHP electricity (MWh)	1 039	313	282	19	52	1 228	175
Total electricity produced (MWh)	1 118	314	283	21	52	1 556	230
Self-consumed electricity (MWh)	1 072	293	195	18	32	823	175
Electricity drawn from the grid (MWh)	2 521	333	87	401	24	3 477	-

Consumption of back-up boiler (MWh)	1 421	980	793	69	161	2 018	242
Consumption of HE CHP system (MWh)	2 993	1 078	919	60	169	3 243	503
Total CHP system consumption (MWh)	3 223	1 081	923	65	169	4 109	661

Table 79: Energy demand of typical users with indication of cogenerated heat and electricity





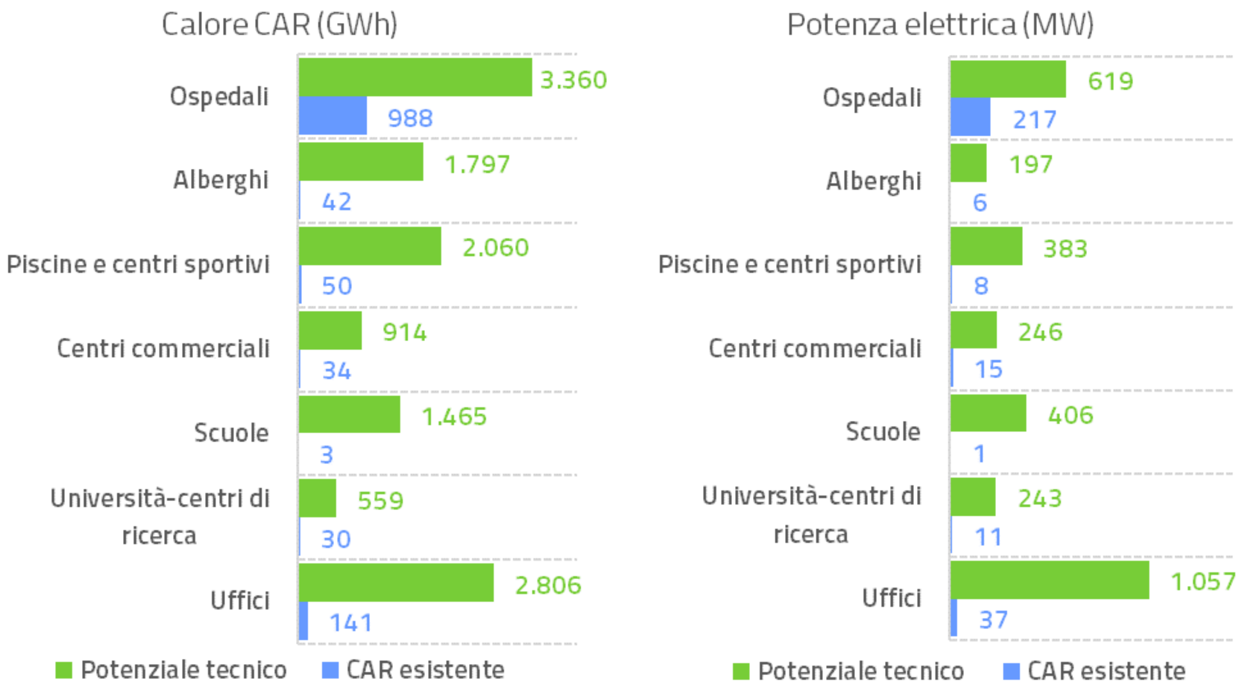
Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres
Scuole	Schools
Università-centri di ricerca	Universities and research centres
Uffici	Offices
Fabbisogno calore utenza tipo (MWh)	Heat demand of typical user (MWh)
Fabbisogno elettrico utenza tipo (MWh)	Power demand of typical user (MWh)

Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres
Scuole	Schools

Università-centri di ricerca	Universities and research centres
Uffici	Offices
Calore cogenerato (MWh)	Cogenerated heat (MWh)
Elettricità cogenerata (MWh)	Cogenerated electricity (MWh)

By extending the energy outputs obtained in the case study to the entire reference subsector, it is possible to estimate the technical potential; these values represent, on the basis of the assumptions made, the theoretical maximum amount of cogenerated heat and electricity technically obtainable in the service subsectors that can be supplied by a cogenerator, without considering economic and financial factors, which are discussed later.

Table 80: Technical HE CHP potential and existing HE CHP potential in the service sector. HE CHP heat (GWh) and electrical capacity (MW)

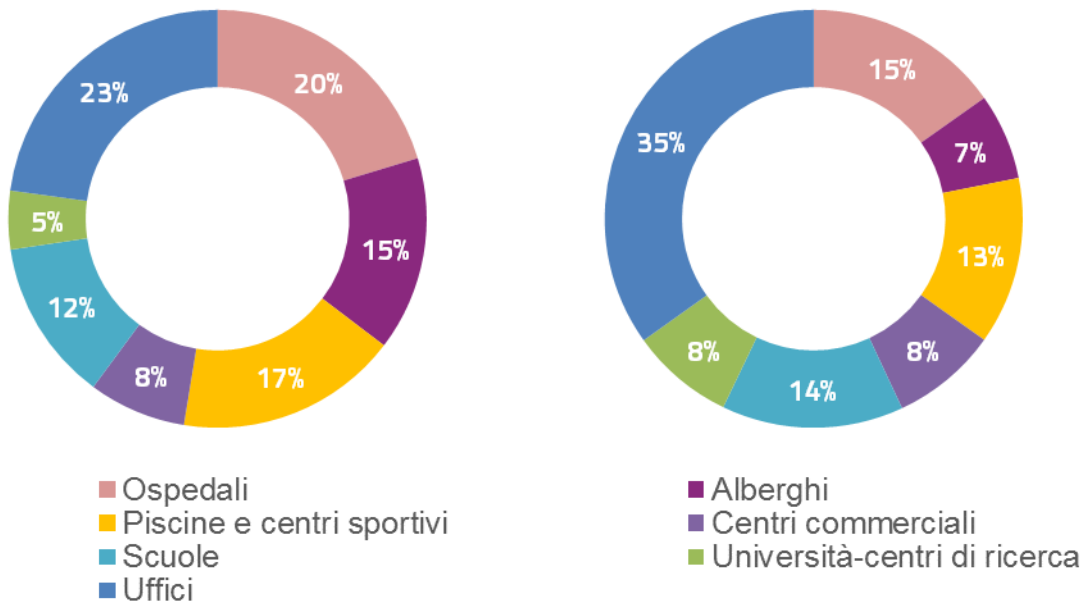


Calore CAR(GWh)	HE CHP heat (GWh)
Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres
Scuole	Schools
Università-centri di ricerca	Universities and research centres
Uffici	Offices
Potenziale tecnico	Technical potential
CAR esistente	Existing HE CHP

Potenza elettrica (MW)	Electrical capacity (MW)
Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres

Scuole	Schools
Università-centri di ricerca	Universities and research centres
Uffici	Offices
Potenziale tecnico	Technical potential
CAR esistente	Existing HE CHP

Table 81: Incremental technical potential in the service sector. Distribution of HE CHP heat (GWh) and electrical capacity (MW)



Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres
Scuole	Schools
Università-centri di ricerca	Universities and research centres
Uffici	Offices

Overall, the service sector is associated with a technical potential of **12 960 GWh** of heat, corresponding to a capacity of **3 152 MW**.

Hospitals account for the greatest share of technical potential (3.4 TWh of heat), followed by offices (2.8 TWh) and swimming pools and large shopping centres with 2.0 TWh of heat. Hospitals are also the type of user in the service sector with the highest current level of development (around 1.0 TWh), demonstrating that HE CHP is very suitable for such facilities, which have a high heat and power demand that is mostly constant throughout the year. This results in an incremental potential that, in terms of heat, is distributed quite widely between offices, hospitals, swimming pools/sports centres, hotels and schools.

8.6.3 Economic potential in the service sector

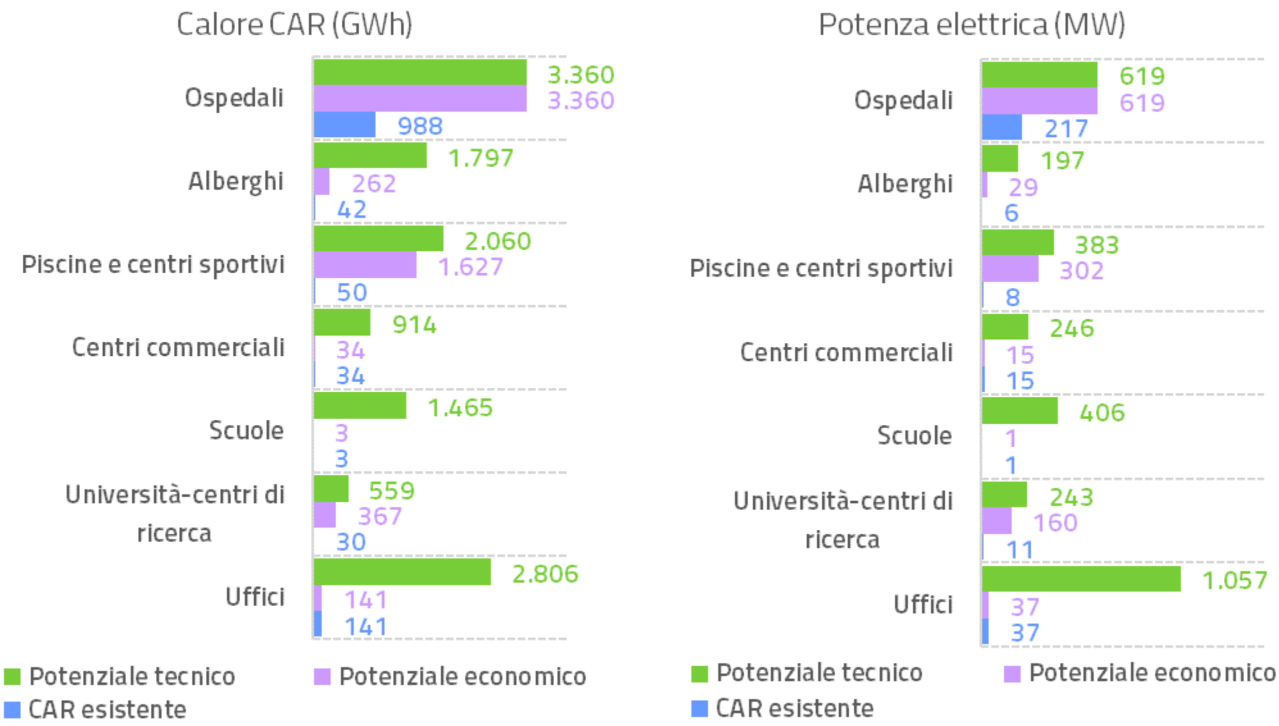
As described in detail in the methodology, a detailed business case was thus simulated for each user, considering the possible cost components, such as investment costs, O&M costs and fuel costs, including electricity drawn from the grid, as well as revenues from incentives and the possible sale of energy under the current regulatory conditions. The cash flows were compared with the baseline scenario for the sector, in which heat is assumed to be generated by a gas boiler, obtaining the relevant economic and financial performance indicators for investment in the cogeneration plant. As stated, the project IRR was used to determine the percentage of the technical potential that could be implemented, which translates into economic potential.

The economic potential results for different typical users in the service sector are shown below.

Table 82: Main costs and revenues of economic simulations and financial outputs in the service sector

Case study	Hospitals	Hotels	Swimming pools and sports facilities	Shopping centres	Schools	Universities and research centres	Offices
CHP investment cost (€)	334 604	161 798	196 201	28 982	84 709	505 663	175 205
Annual CHP O&M cost (€)	20 939	11 380	8 259	2 898	3 877	23 928	7 603
CHP fuel cost (€)	113 310	48 324	47 243	3 873	10 055	159 603	32 660
Fuel cost for back-up boiler (€)	51 283	44 598	50 518	4 124	11 594	109 569	15 391
Cost of electricity drawn from the grid (€)	398 600	54 406	16 333	75 308	5 403	549 768	-
Revenues from feed-in energy (€)	2 431	-	59	-	0	38 347	2 875
Revenues from exchanged energy (€)	-	1 713	6 959	262	1 590	-	0
Revenues from white certificates (€)	31 720	13 260	11 700	780	2 080	30 940	5 720
Ex-ante backup boiler fuel cost (€)	106 839	76 454	87 736	6 400	19 323	182 616	30 349
Ex-ante cost of electricity drawn from the grid (€)	568 071	102 194	52 927	78 638	12 626	679 871	32 928
NPV (€)	342 000	6 626	67 792	<0	<0	162 472	<0
IRR	>15%	8%	13%	Not cost-effective	Not cost-effective	12%	Not cost-effective
Discounted time for return on investment (years)	3.4	6.7	7.5			8.6	

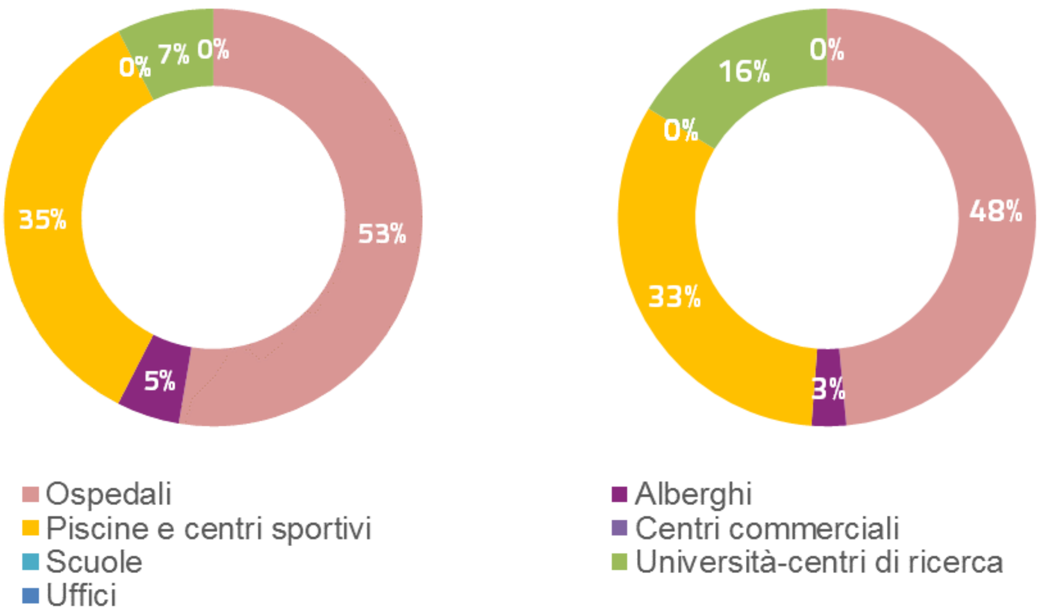
Figure 142: Technical potential, economic potential and existing HE CHP in the service sector. HE CHP heat (GWh) and electrical capacity (MW)



Calore CAR(GWh)	HE CHP heat (GWh)
Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres
Scuole	Schools
Università-centri di ricerca	Universities and research centres
Uffici	Offices
Potenziale tecnico	Technical potential
Potenziale economico	Economic potential
CAR esistente	Existing HE CHP

Potenza elettrica (MW)	Electrical capacity (MW)
Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres
Scuole	Schools
Università-centri di ricerca	Universities and research centres
Uffici	Offices
Potenziale tecnico	Technical potential
Potenziale economico	Economic potential
CAR esistente	Existing HE CHP

Figure 143: Incremental economic potential in the service sector. Distribution of HE CHP heat (GWh) and electrical capacity (MW)



Ospedali	Hospitals
Alberghi	Hotels
Piscine e centri sportivi	Swimming pools and sports facilities
Centri commerciali	Shopping centres
Scuole	Schools
Università-centri di ricerca	Universities and research centres
Uffici	Offices

Overall, the service sector is associated with an economic potential of **5 793 GWh** of heat, corresponding to a capacity of **1 163 MW.** This potential is around three times greater than the current installed capacity, demonstrating the significant growth potential for HE CHP in the service sector.

Hospitals account for the largest share of the economic potential (3.4 TWh of heat), equal to the entire technical potential identified, demonstrating that HE CHP is particularly suitable for these establishments. This is followed by sports centres/swimming pools, with 1.6 TWh. Hospitals and sports centres/swimming pools therefore also make the largest contributions in terms of incremental potential in relation to existing development.

Universities/research centres and hotels also show significant growth margins, with an incremental economic potential for HE CHP heat of 0.3 and 0.2 TWh respectively. Intermediate cost-effectiveness has been noted for these establishments, which is largely dependent on specific characteristics in terms of size and demand, which can also vary considerably in these users.

On the other hand, under current regulatory conditions, there is no scope for cost-effective installations in offices, shopping centres and schools. As mentioned above, this result is to be understood as referring to the simulated typical cases and the related assumptions made, without ruling out the possibility that there may be conditions different to the average case represented here for which a significant economic result may be obtained.

8.7 HE CHP potential in the residential sector

The development of high-efficiency CHP in the residential sector, albeit with a sizeable number of installations (estimated at 243 units), is somewhat low in terms of energy output. The installed electrical capacity amounts to 3.1 MWe, equivalent to just 0.02% of the total high-efficiency CHP capacity installed in Italy, while cogenerated heat is just under 11 GWh and covers only a fraction of the total heating demand from the residential sector.

The main barriers that so far have hampered the deployment of high-efficiency CHP in the residential sector, and which are likely to persist at least in part in the near future, can be classed as technical, regulatory, economic and behavioural.

As concerns technical issues, the main hurdles are the characteristics of the demand for heat and electricity of residential users. This is fairly low (even in the coldest parts of the country) and short-lived, with strong load fluctuations over time, a possible time mismatch between demand for heat and for power, and h/e ratios which often sees much higher demand for heat.

All these technical factors inevitably have economic consequences. Residential customers usually demand micro-CHP installations (<50 kW) which have not yet achieved economies of scale making them fully competitive under the current market conditions. Specific investment costs have a more than linear increase with decreasing size. This has a significant negative impact on return on investment, in view of the small number of hours of operation of residential sector installations (usually less than 2 000 equivalent hours). Moreover, the variable production costs are significant on account of the high prices of fuel and poorer electrical efficiency[59] compared with larger-sized systems. This prevents the production of electricity at competitive costs compared with prices on the electricity market. Consequently, these CHP installations operate only where electricity self-consumption or net metering are available.

From the regulatory viewpoint, micro-CHP installations in the residential sector are eligible for a greater rebate of excise duty compared with other sectors, since the excise duty differential on fuel supplying the cogenerator in the civil sector is much wider than in other sectors; however, since the electrical efficiency of these systems is lower than that of larger installations, the share of CHP consumption to which the rebate applies is lower, marginally offsetting the added benefits of the tax rebate[60]. The

[59] In the case of gas, the main fuel for these systems, the higher excise duties applied to the sector and the higher market price on account of the lower economies of scale makes its final price much higher than that of gas supplied to CHP systems in a utility or an energy-intensive industrial plant. As concerns electrical efficiency, HE CHP applications in the residential sector are usually about 10 percentage points less efficient than larger CHP systems; although this shortfall is balanced by better heat efficiency, in economic terms, the overall balance is negative.

[60] The excise duty on gas for civil uses, taking into account the different consumption bands and standard consumption by users, ranges from 17 to 19 €c/Nm^3, while excise duty on industrial uses ranges, according to consumption, from 0.75 to 1.25 €c/Nm^3. The excise duty on the gas used by cogenerators below the specific electric consumption threshold of 0.22 kWh/Nm^3 is discounted and amounts respectively to 0.04493 €c/Nm^3 and 0.013479 €c/Nm^3 according to whether it applies to electricity production or self-production. For the typical efficiencies of

schemes supporting HE CHP systems, particularly white certificates, despite including elements designed to increase the premium[61] for small-size installations, are unable to offset the higher investment and operation costs.

One aspect of the current regulations that severely limits the viability of residential installations is the fact that HE CHP can only supply electricity for common utilities; this is relevant in apartment blocks, where, with numerous dwellings, the possibility of meeting the power demand of individual users would drastically change the size of the cogenerator and the corresponding economic drivers. Currently, collective self-consumption groups and energy communities can only use applications powered by renewable sources.

The HE CHP potential for the residential sector was calculated by characterising the heat demand for cases deemed to be most suited to HE CHP systems. On the basis of a number of considerations and technical constraints, the proportion of heat demand that can be technically met by high-efficiency cogeneration has been determined; extending this result to the reference population of the typical user in question gives the technical potential. The economic and financial potential, in terms of the heat that can be produced using HE CHP and, consequently, the capacity that can be installed, has been calculated by means of an economic and financial analysis carried out on different application scenarios for cogeneration plants.

8.7.1 Characterisation of heat demand in the residential sector

Characterisation of heat demand in the residential sector, already extensively described in the opening chapter of the report, was based on multiple sources of information, starting with the consumption data from the 2018 national energy balance.

Overall, residential heat consumption in 2018 totalled around 31.9 Mtoe. Gas was the main source used (52%), followed by renewables (20%) and electricity (18%).

In 2018, the total demand for heating and cooling by Italian households exceeded 27.5 Mtoe, including almost 21.2 Mtoe for space heating, about 3.9 Mtoe for domestic hot water production, 2.1 for cooking and 0.2 for summer air conditioning. Excluding uses relating to cooking, which upon an initial assessment are not considered to be easily replaceable by efficient district heating or by high efficiency cogeneration, the heat consumption relevant to subsequent assessments is thus 25.1 Mtoe, equal to 291 TWh, 84% of which is used for winter heating and the remaining 16% for domestic hot water consumption.

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residential installations, which range from 15% to 30%, the final excise duty applied to the gas used by the cogenerator is in the range of 8-12 €c/Nm^3, thus with a final rebate on excise duty between 5 and 11 €c/Nm^3, much higher than the rebates available in the industrial sector.

[61] Certain factors are used to increase the calculation of the primary energy savings against which white certificates are granted. They include coefficient K, ranging from 1 to 1.4, which increases with the plant's decreasing size, and the factor that takes into account savings of network losses, which are higher for installations connected in low voltage mode.

Since, for the reasons described in the previous paragraph, the development of HE CHP in the residential sector has been very moderate, it was considered appropriate to focus the analysis in this study on a number of typical cases, deemed to be potentially suitable for HE CHP on the basis of analysis of existing installations, and on the basis of technical considerations relating to the size of heat and power demand. Specifically:

- **single-family homes**: houses with a stand-alone heating system and located in climate zones E and F have been considered;
- **medium-sized apartment blocks**: apartment blocks with 5–15 dwellings, with a high level of occupancy (above 50%), central heating and located in climate zones E and F have been considered;
- **large apartment blocks**: apartment blocks with 16 dwellings or more, with a high level of occupancy (more than 50%), central heating and located in climate zones E and F have been considered.

As indicated, after an initial overall survey, it was decided to focus the analysis in climate zones E and F, because of the greater demand. In addition, only apartment blocks with a high level of occupancy (greater than 50%) have been taken into account, firstly to increase the accuracy when determining the demand of each typical user, given that, especially in zone F, which tends to attract a lot of tourists, many apartment blocks are not permanently occupied; secondly, it was considered that apartment blocks with a low occupancy rate were likely to be less interested in investing in HE CHP installations, for which cost-effectiveness depends largely on self-consumption. Lastly, again in relation to apartment blocks, only those with central heating have been considered, given that, where each of the flats has an independent heating system, the system conversion required and the likely unwillingness of residents to switch to central heating would effectively make the CHP option infeasible.

The heat and power demand for the aforementioned typical users was defined based on the overall demand, considering all the available information in great detail, down to census zone, building stock and related floor area, population, systems etc.

In the case of single-family homes, the total demand for heat and power has been considered (excluding demand for cooking). In the case of apartment blocks, the CHP system can only cover the demand for power in the building's common areas (lighting, lifts, etc.) under current regulations. Furthermore, with regard to heat consumption, the only demand technically attributable to the CHP system is that for space heating, excluding the demand for DHW which is almost always covered by individual units[62].

By determining the demands of the populations relating to the selected typical users and their size in terms of number and area, the average demand could be calculated and used as a reference for the simulations at typical users' premises.

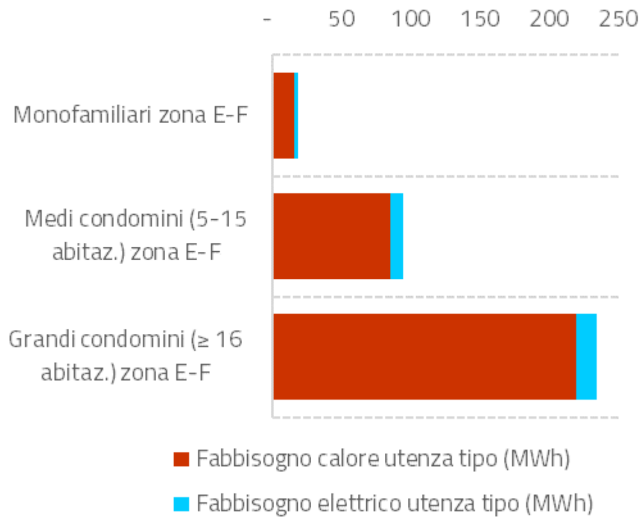
The heat and power demand in the above cases, and for the corresponding reference populations, are illustrated below.

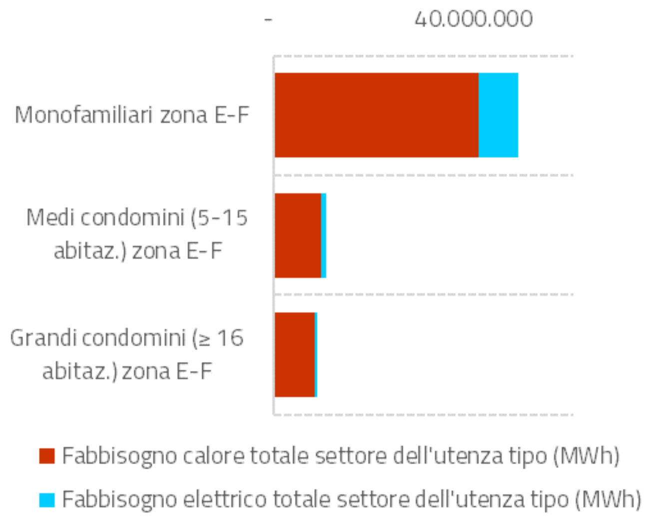
[62] 73.9% of Italian households have independent DHW systems. Source: ISTAT 2013.

Table 83: Heat and power demand of the typical users chosen and the corresponding reference populations

Case study	Specific heat demand of typical user (kWh/m^2)	Average floor area (m^2)	Heat demand of typical user (MWh)	Power demand of typical user (MWh)	Total heat demand of typical user sector (MWh)	Total power demand of typical user sector (MWh)
Single-family homes zone E-F	123	111	16	3	41 072 855	7 947 639
Medium-sized apartment blocks (5-15 dwellings) zones E-F	115	741	85	9	9 385 964	990 769
Large apartment blocks (≥ 16 dwellings) zones E-F	86	2 540	219	15	8 169 078	558 347
					58 627 897	**9 496 755**

Figure 144: Heat and power demand of the typical users chosen and the corresponding reference populations





Monofamiliari zona E-F	Single-family homes zone E-F
Medi condomini (5-15 abitaz.) zona E-F	Medium-sized apartment blocks (5-15 dwellings) zones E-F
Grandi condomini (≥ 16 abitaz.) zona E-F	Large apartment blocks (≥ 16 dwellings) zones E-F
Fabbisogno calore utenza tipo (MWh)	Heat demand of typical user (MWh)
Fabbisogno elettrico utenza tipo (MWh)	Power demand of typical user (MWh)

Monofamiliari zona E-F	Single-family homes zone E-F
Medi condomini (5-15 abitaz.) zona E-F	Medium-sized apartment blocks (5-15 dwellings) zones E-F
Grandi condomini (≥ 16 abitaz.) zona E-F	Large apartment blocks (≥ 16 dwellings) zones E-F
Fabbisogno calore totale settore dell'utenza tipo (MWh)	Total heat demand of typical user sector (MWh)

Fabbisogno elettrico totale settore dell'utenza tipo (MWh)	Total power demand of typical user sector (MWh)

It should be noted that, in terms of the demand from individual typical users, large apartment blocks obviously dominate, but the number of single-family homes is such that, when the relevant reference populations are considered, their contribution of 41 TWh is the largest. The overall heat demand of the reference populations of the typical users totals around 58 TWh.

8.7.2 Technical potential in the residential sector

After characterising the demand for heat and power from the typical users considered, the CHP system was chosen, its size estimated and its operating conditions simulated.

Next, the size and type of the CHP systems that can be installed at the users’ premises were identified: in the case of single-family homes, the typical system envisaged is a Stirling-type micro-CHP system, with thermal capacity of about 5 kWt, suitable for single-family dwellings or detached houses with an independent heating system. In the case of medium-sized apartment blocks, a commercial micro-CHP system of slightly larger size has been envisaged (13 kWt), while in the case of large apartment blocks, the CHP system chosen has a thermal capacity of around 100 kWt which is typical of applications in large multi-apartment buildings, as recorded in the database of existing systems.

Operating conditions were simulated using the specific performance indicators taken from operating data at residential user premises having similar energy demand, held in GSE’s database on HE CHP. In particular, the hours of operation (in HE CHP and electricity-only mode), the electric and thermal efficiency, the share of self-consumption, etc. were estimated.

It has been assumed that the cogenerator will be installed at a demand point receiving its electricity from the national grid and heat from a gas boiler with efficiency in line with the market baseline (90% efficiency), to be maintained after installation of the cogenerator to serve as a backup boiler.

As shown by the results of the simulations, only a share of the user’s heat demand would be covered by the HE CHP system. Most of the share of heat demand which cannot be covered by the cogenerator is due to peaks in demand, the non-simultaneous presence of electrical and thermal loads and a heat-power ratio that is not always favourable for CHP applications. Although there are solutions, such as hot water tanks and electrical batteries, to distribute the thermal and electrical load over time, costs and space constraints mean that they cannot be easily deployed.

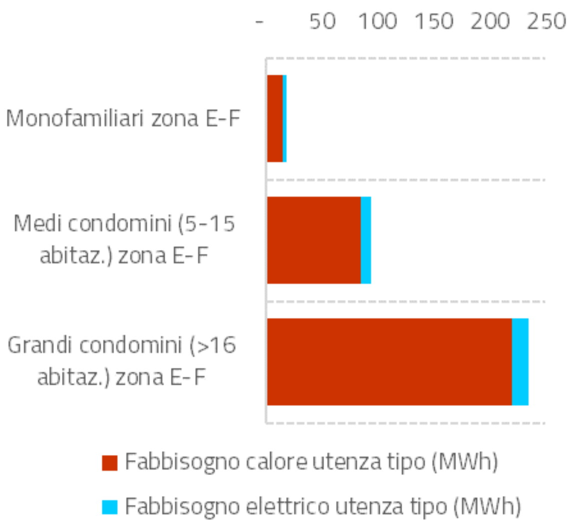
The size of the cogenerator, on the basis of the technical parameters obtained from the installations in operation, prevents achievement of a heat-power ratio similar to that required by the user, especially in apartment blocks. This imbalance restricts electrical self-consumption, which is very limited.

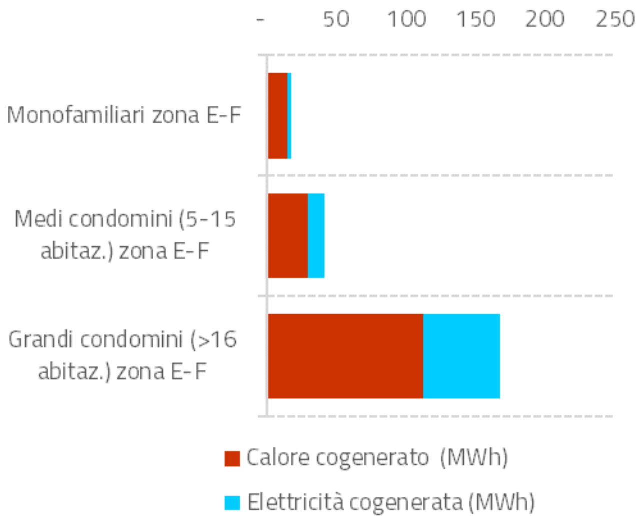
Moreover, the simulations show that to maximise its use, the CHP system must be undersized with respect to the user’s overall heat demand. Hence, boilers continue to play a major role in covering the demand for heat.

Table 84: Technical parameters and energy outputs of HE CHP systems under the operating conditions assumed for the residential sector

Case study	Single-family homes zone E-F	Medium-sized apartment blocks (5-15 dwellings) zones E-F	Large apartment blocks (≥ 16 dwellings) zones E-F
HE CHP technology	ICE gas Stirling	ICE gas	ICE gas
System capacity	0.001-0.02 MW	0.001-0.02 MW	0.02-0.1 MW
Electrical capacity (MW)	0.001	0.005	0.050
Thermal capacity (MW)	0.005	0.013	0.101
HE CHP electrical efficiency (%)	15%	27%	28%
HE CHP thermal efficiency (%)	75%	64%	56%
Self-consumption (%)	41%	41%	41%
CHP electricity share (%)	100%	100%	99%
Equivalent hours of electricity	3 000	2 272	1 125
Share of heat that can be cogenerated (%)	60%	34%	51%
Cogenerated heat (MWh)	15	29	112
HE CHP electricity (MWh)	3	12	55
Total electricity produced (MWh)	3	12	56
Self-consumed electricity (MWh)	1	5	15
Electricity drawn from the grid (MWh)	2	4	-
Consumption of back-up boiler (MWh)	1	62	119
Consumption of HE CHP system (MWh)	20	46	199
Total CHP system consumption (MWh)	20	46	202

Table 85: Energy demand of typical users with indication of cogenerated heat and electricity.



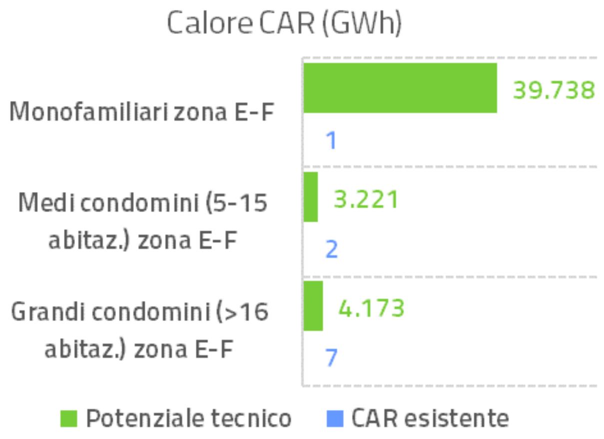


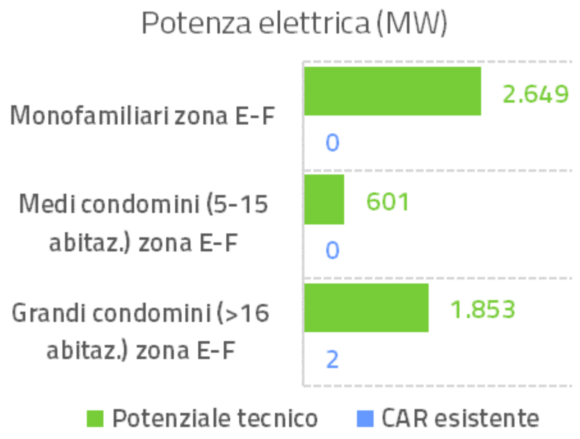
Monofamiliari zona E-F	Single-family homes zone E-F
Medi condomini (5-15 abitaz.) zona E-F	Medium-sized apartment blocks (5-15 dwellings) zones E-F
Grandi condomini (>16 abitaz.) zona E-F	Large apartment blocks (> 16 dwellings) zones E-F
Fabbisogno calore utenza tipo (MWh)	Heat demand of typical user (MWh)
Fabbisogno elettrico utenza tipo (MWh)	Power demand of typical user (MWh)

Monofamiliari zona E-F	Single-family homes zone E-F
Medi condomini (5-15 abitaz.) zona E-F	Medium-sized apartment blocks (5-15 dwellings) zones E-F
Grandi condomini (>16 abitaz.) zona E-F	Large apartment blocks (> 16 dwellings) zones E-F
Calore cogenerato (MWh)	Cogenerated heat (MWh)
Elettricità cogenerata (MWh)	Cogenerated electricity (MWh)

By extending the energy outputs obtained in the case study to the entire reference subsector, it is possible to estimate the technical potential; these values represent, on the basis of the assumptions made, the theoretical maximum amount of cogenerated heat and electricity technically obtainable in the service subsectors that can be supplied by a cogenerator, without considering economic and financial factors, which are discussed later.

Table 86: Technical HE CHP potential and existing HE CHP in the residential sector. HE CHP heat (GWh) and electrical capacity (MW)

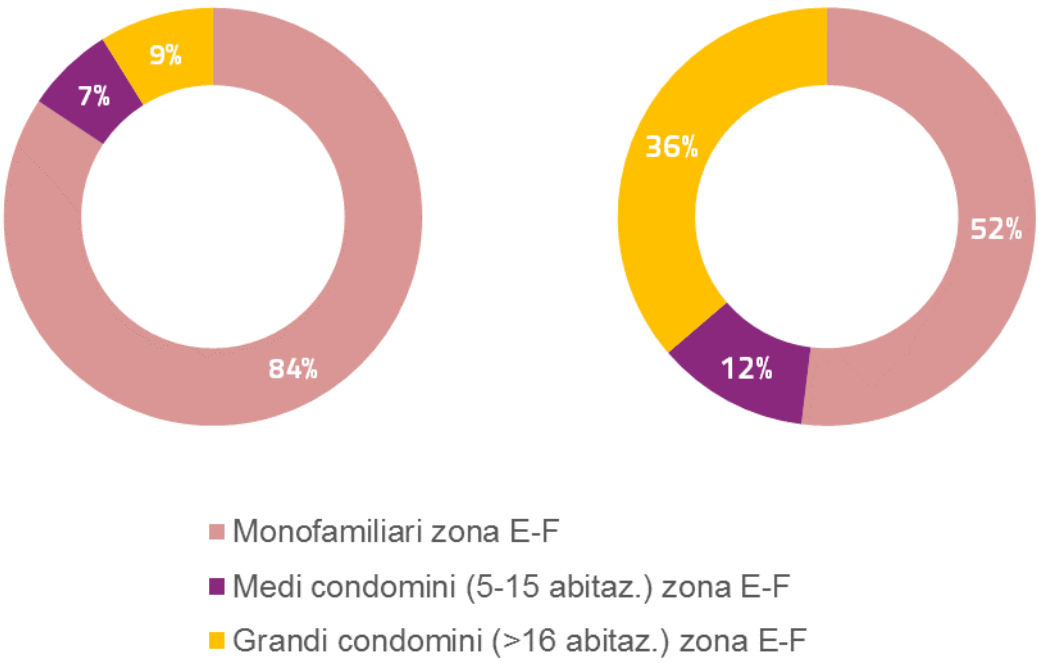




Calore CAR (GWh)	HE CHP heat (GWh)
Monofamiliari zona E-F	Single-family homes zone E-F
Medi condomini (5-15 abitaz.) zona E-F	Medium-sized apartment blocks (5-15 dwellings) zones E-F
Grandi condomini (>16 abitaz.) zona E-F	Large apartment blocks (> 16 dwellings) zones E-F
Potenziale tecnico	Technical potential
CAR esistente	Existing HE CHP

Potenza elettrica (MW)	Electrical capacity (MW)
Monofamiliari zona E-F	Single-family homes zone E-F
Medi condomini (5-15 abitaz.) zona E-F	Medium-sized apartment blocks (5-15 dwellings) zones E-F
Grandi condomini (>16 abitaz.) zona E-F	Large apartment blocks (> 16 dwellings) zones E-F
Potenziale tecnico	Technical potential
CAR esistente	Existing HE CHP

Table 87: Incremental technical potential in the residential sector. Distribution of HE CHP heat (GWh) and electrical capacity (MW)



Monofamiliari zona E-F	Single-family homes zone E-F
Medi condomini (5-15 abitaz.)zona E-F	Medium-sized apartment blocks (5-15 dwellings) zones E-F
Grandi condomini (>16 abitaz.) zona E-F	Large apartment blocks (> 16 dwellings) zones E-F

Overall, the residential sector is associated with a technical potential of **47 132 GWh** of heat, corresponding to a capacity of **5 103 MW.**

Due to the number of single-family homes in Italy, they account for the majority of the technical potential in the residential sector, both for heat (40 TWh) and for electrical capacity (2.6 GW).

Medium-sized and large apartment blocks account for 3.2 TWh and 4.2 TWh respectively.

Given the minimal development of existing HE CHP in the residential sector, the incremental potential mostly corresponds to the technical potential.

8.7.3 Economic potential in the residential sector

As described in detail in the methodology, a detailed business case was thus simulated for each user, considering the possible cost components, such as investment costs, O&M costs and fuel costs, including electricity drawn from the grid, as well as revenues from incentives and the possible sale of energy under the current regulatory conditions. The cash flows were compared with the baseline scenario for the sector, in which heat is assumed to be generated by a gas boiler, obtaining the relevant economic and financial performance indicators for investment in the cogeneration plant. As stated, the project IRR was used to determine the percentage of the technical potential that could be implemented, which translates into economic potential.

Table 88: Main costs and revenues of economic simulations and financial outputs in the residential sector

Case study	Single-family homes zone E-F	Medium-sized apartment blocks (5-15 dwellings) zones E-F	Large apartment blocks (≥ 16 dwellings) zones E-F
CHP investment cost (€)	6 000	17 270	134 831
Annual CHP O&M cost (€)	180	345	2 697
CHP fuel cost (€)	1 594	2 801	12 288
Fuel cost for back-up boiler (€)	48	4 483	8 594
Cost of electricity drawn from the grid (€)	413	1 484	-
Revenues from feed-in energy (€)	-	178	2 144
Revenues from exchanged energy (€)	142	317	-
Revenues from white certificates (€)	-	520	2 080
Ex-ante backup boiler fuel cost (€)	1 467	6 826	17 569
Ex-ante cost of electricity drawn from the grid (€)	696	3,373	5 621
NPV (€)	<0	<0	<0
IRR	Not cost-effective	Not cost-effective	Not cost-effective
Discounted time for return on investment (years)			

As expected, under current regulations, which provide for HE CHP to supply electricity only for common utilities, the simulations do not reveal economic benefits in any of the case studies considered, with the NPV always negative.

Although all the cases simulated benefit from the net metering system, a significant share of the electricity fed into the grid (the part exceeding the power drawn from the grid) is priced at market values, which for these small installations are unable to cover the costs of production. No white certificates are granted to single-family homes, because the savings calculated are less than 1 toe, which is the minimum threshold value for obtaining the white certificates. Lastly, in view of the high extra-technological costs of investments in and maintenance of the CHP system, the overall electricity and heat production costs are higher than in the ex-ante situation.

Therefore, the economic and financial potential is formally in line with the current development of HE CHP.

As expected, this result is to be understood as referring to the simulated typical cases and the related assumptions made, without ruling out the possibility that some niche customers with different conditions to the average, such as specific heat and power demand high enough to justify investment[63] may have a significant economic result.

Furthermore, if, as a result of regulatory changes, the electricity consumption of individual tenants, who usually account for most of the electricity demand, were allowed to use HE CHP, the economic drivers would change significantly in favour of HE CHP,

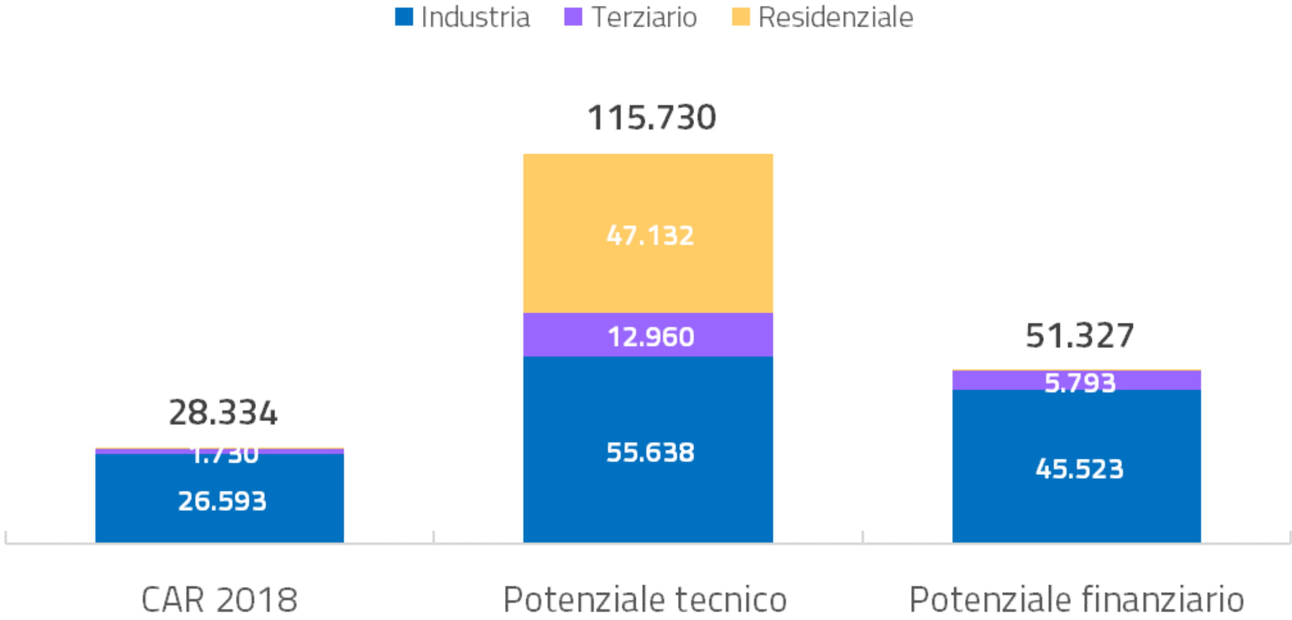
8.8 Total national potential of HE CHP and environmental benefits

By aggregating the results of the HE CHP potential analysed above for the residential, service and industrial sectors, the following technical and economic potential for heat produced by CHP systems is obtained.

The results show a technical potential of **116 TWh**, of which 56 TWh relates to industry, 47 TWh to the residential sector (given the residential demand that can theoretically be cogenerated) and 13 TWh to the service sector. This potential is around four times greater than the existing HE CHP in 2018.

Moving on to what is financially viable under current regulations, there is an economic potential of **51 TWh**, of which 89% relates to industry (45.5 TWh) and 5.8 TWh to the service sector. This potential is around 1.8 times greater than the existing HE CHP in 2018.

Figure 145: Comparison between the current level of HE CHP and the technical and financial potential. HE CHP heat (GWh)



Industria	Industry

[63] Some examples would be luxury villas, resorts, large apartment buildings and complexes with various common facilities such as swimming pools and larger economies of scale. These cases are not covered in this study as they are felt to be marginal at national level.

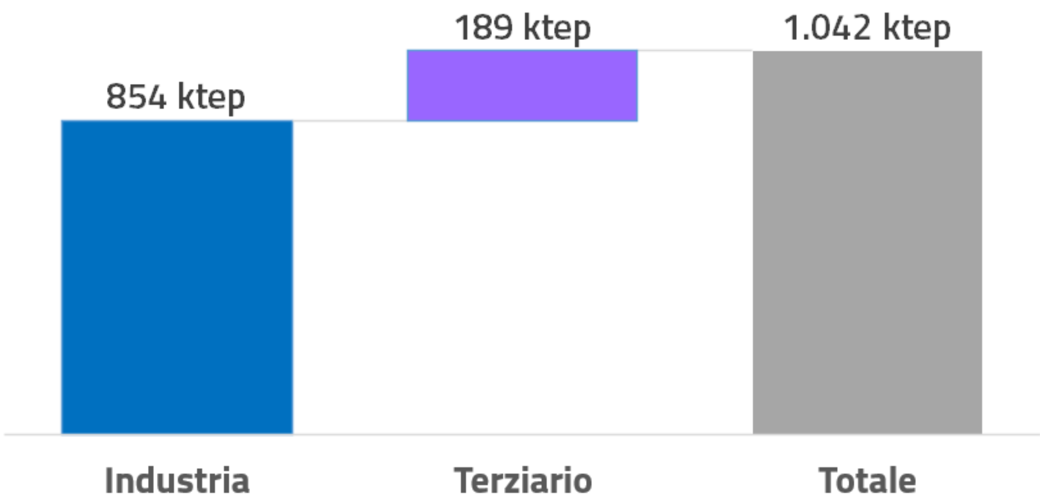
Terziario	Services
Residenziale	Residential
CAR 2018	HE CHP 2018
Potenziale tecnico	Technical potential
Potenziale finanziario	Financial potential

The assessment of the technical and economic potential was accompanied by an assessment of the environmental benefits, such as savings on GHG emissions and primary energy savings, linked to the development of the potential of high-efficiency CHP.

As described in the methodology, the primary energy savings were calculated on the basis of the efficiency reference values of separate heat and power production, processed by GSE on the basis of the technologies assumed to have been replaced in the various sectors[64], and the correction factors that take into account the network voltage and relationship between self-consumed energy and energy fed into the grid, which in turn leads to network losses.

The GHG emissions prevented as a result of potential HE CHP developments were calculated using the primary energy savings, by applying the GHG emission factors of the prevailing marginal fuel, natural gas.

Figure 146: Primary energy savings associated with incremental economic potential (ktoe)

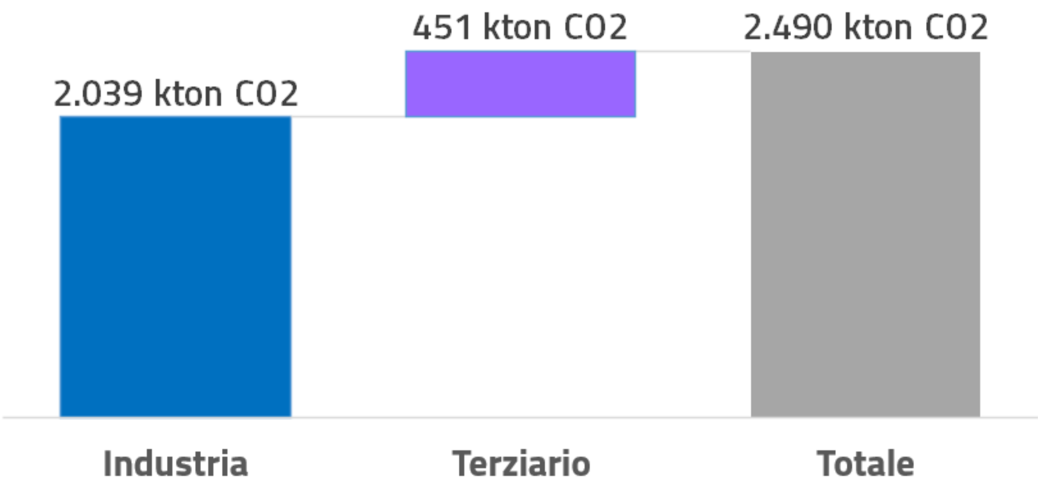


854 ktep	854 ktoe
189 ktep	189 ktoe
1.042 ktep	1,042 ktoe
Industria	Industry
Terziario	Services
Totale	Total

The incremental economic potential is associated with **1 042 ktoe** of primary energy savings, most of which can be attributed to industry (854 ktoe).

[64]More specifically, the reference electrical efficiency for separate production was set at 53%. The reference thermal efficiency for separate heat production was 92%.

Figure 147: Emissions prevented in relation to incremental economic potential (kton CO_2)



2.039 kton CO2	2 039 kton CO_2
451 kton CO2	451 kton CO_2
2.490 kton CO2	2,490 kton CO_2
Industria	Industry
Terziario	Services
Totale	Total

Prevented CO_2 emissions are in line with energy savings: the incremental economic potential is associated with **2 490 ktoe of prevented emissions**, of which 82% are in the industrial sector (2 039 kton CO_2).

There are no economic benefits associated with the residential sector since, as described above, there is no incremental economic potential under current regulations.

8.9Regional potential of HE CHP

The results of the high-efficiency CHP potential at the national level were recalculated for the regional level using a top-down approach, comprising:

- an analysis of the availability of high-efficiency CHP (in terms of heat, electricity and electrical capacity) in each sector of use (reconstructed on the basis of detailed records held by the unit), by Region and Autonomous Province of origin;
- the calculation of the technical and economic potential of high-efficiency CHP at regional level by distributing the potential calculated at national level according to the regional demand for heat in each sector[65] – this being the main variable used to determine the size of the high-efficiency CHP plants in the case studies used to estimate the potential;

[65] In the industrial sector, the regional distribution of heat demand in the different sectors was estimated using the distribution of ETS emissions in the different sectors.

- a consistency check between the regional distribution of sectoral potential calculated and the high-efficiency CHP existing at the regional sectoral level, adjusting the potential if the value was found to be less than the existing capacity.

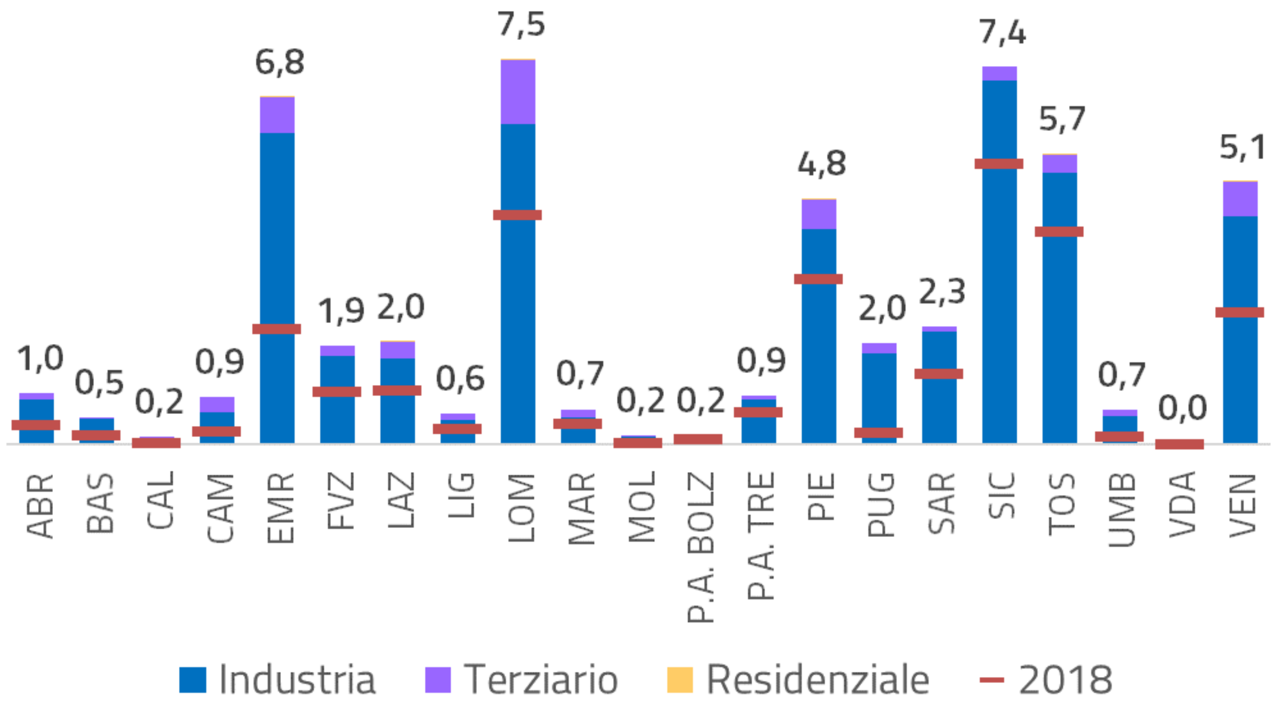
The economic and financial potential in terms of HE CHP heat at regional level and per sector is set out below, compared to the existing development as of 2018.

Table 89: Breakdown by region/autonomous province and sector of the economic and financial potential of HE CHP heat (TWh) and of existing HE CHP heat to 2018

Region	Industry	Services	Residential	Total	HE CHP 2018
ABRUZZO	0.9	0.1	-	1.0	0.4
BASILICATA	0.5	0.0	-	0.5	0.2
CALABRIA	0.0	0.1	-	0.2	0.0
CAMPANIA	0.6	0.3	-	0.9	0.3
EMILIA-ROMAGNA	6.1	0.7	0.0	6.8	2.2
FRIULI-VENEZIA GIULIA	1.7	0.2	-	1.9	1.0
LAZIO	1.7	0.3	0.0	2.0	1.1
LIGURIA	0.5	0.1	-	0.6	0.3
LOMBARDY	6.3	1.3	0.0	7.5	4.5
MARCHE	0.5	0.2	-	0.7	0.4
MOLISE	0.2	0.0	-	0.2	0.0
AP OF BOLZANO	0.1	0.1	0.0	0.2	0.1
AP OF TRENTO	0.9	0.1	-	0.9	0.6
PIEDMONT	4.2	0.6	0.0	4.8	3.2
APULIA	1.8	0.2	-	2.0	0.2
SARDINIA	2.2	0.1	-	2.3	1.4
SICILY	7.1	0.3	-	7.4	5.5
TUSCANY	5.3	0.4	0.0	5.7	4.1
UMBRIA	0.6	0.1	-	0.7	0.2
VALLE D'AOSTA	0.0	0.0	-	0.0	0.0
VENETO	4.5	0.7	0.0	5.1	2.6
TOTAL	**45.5**	**5.8**	**0.0**	**51.3**	**28.3**

Overall, the regional breakdown of the potential of HE CHP shows that the largest contribution is in Lombardy (7.5 TWh), followed by Sicily (7.4 TWh), Emilia-Romagna (6.8 TWh), Tuscany (5.7 TWh), Veneto (5.1 TWh) and Piedmont (4.8 TWh). When compared with the state of development in 2018, Emilia-Romagna shows the greatest growth potential (4.5 TWh), while Lombardy shows the greatest growth potential in the service sector (0.7 TWh).

Figure 148: Regional breakdown of the economic and financial potential of HE CHP heat (TWh) and of existing HE CHP heat



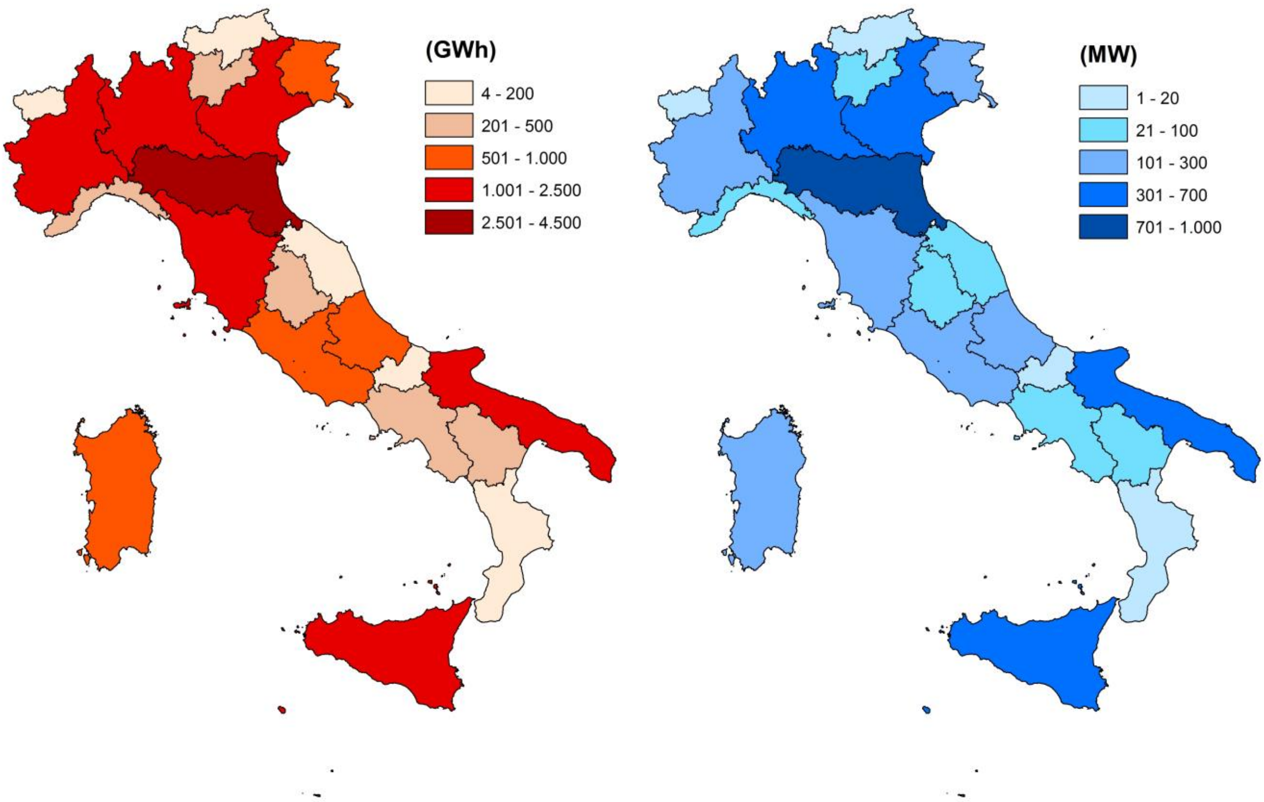
ABR	ABR
BAS	BAS
CAL	CAL
CAM	CAM
EMR	EMR
FVZ	FVZ
LAZ	LAZ
LIG	LIG
LOM	LOM
MAR	MAR
MOL	MOL
P.A. BOLZ	AP BOLZ
P.A. TRE	AP TRE
PIE	PIE
PUG	APU
SAR	SAR
SIC	SIC
TOS	TUS
UMB	UMB
VDA	VDA
VEN	VEN
Industria	Industry
Terziario	Services
Residenziale	Residential
2018	2018

8.9.1 Regional potential of HE CHP for industry

Below is a map showing the economic and financial growth potential compared to the state of development in 2018, showing HE CHP heat and the corresponding electrical power. It should be noted that national economic growth potential is listed by region, according to the regional breakdown of energy demand for each sub-sector under consideration.

In industry, the greatest economic growth potential is in Emilia-Romagna (more than 4.1 TWh of heat), followed by Lombardy (2.5 TWh) and Veneto (2.1 TWh).

Figure 149: Map showing the regional distribution of the economic growth potential in industry of HE CHP heat (GWh, on the left) and electrical power (MW, on the right)



(GWh)	(GWh)
(MW)	(MW)

Table 90: Regional distribution of the economic growth potential in industry of HE CHP heat (GWh) and electrical power (MW)

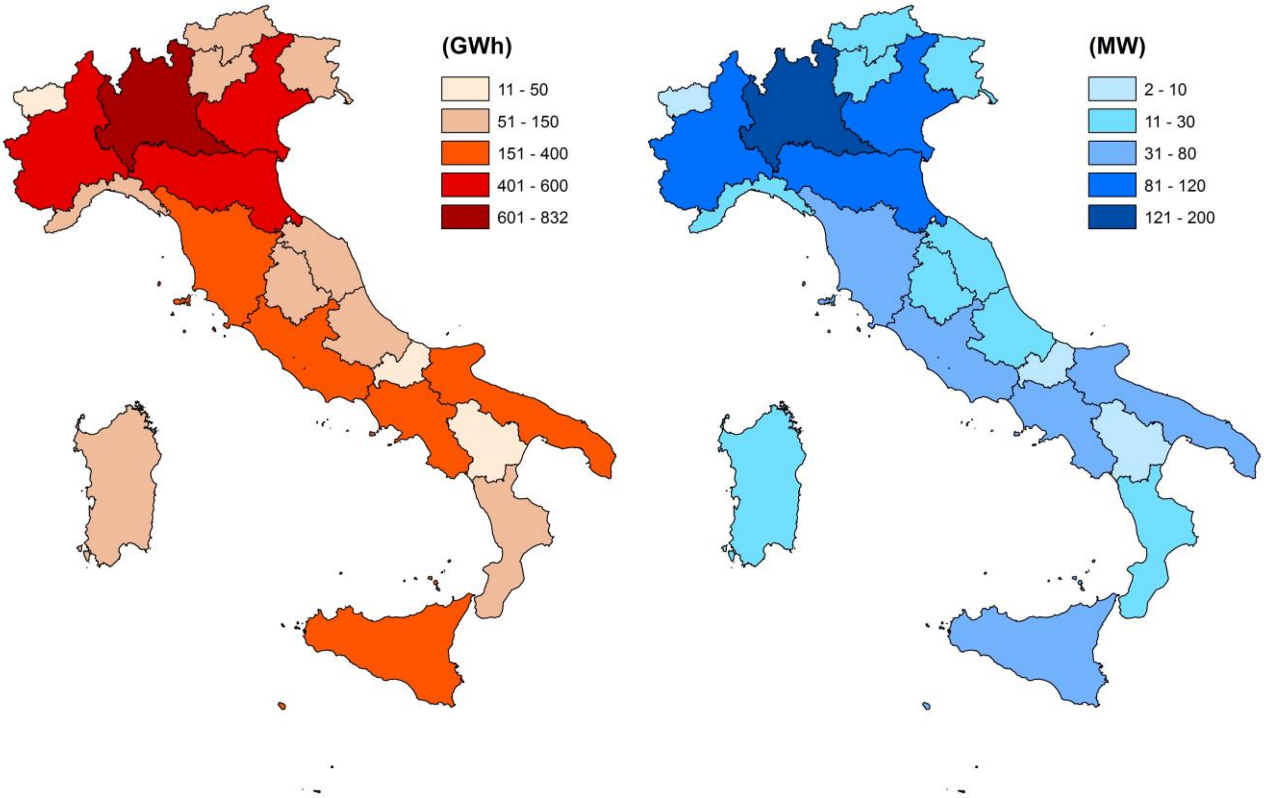
Region	Potential economic growth, HE CHP heat (adj.) (GWh)	Potential economic growth, HE CHP electrical capacity (adj.) (MW)
ABRUZZO	513	106
BASILICATA	309	59
CALABRIA	39	6
CAMPANIA	388	84
EMILIA-ROMAGNA	4 142	937
FRIULI-VENEZIA GIULIA	824	177
LAZIO	785	156
LIGURIA	234	42
LOMBARDY	2 446	606
MARCHE	173	42
MOLISE	112	18
AP OF BOLZANO	4	1
AP OF TRENTO	270	46
PIEDMONT	1 173	258
APULIA	1 572	400
SARDINIA	850	224
SICILY	1 788	449
TUSCANY	1 367	203
UMBRIA	426	72
VALLE D'AOSTA	10	3
VENETO	2 140	385
Total	**19 565**	**4 272**

8.9.2 Regional potential of HE CHP in the service sector

Below is a map showing the economic and financial growth potential compared to the state of development in 2018, showing HE CHP heat and the corresponding electrical power. It should be noted that national economic growth potential is listed by region, according to the regional breakdown of energy demand for each sub-sector under consideration.

In the service sector, the greatest economic growth potential is in Lombardy (0.8 TWh of heat), followed by Veneto (0.5 TWh) and Emilia-Romagna (0.5 TWh).

Figure 150: Map showing the regional distribution of the economic growth potential in the service sector of HE CHP heat (GWh, on the left) and electrical power (MW, on the right)



(GWh)	(GWh)
(MW)	(MW)

Table 91: Distribution by region/autonomous province of the economic growth potential in the service sector, HE CHP heat and electrical power

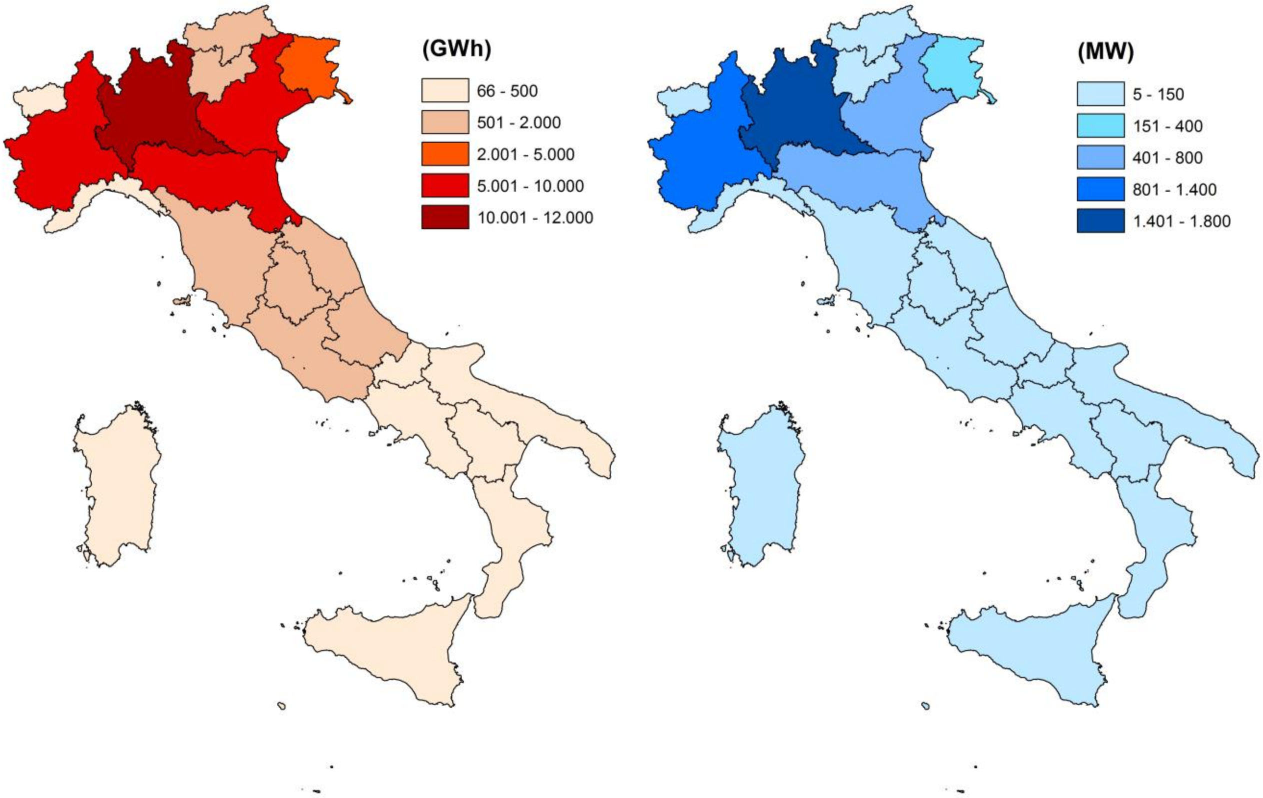
Region	Potential economic growth, HE CHP heat (adj.) (GWh)	Potential economic growth, HE CHP electrical capacity (adj.) (MW)
ABRUZZO	120	24
BASILICATA	22	4
CALABRIA	88	16
CAMPANIA	297	56
EMILIA-ROMAGNA	505	99
FRIULI-VENEZIA GIULIA	124	26
LAZIO	223	44
LIGURIA	91	17
LOMBARDY	832	179
MARCHE	131	26
MOLISE	20	4
AP OF BOLZANO	67	14
AP OF TRENTO	67	14
PIEDMONT	484	95
APULIA	188	36
SARDINIA	99	19
SICILY	255	48
TUSCANY	271	53
UMBRIA	101	19
VALLE D'AOSTA	11	2
VENETO	506	105
Total	**4 506**	**901**

8.9.3 Regional potential of HE CHP in the residential sector

Since, as shown above, under the regulation currently in force and according to simulated case studies, there is no economic benefit to developing HE CHP in the residential sector, the following map shows only the technical potential, highlighting HE CHP heat and the corresponding electrical power.

In the residential sector, the greatest technical potential is in Lombardy (more than 11.2 TWh of heat), followed by Piedmont (9.2 TWh) and Veneto (8.2 TWh). It should be noted that the technical potential only relates to climate zones E-F and is listed according to the regional breakdown of energy demand.

Figure 151: Map showing the distribution by region/autonomous province of the technical potential in the residential sector of HE CHP heat (GWh, on the left) and electrical power (MW, on the right)

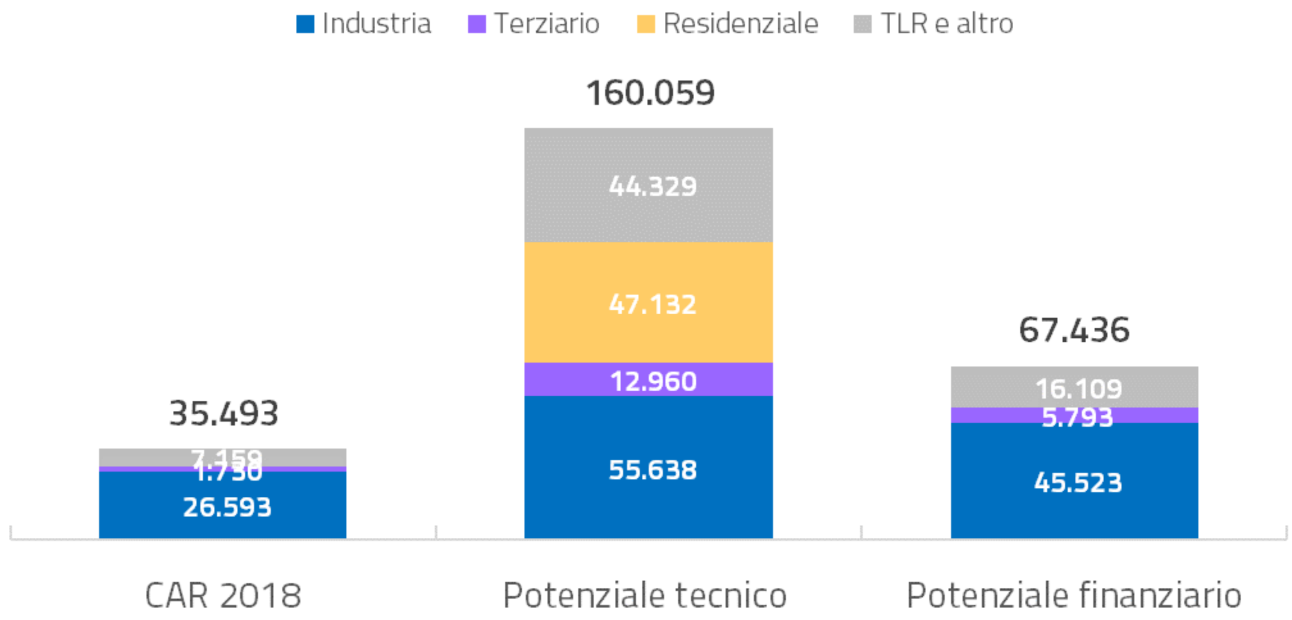


(GWh)	(GWh)
(MW)	(MW)

8.10 Total national potential of HE CHP

Any overview of cogeneration at national level must also include the results for HE CHP serving district heating, which has been specifically discussed in detail in the previous sections. The overall results for technical and economic and financial potential are shown below in relation to the state of development in 2018. It should be noted that the district heating contribution also includes minimal contributions from the agricultural sector.

Figure 152: Comparison between the current level of HE CHP and the technical and financial potential HE CHP heat (GWh)



Industria	Industry
Terziario	Services
Residenziale	Residential
TLR e altro	District heating and other
CAR 2018	HE CHP 2018
Potenziale tecnico	Technical potential
Potenziale finanziario	Financial potential

The results show a technical potential of **160 TWh**, of which 56 TWh relates to industry, 47 TWh to the residential sector (given the residential demand that can theoretically be cogenerated) and 13 TWh to the service sector, to which can be added 44 TWh of HE CHP serving district heating in the civil sector. This potential is around 4.5 times greater than that observed in 2018.

Moving to what is financially viable under current regulations, there is an economic potential of **67 TWh**, of which 45.5 TWh relates to industry (67%) 16.1 TWh to HE CHP serving district heating (24%) and 5.8 TWh to the service sector (9%). This potential is around 1.9 times greater than that observed in 2018.

9 Scenarios and optimum system scenario for the thermal sector

The regional and sectoral data on heat supply and demand (technical potential of different technologies) have been processed in the national energy system model (TIMES-RSE), with support from RSE, in order to update the technological mix for 2030 proposed in the INECP as the optimum system scenario, in light of the advances made in the field of HE CHP and district heating. These tools can be used to account for the evolving scenarios of heat demand and the prices of commodities and to identify a mix of technological solutions that allows the energy and climate targets for 2030 to be achieved while minimising system costs.

As part of this work, the energy targets and the other macro-economic assumptions made in line with the INECP scenario, which will likewise be updated in the future but which had not yet been given a definitive, official wording when the present report was drafted, were kept more or less the same.

9.1Methodology and assumptions

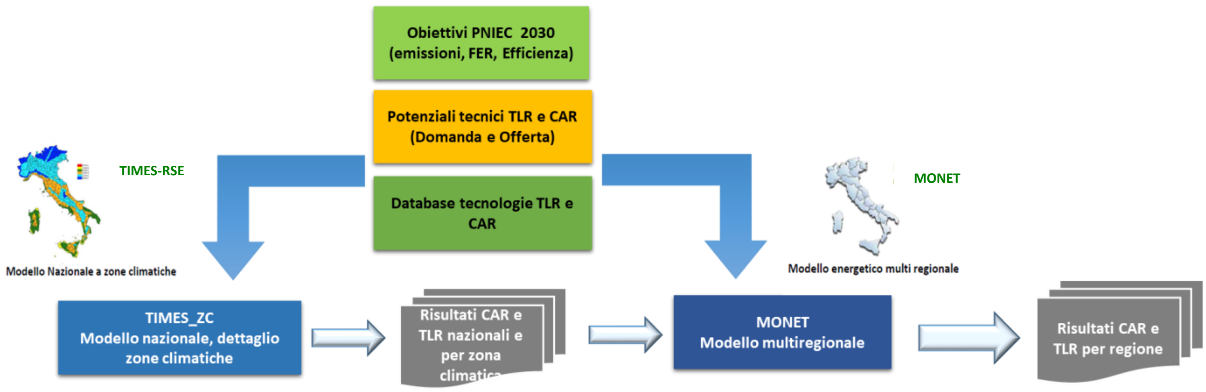
The optimum technological system configuration for the heating sector has been estimated using the TIMES-RSE model.

The TIMES-RSE is an Italian energy system model that has been used in all scenario analyses carried out to date on behalf of the Italian Government, such as the strategia energetica nazionale (the national energy strategy, the 'NES'), the INECP and the LTS. It is a partial equilibrium model with intertemporal optimisation, which minimises the total cost of the energy system for meeting a certain demand, subject to a number of constraints (environmental, energy, technological or policy). The equilibrium solution is calculated using linear programming techniques.

The aim is to minimise the overall cost incurred to supply a given volume of energy services to the system while adhering to a number of constraints, including targets such as reducing emissions, ensuring energy efficiency and increasing the penetration of renewables. In the TIMES model, the quantities and prices of the different raw materials are balanced, such that suppliers produce exactly the quantities required by consumers in each time period. In order to model energy supply as accurately as possible, consideration was also given to 12 time intervals within 1 year, resulting from a combination of the four seasons, day and night, and the period of peak demand. The model also accounts for the energy generation and energy transformation sectors (refineries and the electricity sector) and five end-use sectors (agriculture, industry, residential, services, transport), resulting in just under 50 different types of energy demand in total.

Following the further development of the models in recent years, the present study uses two cascading TIMES models: the national TIMES-RSE model and the multi-regional MONET model. The national model was used to identify the optimum system scenario, which includes an assessment of the technical potential of district heating and HE CHP on the basis of the targets set out in the INECP. The national model, which contains details of the climate zones, was used in order to better analyse the characteristics of different heating demands and their influence on whether or not district heating or high-efficiency cogeneration can be used. The multi-regional MONET model is then used to distribute the national results among the different regions, in consideration of existing regional constraints on installed national stock, supply potential, consumption trends and demand.

Figure 153: Overview of the TIMES-RSE methodology and models used to identify the optimum system scenario



Obiettivi PNIEC 2030 (emissioni, FER, Efficienza)	INECP 2030 targets (emissions, renewables, efficiency)
Potenziali tecnici TLR e CAR (Domanda e Offerta)	Technical potential of district heating and HE CHP (supply and demand)
Database tecnologie TLR e CAR	Database of district heating and HE CHP technologies
Modello Nazionale a zone climatiche	National climate zone model
Modello energetico multi regionale	Multi-regional energy model
TIMES_ZC Modello nazionale, dettaglio zone climatiche	TIMES_ZC National model, incl. details of climate zones
Risultati CAR e TLR nazionali e per zona climatica	National HE CHP and district heating results by climate zone
MONET Modello multiregionale	MONET Multi-regional model
Risultati CAR e TLR per regione	HE CHP and district heating results by region

The following assumptions and boundary conditions were used to update the INECP scenario in the thermal sector:

- meeting the 2030 targets underlying the current integrated national energy and climate plan (INECP) in terms of emissions, efficiency and renewables;

- maintaining INECP socio-economic drivers (population, GDP, commodity prices, etc.);
- achieving maximum HE CHP and district heating development in line with the technical potential for the deployment of district heating (TLR) and high-efficiency cogeneration (HE CHP) as defined in Chapters 7 and 8.

The 2030 targets of the INECP have remained the same in the new scenario and assume the simultaneous achievement of:

- the minimum target share of renewables for Italy, set at 30% by 2030;
- an annual increase in thermal renewables of 1.3%;
- the 2030 energy efficiency target of a 32.5% reduction in primary energy compared to the PRIMES 2007 scenario and a binding target for savings in final consumption through compulsory schemes of 0.8% per year during the period 2021-2030;
- the emissions targets for ETS and non-ETS sectors (ESR sectors) (33% reduction compared to 2005);
- the phase-out of coal in electricity generation by 2025.

Table 92: Country-specific EU and INECP targets for 2030

Commodities	EU 2030	ITALY (INECP) 2030
Renewable energies		
Energy from renewables in gross final consumption	32%	30%
Energy from renewables in gross final consumption for transport	14%	22%
Energy from renewables in gross final consumption for heating and cooling	+1.3% per year	+1.3% per year
Energy efficiency		
Reduction in primary energy consumption compared to the PRIMES 2007 scenario	-32.5%	-43%
Reductions in final consumption through compulsory schemes	-0.8% per year (with transport)	-0.8% per year (with transport)
Emissions		
Reduction in GHG vs 2005 for all non-ETS sectors	-30%	-33%

The main socio-economic drivers used in the INECP and retained as inputs to the model are shown in the following tables.

Table 93: Population trends in the INECP scenario (source: historical values: ISTAT, growth rates: EU Reference Scenario 2016).

Commodities	2017	2020	2025	2030
population	60.6	61.2	62.2	63.3

Table 94: Trends in GDP and sectoral value added in the INECP scenarios in % (source: average annual growth rates: EU Reference Scenario 2016)

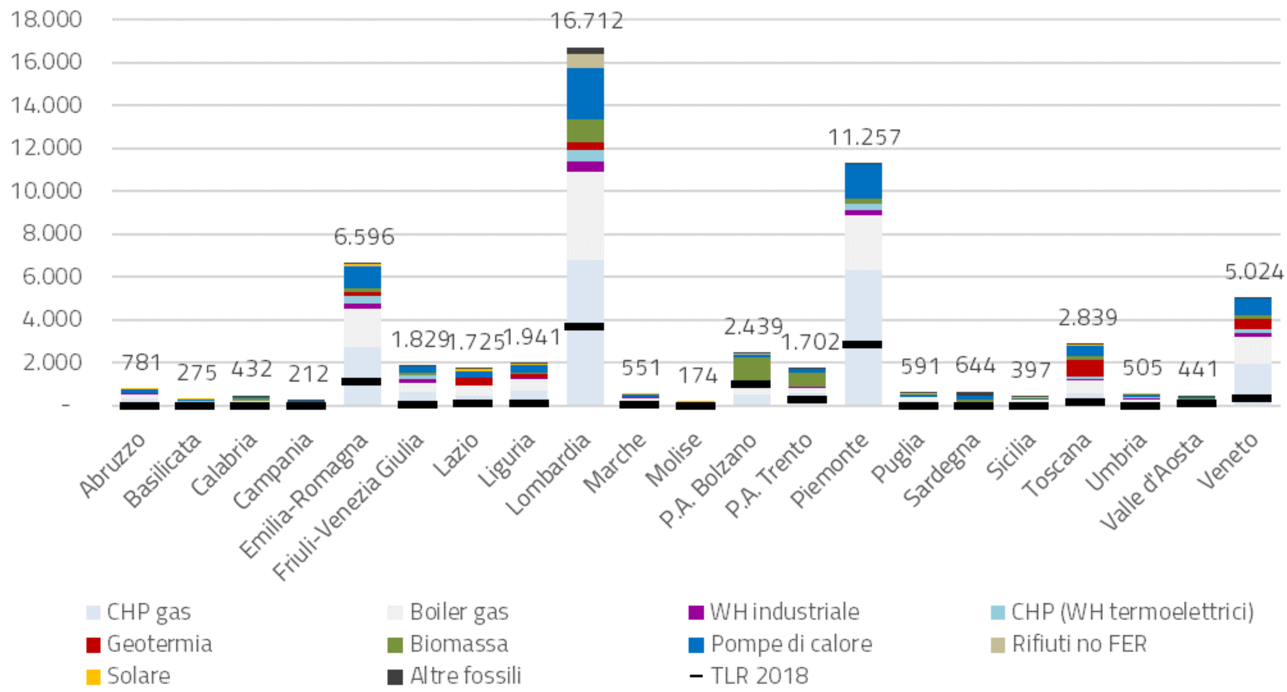
Variable and Sector	2018-2020	2020-2025	2025-2030
GDP	1.37	1.18	1.19
Agriculture value added	0.78	0.55	0.34
Construction value added	1.49	0.93	1.22
Services value added	1.47	1.34	1.31
Energy sector value added	1.26	0.58	0.91
Industry value added	0.93	0.61	0.7

Table 95: Changes to energy commodity price and CO_2 price

Commodities	2017	2020	2025	2030
Petrol (EUR_{2013}/GJ)	9.19	11.61	13.18	14.52
Natural gas (EUR_{2013}/GJ GCV)	6.58	7.47	8.08	8.79
Coal (EUR_{2013}/GJ)	1.95	2.21	2.65	3.18
CO_2 (EUR/tCO_2)	7.5	15.0	22.5	33.5

The technical potential for developing district heating, namely 57 TWh of delivered heat (68 TWh in terms of input) as referred to in Paragraphs 7.2 and 7.3, has been input to the TIMES model by region and climate zone in order to identify an optimum system solution compatible with the technical potentials for exploitation.

Figure 154: Technical potential for district heating energy delivered, by source and region/autonomous province (GWh)

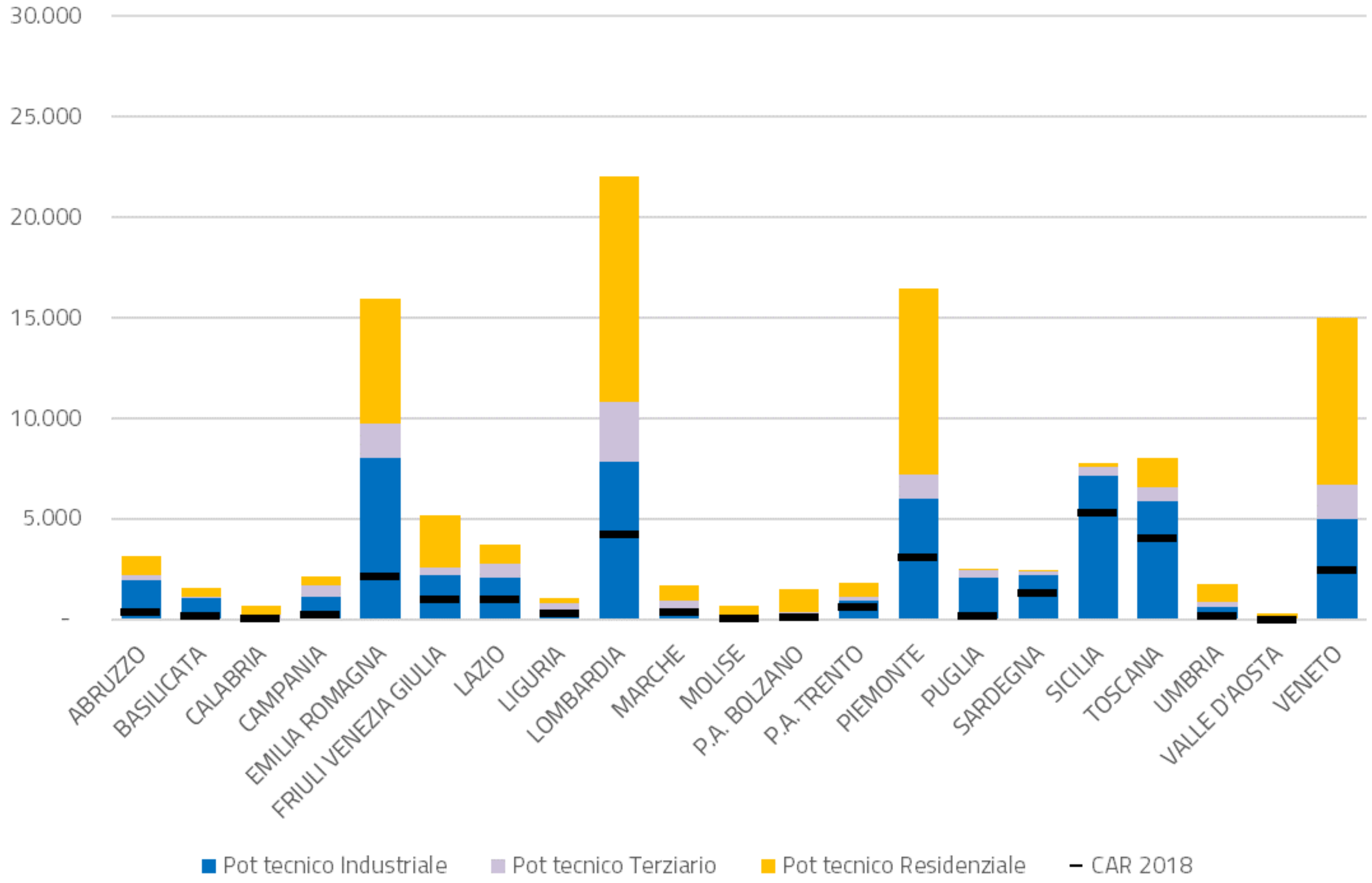


Abruzzo	Abruzzo
Basilicata	Basilicata
Calabria	Calabria
Campania	Campania
Emilia-Romagna	Emilia-Romagna
Friuli-Venezia Giulia	Friuli-Venezia Giulia
Lazio	Lazio
Liguria	Liguria
Lombardia	Lombardy
Marche	Marche
Molise	Molise
P.A. Bolzano	AP of Bolzano
P.A. Trento	AP of Trento
Piemonte	Piedmont
Puglia	Apulia
Sardegna	Sardinia
Sicilia	Sicily
Toscana	Tuscany
Umbria	Umbria
Valle d'Aosta	Valle d'Aosta
Veneto	Veneto
CHP gas	HE CHP gas
Geotermia	Geothermal power
Solare	Solar power
Boiler gas	Gas boiler
Biomassa	Biomass
Altre fossili	Other fossil fuels
WH industriale	Industrial WH
Pompe di calore	Heat pumps

TLR 2018	DH 2018
CHP (WH termoelettrici)	HE CHP (thermoelectric WH)
Rifiuti no FER	Non-renewable waste

Similarly, the technical development potentials in the residential, service and industrial sectors as set out in Paragraphs 8.5, 8.6 and 8.7 for each region were used for HE CHP.

Figure 155: Technical potential of HE CHP heat by sector and region/autonomous province (GWh)



ABRUZZO	ABRUZZO
BASILICATA	BASILICATA
CALABRIA	CALABRIA
CAMPANIA	CAMPANIA
EMILIA-ROMAGNA	EMILIA-ROMAGNA
FRIULI-VENEZIA GIULIA	FRIULI-VENEZIA GIULIA
LAZIO	LAZIO
LIGURIA	LIGURIA
LOMBARDIA	LOMBARDY
MARCHE	MARCHE
MOLISE	MOLISE
P.A. BOLZANO	AP OF BOLZANO
P.A. TRENTO	AP OF TRENTO
PIEMONTE	PIEDMONT
PUGLIA	APULIA
SARDEGNA	SARDINIA

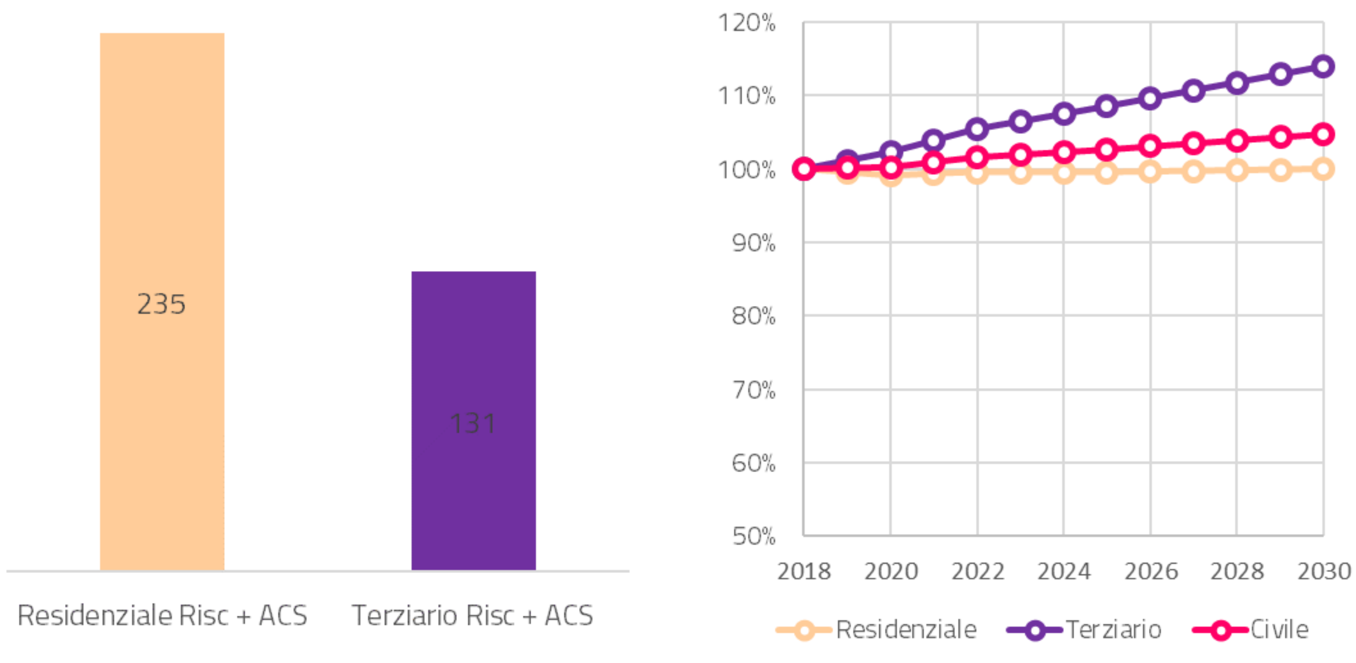
SICILIA	SICILY
TOSCANA	TUSCANY
UMBRIA	UMBRIA
VALLE D'AOSTA	VALLE D'AOSTA
VENETO	VENETO
Pot tecnico Industriale	Technical pot. Industry
Pot tecnico Terziario	Technical pot. Services
Pot tecnico Residenziale	Technical pot. Residential
CAR 2018	HE CHP 2018

9.2 Heat demand scenarios

The heat demand scenario used for the purposes of this analysis shows a 5% growth in energy demand in the civil sector, primarily driven by growth in demand in the service sector.

For the service sector, consideration has been given to an increase in heat demand of 14%, which is mainly due to expected economic growth in this sector (shown in the tables in Paragraph 9.1 on trends in sectoral added value for the period 2018-2030) and which is directly reflected in the heat demand for buildings and the heat demand for domestic hot water. For the residential sector, the demand observed for 2030 is in line with the current level, which, considering the expected growth of 6% in the number of households between 2018 and 2030, suggests the implementation of energy efficiency measures, particularly in relation to building envelopes, to compensate for the increase in heat demand in the sector.

Figure 156: Heat demand in the civil sector in 2018 and trends in heat demand



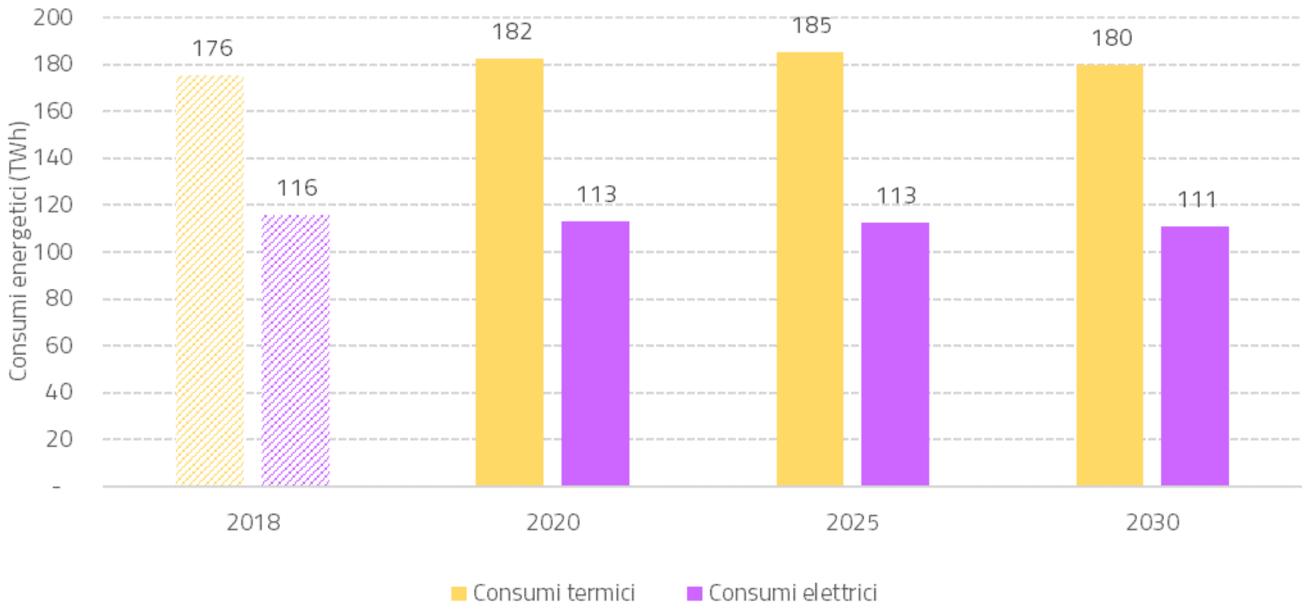
Residenziale Risc + ACS	Residential Heating + DHW
Terziario Risc + ACS	Services Heating + DHW
Residenziale	Residential

Terziario	Services
Civile	Civil

Civil to 2030 (TWh)

The evolving consumption scenario in the industrial sector shows a trend that is stable overall, although the trends in each individual sector are uneven due to the different levels of economic growth expected in the different production sectors.

Figure 157: Trends in final electricity and heat consumption in the industrial sector (TWh)



Consumi energetici (TWh)	Energy consumption (TWh)
Consumi termici	Heat consumption
Consumi elettrici	Electricity consumption

9.3 Optimum system scenario for the 2030 targets in the heating sector

9.3.1 Economic system potential of thermal renewables

The mix of technologies that allows the renewables target in the thermal sector to be achieved at the lowest cost to the system (33.9% by 2030 as set out in the INECP) consists of 14.8 Mtoe of thermal renewables: 7 Mtoe from solid biomass (in line with the current level), 5.8 Mtoe from heat pumps (almost twice the current level), 0.9 Mtoe from solar and geothermal power combined (almost three times the current level), 0.5 Mtoe of heat from renewable district heating (twice the current level) and 0.6 Mtoe of heat from non-district heating derived from renewables.

If the contribution from recovered waste heat is also included in the report (a possibility under Directive 2001/2018), the 'renewables + waste heat' target in the thermal sector is 34.3%, as illustrated in the following table[66].

Table 96: Final consumption from renewables and recovered heat in the thermal sector to 2030 in relation to the optimum system scenario

Consumption per source (ktoe)	2018	Scenario 2030
Numerator (A)	**10 678**	**14 976**
Gross heat production from renewables and waste heat	956	1 282
*of which from district heating**	*257*	*675*
Final consumption from renewables for heating	9 722	13 694
of which from biomass	*6 780*	*7 016*
of which from solar power	*218*	*675*
of which from geothermal	*128*	*180*
of which from heat pumps	*2 596*	*5 772*
Denominator (B)[67]		
Final energy consumption for heating	52 792	43 722
Share of renewables (%)	**20.2%**	**34.3%**

*includes thermal energy consumption from renewables for power absorption refrigerator units.

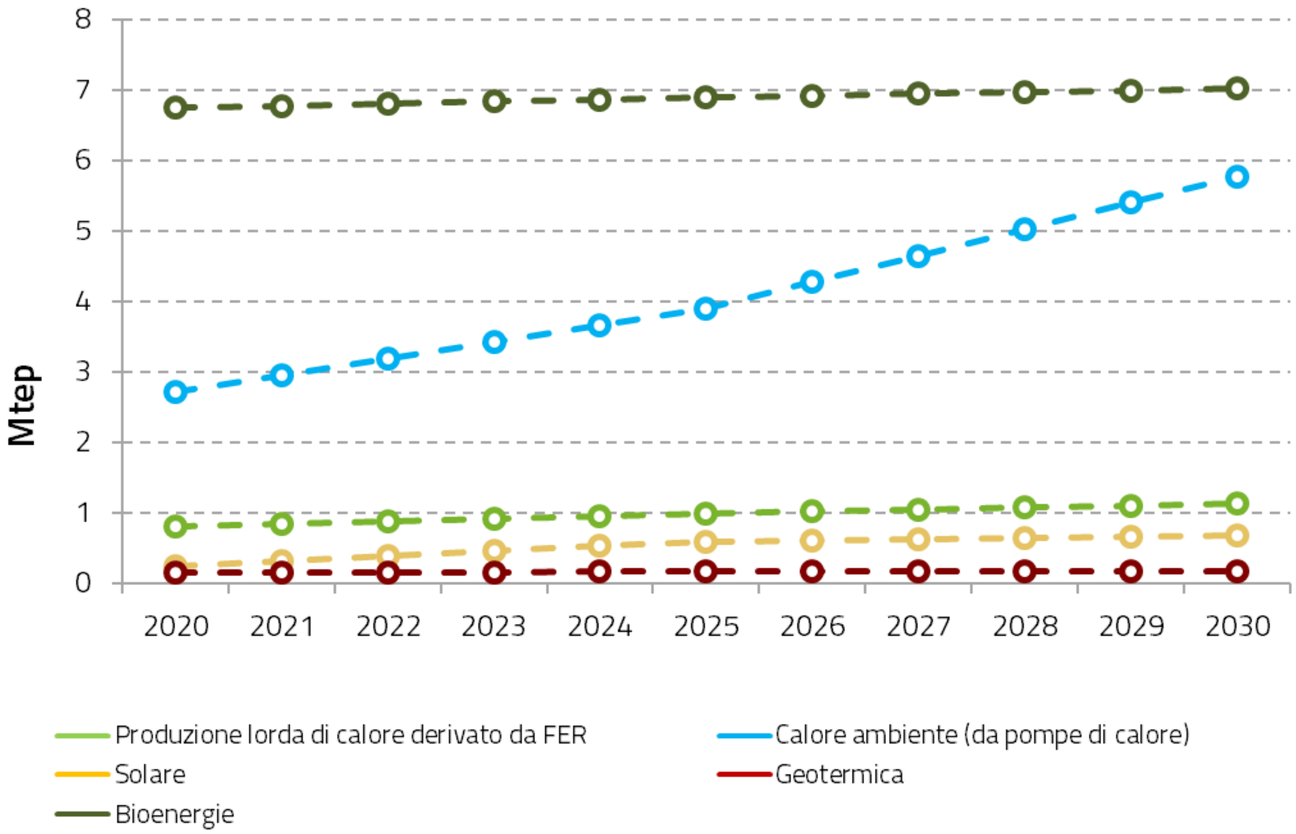
The development trends for thermal renewables show significant growth, driven mainly by the development of heat pumps and characterised by the contribution from bioenergy remaining broadly at the same high level. Significant growth

[66] Without accounting for waste heat, the renewables target in the thermal sector is 33.9%.

[67] Final heating consumption does not include electricity consumption nor ambient energy from heat pumps, in line with Directive 2018/2001. Only if the recovery of waste heat is to be counted (case shown in the table) is it added to both the numerator and the denominator.

rates are also reported for individual thermal solar power (+210%), district heating from renewables (106%) and geothermal power (41%).

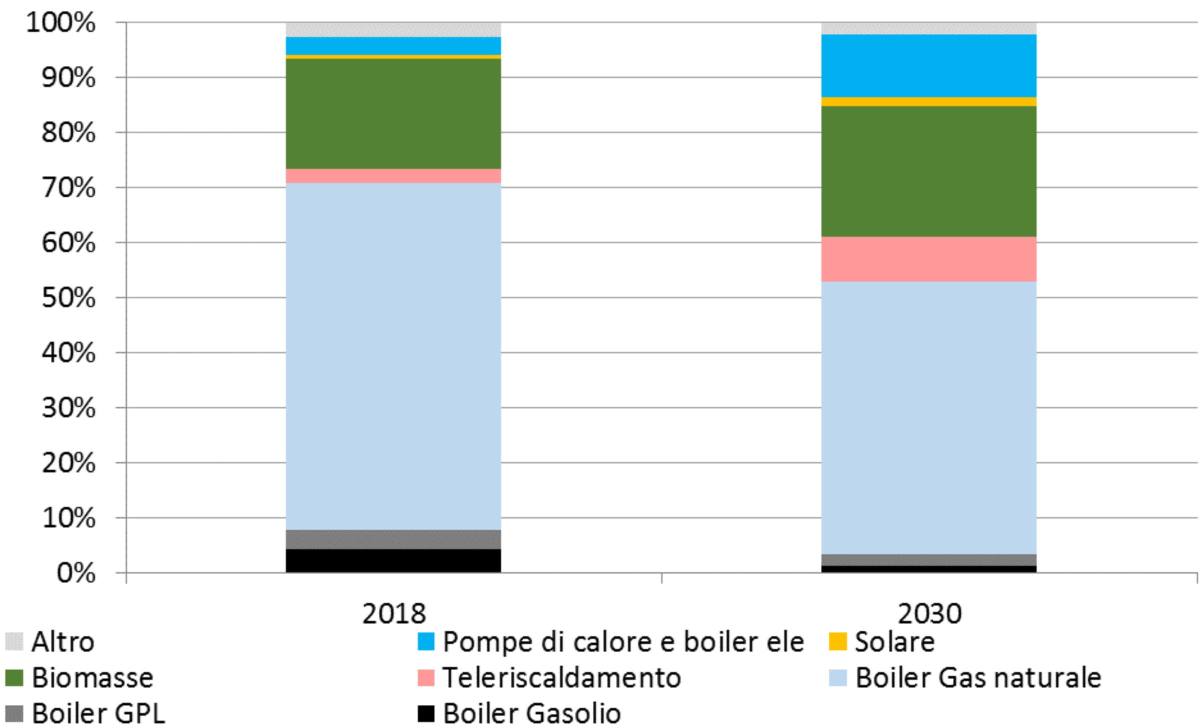
Figure 158: Development trajectories for thermal renewables to 2030 [Mtoe]



Mtep	Mtoe
Produzione lorda di calore derivato da FER	Gross production of heat derived from renewables
Solare	Solar power
Bioenergie	Bioenergy
Calore ambiente (da pompe di calore)	Ambient heat (from heat pumps)
Geotermica	Geothermal power

With regard to heating and DHW use in the residential sector, the energy transition path towards 2030 leads to a reduction in the contribution of fossil fuel boilers to the production of heat for heating and domestic hot water: primarily diesel (72% reduction compared to 2018), followed by LPG (28% reduction) and natural gas (13% reduction). The brake applied to these technologies is necessary in order to make room for low-carbon, efficient heating methods, namely biomass generators, whose share will reach 24% in 2030, rising from 20% in 2018. The increase in demand met by biomass is accompanied by a gradual technological evolution where obsolete appliances will be gradually replaced with more efficient generators, with the consumption level of this resource remaining relatively stable. The share of heat pumps and district heating in the technology supply mix is also increasing rapidly. The electrification of heating demand is supported by the high inherent efficiency of heat pumps, which are able to transform the thermal energy present in the external environment into useful heat using smaller quantities of electrical energy, thus limiting the consumption of primary energy from fossil fuels. On the other hand, the favourable conditions for district heating development are the result of economies of scale in generation technologies and the environmental benefits of centralised production and heat distribution in typically high-density urban settings with a sufficiently long winter season, where the presence of countless small and often obsolete boilers at local level makes this technology economically advantageous. Lastly, solar thermal power also showed significant growth, which was primarily concentrated in DHW applications and is therefore not particularly relevant to the sector's overall heat demand.

Figure 159: Changes to the technology mix used to meet heating and DHW demand in the residential sector in 2018 and in the 2030 scenario

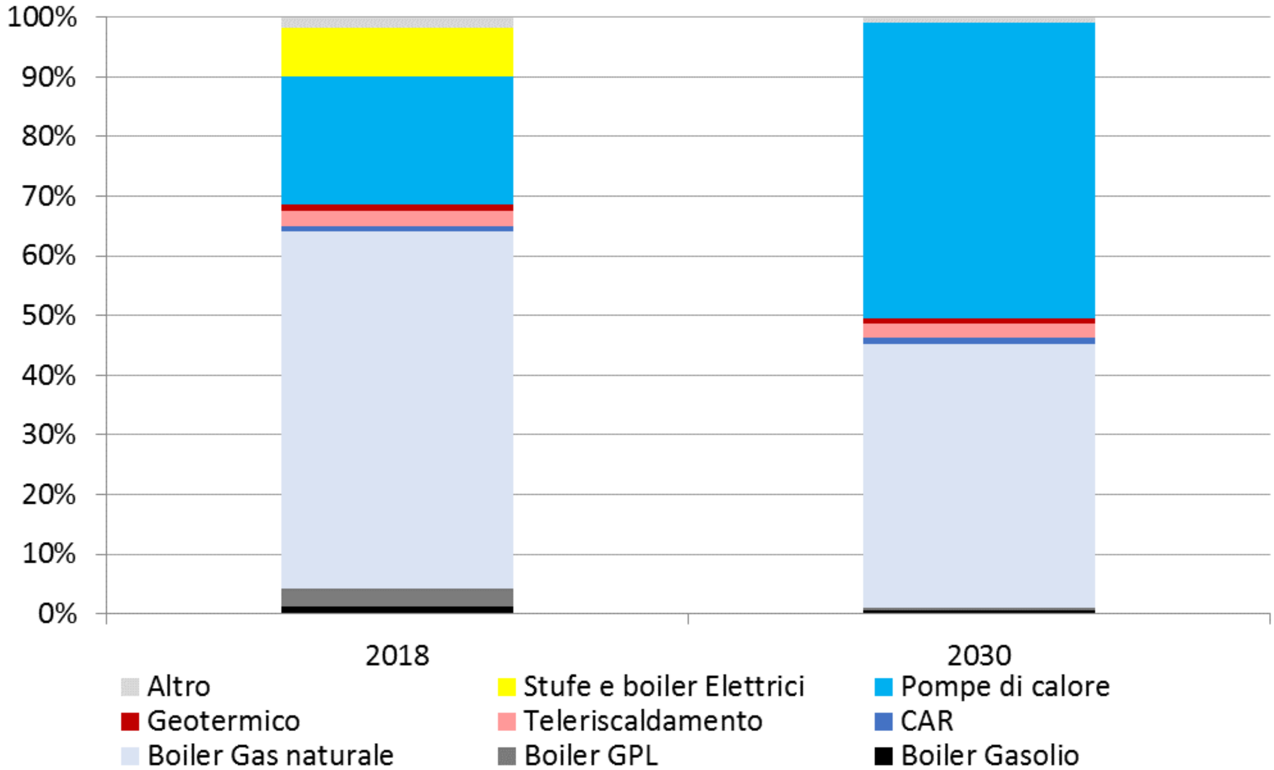


Altro	Other
Biomasse	Biomass
Boiler GPL	LPG boilers
Pompe di calore e boiler ele	Heat pumps and electric boilers
Teleriscaldamento	District heating
Boiler Gasolio	Diesel boilers
Solare	Solar power
Boiler Gas naturale	Natural gas boilers

In the service sector, the growth in heating and DHW demand is accompanied by a considerable transformation of the technology supply structure. Although the service sector already has an electrification rate of over 30%, the highest of all the end-use sectors, the 2030 scenario pushes this rate to

50% through the widespread penetration of heat pumps. As well as completely replacing electric stoves, which are now obsolete, heat pumps also reduce the share traditionally occupied by natural gas (13% reduction compared to 2018) and other fossil sources (diesel: 39% reduction and LPG: 87% reduction), becoming in fact the main technology for heating commercial buildings. The contribution from thermal renewables remains marginal and is limited to direct uses of geothermal power, typically in districts in central Italy. The share of energy delivered by district heating in the service sector is growing, although its role in the supply mix remains quite limited.

Figure 160: Changes to the technology mix used to meet heating and DHW demand in the service sector in 2018 and in the 2030 scenario

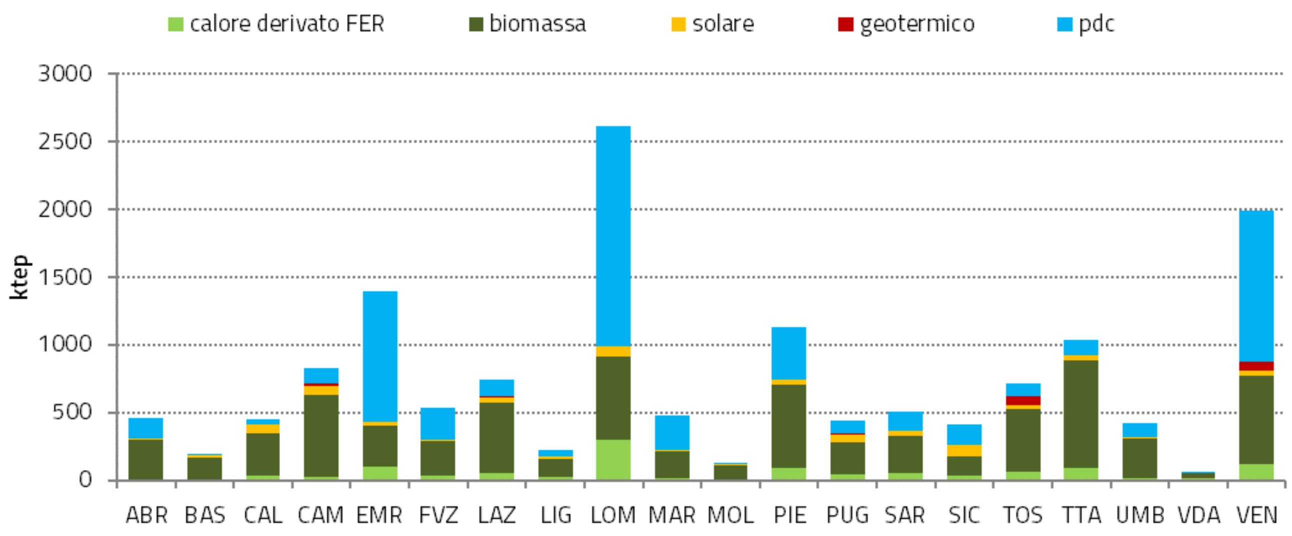


Altro	Other
Geotermico	Geothermal power
Boiler Gas naturale	Natural gas boilers
Stufe e boiler Elettrici	Electric stoves and boilers
Teleriscaldamento	District heating
Boiler GPL	LPG boilers
Pompe di calore	Heat pumps
CAR	HE CHP
Boiler Gasolio	Diesel boilers

The model shows that the regional distribution of thermal renewables to 2030 has a greater concentration in Lombardy (2.6 Mtoe), followed by Veneto (2.0 Mtoe) and Emilia-Romagna (1.4 Mtoe).

In most regions, biomasses make the largest contribution to renewable production, although there are some northern regions where the contribution from heat pumps dominates with strong growth compared to the current situation (Lombardy, Emilia-Romagna, Veneto)

Figure 161: Renewables technology mix in the 2030 system scenario, by region (ktoe)



calore derivato FER	Heat derived from renewables
biomassa	Biomass
solare	Solar power
geotermico	Geothermal power
pdc	Heat pumps
ktep	ktoe
ABR	ABR
BAS	BAS
CAL	CAL
CAM	CAM
EMR	EMR
FVZ	FVZ
LAZ	LAZ
LIG	LIG
LOM	LOM
MAR	MAR
MOL	MOL
PIE	PIE
PUG	APU
SAR	SAR
SIC	SIC
TOS	TUS
TTA	TTA
UMB	UMB
VDA	VDA
VEN	VEN

9.3.2 Economic potential of district heating systems

The system scenario identifies a potential heat supply from district heating of 19.8 TWh by 2030, about two times the current levels, in which there remains a majority contribution from gas cogeneration (about 50%) accompanied by an intriguing growth in contributions from geothermal power and industrial waste heat recovery.

Table 97: Energy delivered by district heating in 2018 and in the optimum system scenario in 2030

Technology	Historical 2018 (TWh)	Scenario 2030 (TWh)
Geothermal power	0.2	1.5
Heat pumps	0.0	0.0
Biomass (HE CHP + boilers)	2.0	2.3
Biogas	0.0	1.3
Solar power	0.0	0.0
Industrial waste heat	0.1	1.5
Non-renewable waste HE CHP	0.8	0.6
HE CHP gas	4.0	10.6
Boilers (gas and other fossil fuels)	2.7	2.0
DISTRICT HEATING TOTAL	**9.8**	**19.8**

The expansion of gas-fired cogeneration plants covers about 40% of the technical potential due to internal competition between district heating technologies and wider needs to optimise the energy system in relation to energy and climate targets (such as reduction of emissions from non-ETS sectors) and economic targets, and is in some cases cheaper than separate production.

Other non-renewable plants (gas and LPG boilers, waste-to-energy) face a 20% reduction in output between 2018 and the 2030 scenario. While the penetration of natural gas cogeneration plants supports the cost-saving target for the energy system, it is also necessary to deliver on the national targets of the INECP concerning climate-changing emissions and renewables. Compliance with these constraints can also be seen in the way district heating supply is structured, with a significant growth in geothermal plants and biogas cogenerators between 2018 and the 2030 scenario. Geothermal power covers 62% of the estimated development potential. Growth is more limited for biomass plants, however, due in part to the limited availability of resources and competition with other strategic system uses, such as meeting civil heat demand in remote areas not served by methane pipelines. For heat pumps and solar thermal power, which are normally only supplementary units intended to support large-scale cogenerators, the scenario does not foresee any further development compared to the current contribution.

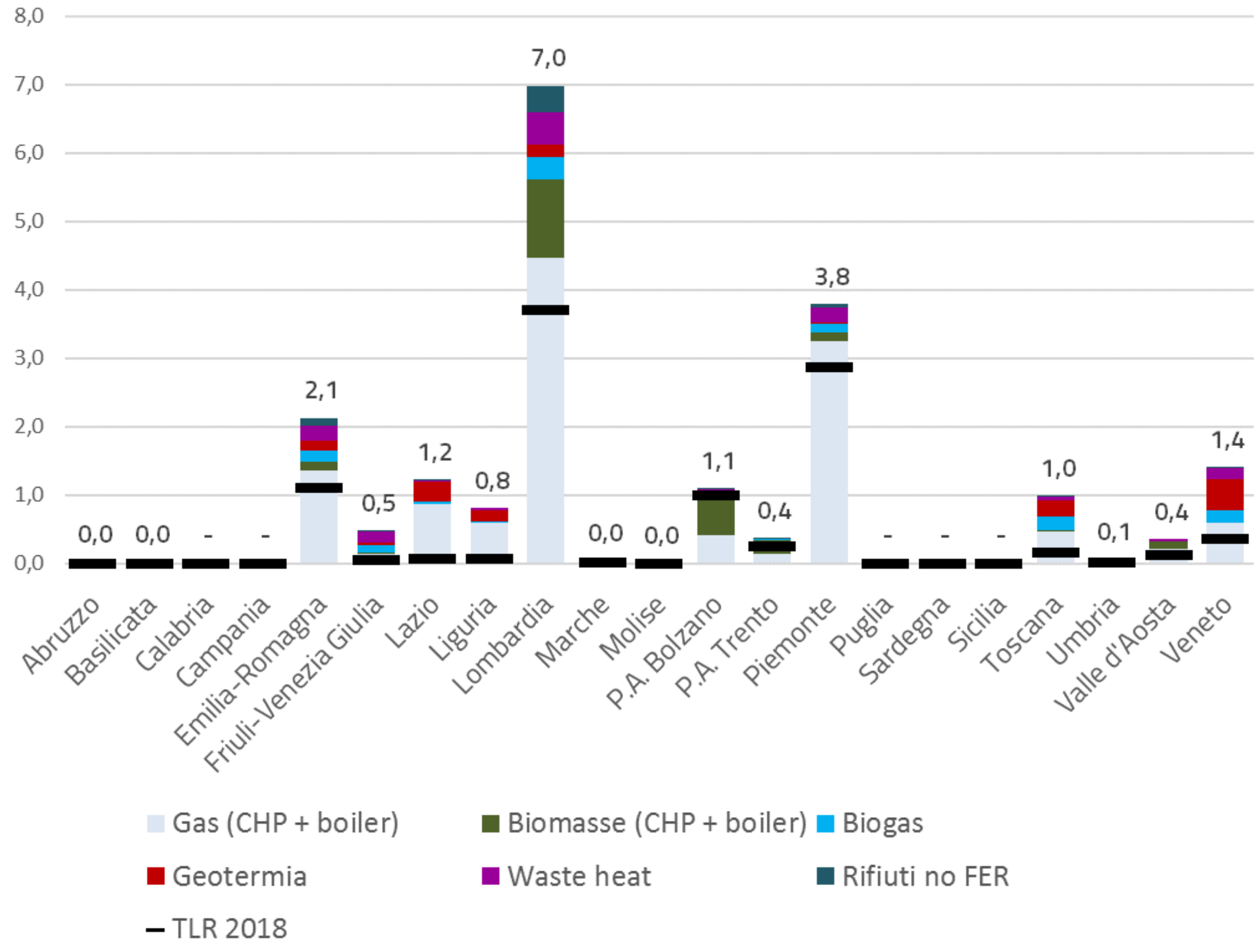
In the residential sector, the model identifies the system optimum as 16.2 TWh of total residential heat demand served by district heating by 2030.

There is thus an increase of 10 TWh in residential district heating demand, more than double the current level (6.2 TWh in 2018). This increase can be fully attributed to the colder climate zones, while for zones A, B and C there is no development of district heating, as in the current situation. This result confirms that district heating is more suitable for colder areas, where higher heat demand and longer heating hours make this centralised mode of heat production economically competitive compared to local solutions for individual flats or buildings, despite having greater infrastructure costs. Compared to the estimated maximum technical expansion potential, the system's economic potential scenario for 2030 realises just under half of that potential overall.

In the scenario, the opportunities for developing district heating in the service sector are smaller than in the residential sector. In fact, if the heat demand served by this technology is 3.3 TWh in 2018, in the scenario it reaches only 3.6 TWh, with an increase of 9%. The technical potential allows for the possibility of expanding district heating in the service sector up to 20.9 TWh; however, the scenario uses only 17% of this margin in 2030. The service sector is a typically electrical sector, where the penetration of heat pumps will reach 51% of the supply mix for heat demand in 2030.

At regional level, the economic potential of the district heating system is concentrated mainly in the northern regions (Lombardy, Piedmont, Emilia-Romagna and Veneto) where, in addition to the main supply from natural gas HE CHP, there are interesting opportunities to exploit waste heat from industrial processes. In Tuscany, Lazio and Veneto, the development of district heating is in many cases linked to the exploitation of geothermal resources.

Figure 162: Economic potential of the district heating system by region/autonomous province to 2030 (TWh)



Abruzzo	Abruzzo
Basilicata	Basilicata
Calabria	Calabria
Campania	Campania
Emilia-Romagna	Emilia-Romagna
Friuli-Venezia Giulia	Friuli-Venezia Giulia
Lazio	Lazio
Liguria	Liguria
Lombardia	Lombardy
Marche	Marche
Molise	Molise
P.A. Bolzano	AP of Bolzano
P.A. Trento	AP of Trento
Piemonte	Piedmont
Puglia	Apulia
Sardegna	Sardinia
Sicilia	Sicily
Toscana	Tuscany
Umbria	Umbria
Valle d’Aosta	Valle d'Aosta
Veneto	Veneto

Gas (CHP + boiler)	Gas (HE CHP + boilers)
Biomasse (CHP + boiler)	Biomass (HE CHP + boilers)
Biogas	Biogas
Geotermia	Geothermal power
Waste heat	Waste heat
Rifiuti no FER	Non-renewable waste
TLR 2018	DH 2018

9.3.3 Economic potential of the HE CHP system

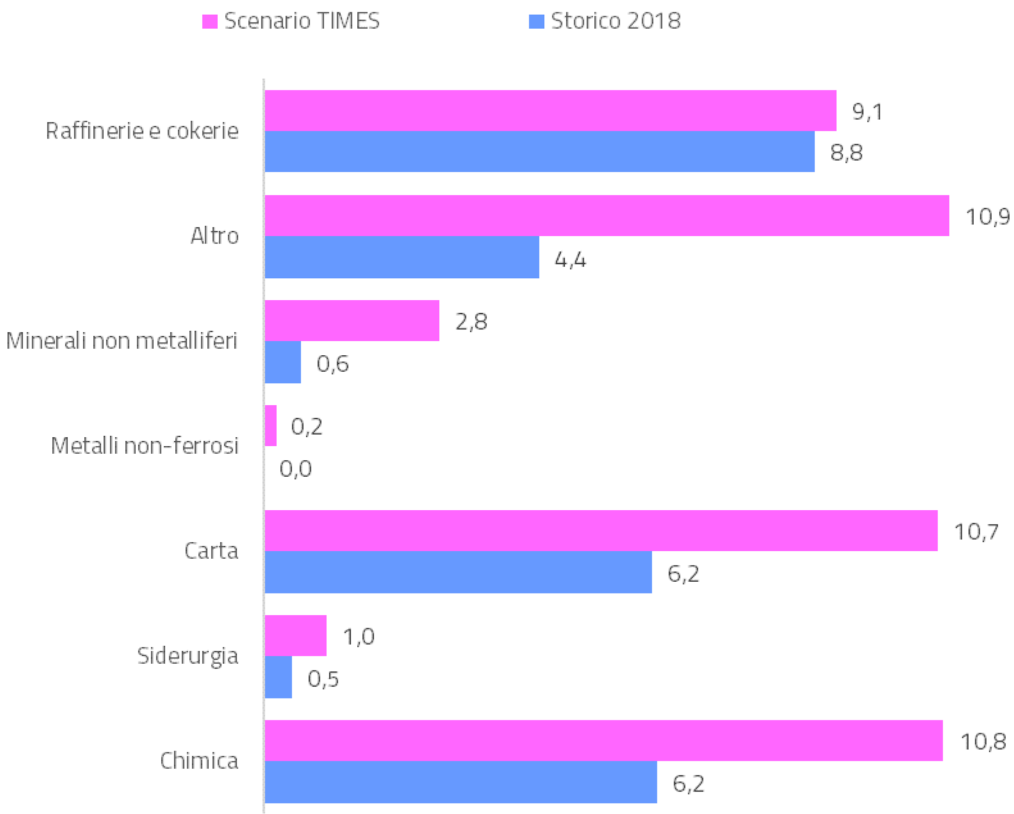
The system's economic scenario identifies a potential for HE CHP heat of 63 TWh by 2030, largely concentrated in the industrial sector (72%).

Table 98: Heat produced by HE CHP in 2018 and in the optimum system scenario in 2030

Technology	Historical 2018 (TWh)	Scenario 2030 (TWh)
Residential	-	-
Services	1.7	1.7
Industry	26.6	45.5
District heating (fed in by HE CHP)	7.1	16.1
Total HE CHP	35.4	63.3

In 2018, the largest contribution to HE CHP in the industrial sector comes from refineries and the chemical sector, as well as the paper industry. In the scenario showing the system's economic potential to 2030, not only are these traditional synergies between industrial processes and HE CHP strengthened, but there are also significant growth margins in the processing of non-metallic mineral products and in the steel industry. These trends in industrial HE CHP mean that the technical potential available to each sector is exploited to a significant extent, and in some cases to near saturation point (chemicals, paper). Overall, the industrial sector could almost double its 2018 levels by 2030, accounting for 81% of the maximum technical expansion potential. The replacement of all non-HE CHP present in 2018 will also be completed by 2030, amounting to around 7 TWh of derived heat.

Figure 163: Economic potential of the HE CHP system for industry to 2030 (TWh)

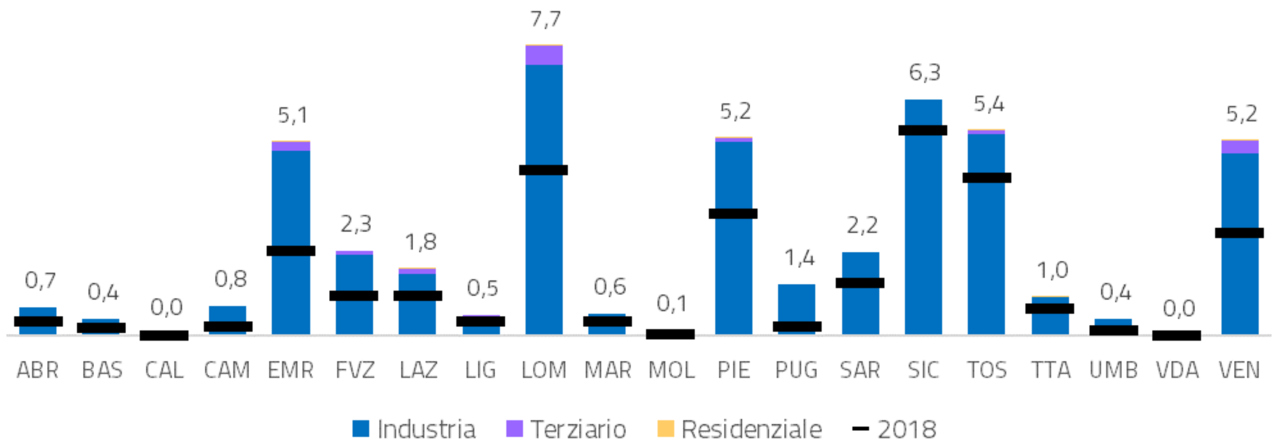


Scenario TIMES	TIMES scenario
Storico 2018	Historical 2018
Raffinerie e cokerie	Refineries and coking plants
Altro	Other
Minerali non metalliferi	Non-metallic mineral products
Metalli non-ferrosi	Non-ferrous metals
Carta	Paper
Siderurgia	Steel industry
Chimica	Chemicals

In 2018, high-efficiency cogeneration covers 1.7 TWh of heat demand in the service sector; in the most important sub-sectors, this contribution amounts to 1.3 TWh, covering just 1% of heat demand. This contribution is thus rather marginal and remains so even in the 2030 scenario, where demand served by HE CHP in the service sector is estimated to be in line with the current situation. The 2030 energy system optimisation model gives priority in this sector to highly efficient, less expensive technologies that are already widely used, in particular heat pumps and, secondly, condensing gas boilers. In the residential sector, HE CHP directly serving buildings (thus excluding HE CHP heat fed into district heating networks) meets a negligible share of residential heat demand in 2018, quantifiable at just 0.04 TWh, which is distributed mainly in climate zones D, E and F. The 2030 scenario confirms the low level of penetration of HE CHP in the residential sector, despite its considerable technical potential. In fact, there is generally a wide range of technological possibilities for decarbonisation available in this sector, meaning that a capital-intensive investment such as a HE CHP internal combustion engine will not be a preferred choice.

The regional breakdown of the potential for HE CHP shows a correlation with those regions whose productive fabric has a strong HE CHP bent and indicates that the largest contribution is in Lombardy (7.7 TWh), followed by Sicily (6.3 TWh), Tuscany (5.4 TWh), Veneto (5.2 TWh), Piedmont (5.2 TWh) and Emilia-Romagna (5.1 TWh).

Figure 164: Economic potential of the HE CHP system by region to 2030 (TWh)



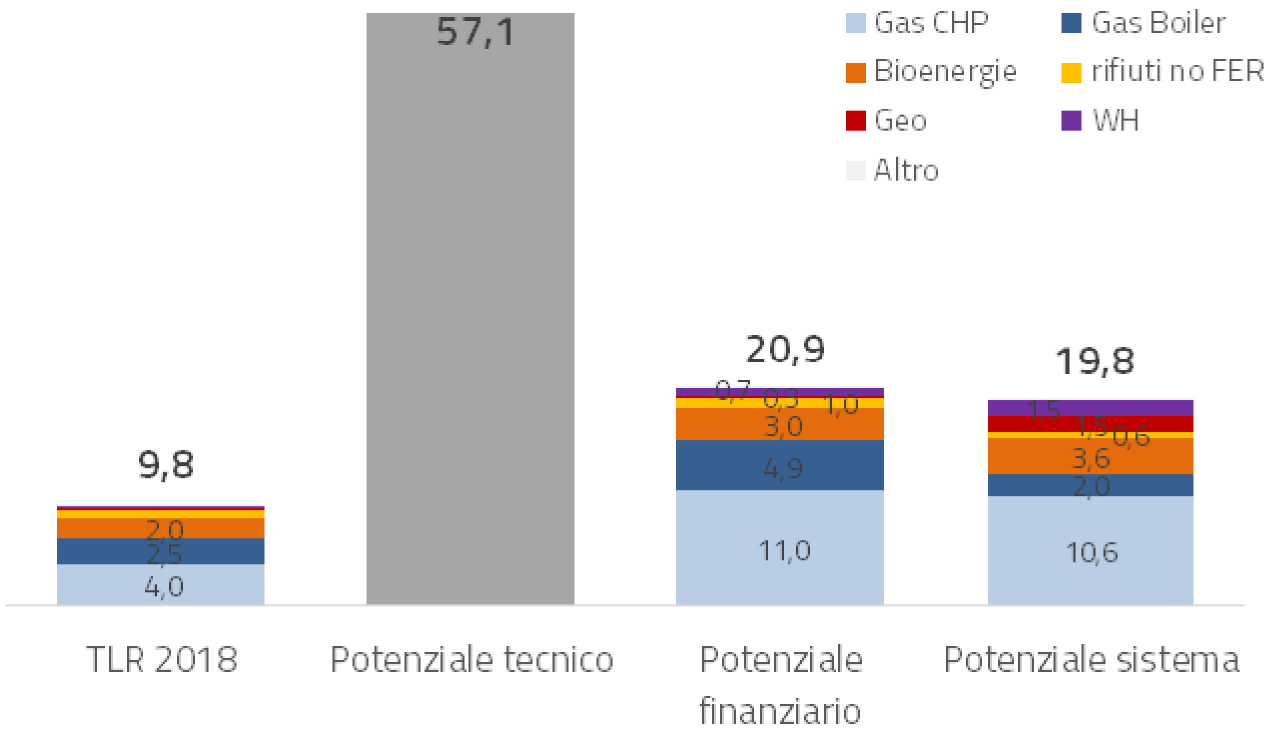
ABR	ABR
BAS	BAS
CAL	CAL
CAM	CAM
EMR	EMR
FVZ	FVZ
LAZ	LAZ
LIG	LIG
LOM	LOM
MAR	MAR
MOL	MOL
PIE	PIE
PUG	APU
SAR	SAR
SIC	SIC
TOS	TUS
TTA	TTA
UMB	UMB
VDA	VDA
VEN	VEN
Industria	Industry
Terziario	Services
Residenziale	Residential
2018	2018

10 Summary of results

According to this study, the economic and financial potential of efficient district heating, under current legislative and market conditions, is estimated to be around 21 TWh – more than double the current level of development – almost half of which is attributable to gas HE CHP technology (including the potential recovery of waste heat from existing thermoelectric plants). With regard to thermal renewables, which could supply district heating networks, there are possibilities for developing bioenergy (up to 3 TWh), in particular in areas not served by methane pipelines, and for developing systems for recovering industrial waste heat (0.7 TWh). Activating this economic and financial potential from district heating may deliver environmental benefits, including 0.3 Mtoe of primary fossil energy saved and 0.6 $MtCO_2$ of greenhouse gas emissions prevented.

In addition to financial potential, the system potential of district heating was also assessed, updating the energy system scenario to achieve the INECP targets in the light of the new technical potential for district heating assessed as part of this study. The system analysis shows results for district heating in line with those shown by the economic and financial analysis, with a potential of almost 20 TWh. Gas HE CHP continues to make a large contribution (11 TWh) to this, but there are also greater contributions from renewables, in particular geothermal power (1.5 TWh) and bioenergy (3.6 TWh), plus 1.5 TWh of waste heat.

Figure 165: Comparison between the current district heating level and the technical, financial and system potential of heat from district heating (TWh)

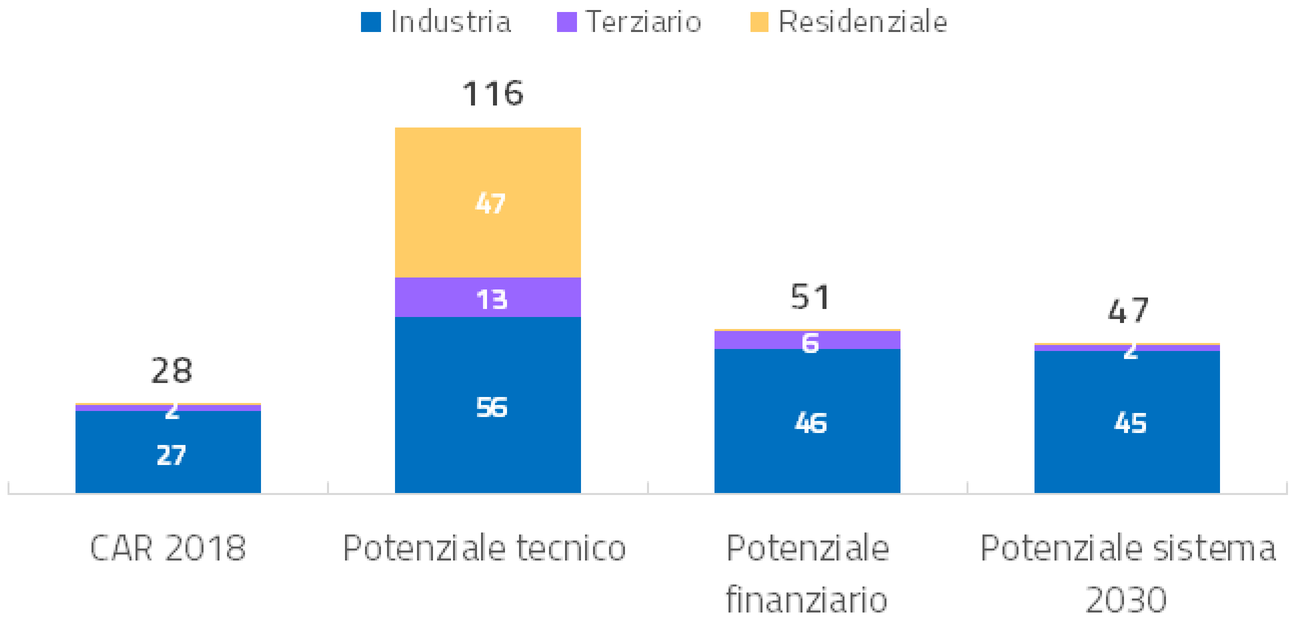


Gas CHP	Gas HE CHP
Gas Boiler	Gas boilers
Bioenergie	Bioenergy
rifiuti no FER	Non-renewable waste
Geo	Geo
WH	WH
Altro	Other
TLR 2018	DH 2018
Potenziale tecnico	Technical potential
Potenziale finanziario	Financial potential
Potenziale sistema	System potential

Cogeneration shows a technical potential of 116 TWh, of which 56 TWh relates to industry, 47 TWh to the residential sector (given the residential demand that can theoretically be cogenerated) and 13 TWh to the service sector. Moving on to what is financially viable under current regulations, there is an economic potential of 51 TWh, of which 89% relates to industry (45.5 TWh) and 5.8 TWh to the service sector. In particular, the paper and basic chemicals sectors have the greatest economic potential in industry for HE CHP heat (10-11 TWh), followed by refining; given current development, the subsectors with the greatest growth potential are ceramics (4.6 TWh), basic chemicals (4.5 TWh) and paper (3.6 TWh), followed by food (1.9 TWh) and mechanical engineering (1.4 TWh). In the service sector, hospitals account for the greatest share of economic potential (3.4 TWh of heat) and growth potential (2.4 TWh), followed by swimming pools and large sports centres with 1.6 TWh of growth heat. Universities/research centres and hotels also show significant margins for growth, with economic growth potential for HE CHP heat of 0.3 and 0.2 TWh, respectively. By contrast, under current regulations, which provide for HE CHP to supply electricity only for common utilities, the case studies examined for the residential sector, which are representative of the average requirements of single-family homes, medium-sized apartment blocks and large apartment blocks, do not show any economic advantage, despite the high technical potential of the sector.

As regards the system potential, the energy scenario optimisation model shows a potential for HE CHP of 47 TWh, almost entirely in industry (45.5 TWh), with the results being fairly closely aligned with those of the financial analysis. From a system perspective, there are no significant margins for growth for HE CHP in the service and residential sectors, which is partly due to the expected penetration of other technologies, including heat pumps, which are part of the strategy for achieving renewables targets by 2030, possibly in conjunction with photovoltaics.

Figure 166: Comparison between the current level of HE CHP (excluding district heating HE CHP) and the technical, financial and system potential of HE CHP heat (TWh)



Industria	Industry
Terziario	Services
Residenziale	Residential
CAR 2018	HE CHP 2018
Potenziale tecnico	Technical potential
Potenziale finanziario	Financial potential
Potenziale sistema 2030	System potential 2030

11 Existing policies, objectives and planned measures

Annex VIII to Directive 2012/27/EU, as amended by Regulation (EU) 2019/826 of 4 March 2019, requires that the assessment of the potential for efficiency in heating also includes a section on the recognition of **existing and planned policies and measures.** This chapter complies with this request by listing the main existing and planned measures at national level.

11.1 The evolution of measures to promote cogeneration and district heating prior to the INECP

11.1.1 Cogeneration

It should first be noted that natural gas used to produce electricity is subject to a specific excise duty regime (which varies according to consumption and end use): gas for a specific consumption up to 0.220 m^3/kWh is subject to an excise duty of EUR 0.000449/m^3 and gas consumed above that limit is subject to an excise duty of between EUR 0.007499/m^3 and EUR 0.044/m^3 (depending on the end use). If the electricity is self-consumed, the excise duty is reduced by 30%. For supplies of methane gas used to produce electricity (including through cogeneration), the reduced VAT rate of 10% applies, while the ordinary rate of 22% applies to supplies of gas used in boilers.

In order to promote energy efficiency, Legislative Decree No 20/2007, implementing Directive 2004/8/EC, provided for a form of economic support aimed at encouraging technological innovations that can, by meeting specific requirements in terms of primary energy savings (PES index), be deemed to operate using high-efficiency cogeneration. The Directive was finally transposed by Ministerial Decree of 4 August 2011, which established the criteria used to assess HE CHP status. Based on the principles of Legislative Decree No 20/2007, Ministerial Decree of 5 September 2011 introduced access to type II white certificates ('WC-HE CHP') for technological innovations made in relation to cogeneration units, subject to certain criteria:

- for newly built cogeneration units that came into operation on or after 7 March 2007, provision is made for a right to issue WC-HE CHP over a period of 10 calendar years, the number of which varies for each reporting year on the basis of the primary energy savings achieved and a harmonisation coefficient 'K' of between 1 and 1.4 in relation to the average electricity generation power under HE CHP; the incentive period is extended to 15 calendar years in the case of units connected to a district heating network, if the network is also newly built;
- for cogeneration units that have undergone a 'refurbishment' operation since 7 March 2007 (replacement of at least two main components with new components, in units that have been in operation for at least 12 years), provision is made for a right to issue WC-HE CHP over a

period of 10 calendar years, the number of which varies for each reporting year on the basis of the primary energy savings achieved (the harmonisation coefficient 'K' is set at 1); the incentive period is extended to 15 calendar years in the case of units connected to a district heating network, if the refurbishment has also increased the network's transport capacity, expressed in terms of toe/y, by no less than 30% of the nominal transport capacity prior to the refurbishment;

- for cogeneration units that entered into operation between 1 April 1999 and 6 March 2007, provided that they are recognised as cogenerative under the rules that applied on the date of entry into operation implementing the provisions of Legislative Decree No 28/2011, provision is made for a right to issue WC-HE CHP for a period of 5 calendar years in a number equal to 30% of the amount attributed to the units referred to above.

White certificates (or energy efficiency certificates, 'EEC') can be used to meet the obligation imposed on electricity and natural gas distributors, namely to achieve certain annual quantitative targets for primary energy savings, expressed in tonnes of oil equivalent saved, pursuant to Ministerial Decree of 20 July 2004, as subsequently amended, or they can otherwise be exchanged and traded on the electronic market managed by GME. Alternatively, GSE may also be asked to revoke white certificates; the price of revocation is the price that applied when the unit entered into operation and remains constant throughout the incentive period. For units that entered into operation prior to Ministerial Decree of 5 September 2011, the price of revocation is the price that applied when that Decree came into force.

The following additional benefits apply to electricity produced by cogeneration units recognised as operating using high-efficiency cogeneration, pursuant to Ministerial Decree of 4 August 2011:

- electricity produced by predominantly HE CHP units, i.e. units for which the percentage of electricity produced using HE CHP is greater than or equal to 50% of the total electricity produced, is given priority over production from conventional sources when it comes to dispatching;
- in relation to the net share of electricity produced using HE CHP and fed into the network by plants fuelled with biomass, biogas and sustainable bioliquids, the base incentive tariff provided for by Ministerial Decree of 6 July 2012 is increased according to the type of fuel used;
- in relation to the net electricity produced using HE CHP and fed into the network by plants fuelled with biomethane, the tariff used for the production of electricity from biogas in accordance with Ministerial Decree of 6 July 2012 is applied pursuant to Ministerial Decree of 5 December 2013;
- a partial exemption from the payment of general system charges is granted if the other requirements for recognising an 'efficient system for users and an existing system equivalent to an efficient system for users ("SEU" and "SEESEU")' set out under Legislative Decree No 115/2008, as amended by Legislative Decree No 56/2010, are met.

By Decree of the Minister for Economic Development of 4 August 2016, the conditions and methods for recognising the enhanced profitability of high-efficiency cogeneration energy obtained following conversion of existing sustainable bioliquid plants supplying industrial or craft sites were defined. The Decree provides for three types of conversion:

- a: interventions on bioliquid plants that are already cogenerative, where the conversion consists in replacing the bioliquid with another fuel input;
- b: interventions on non-cogenerative bioliquid plants, where the conversion consists in replacing bioliquids with another fuel input and converting to operate in cogenerative mode;
- c: complete dismantling of existing bioliquid plants, excluding any reusable infrastructure, with installation of a new cogeneration plant pursuant to Ministerial Decree of 5 September 2011 that uses a different fuel.

The use of special, unique models is provided for by Decree of the Minister for Economic Development of 16 March 2017, which applies to high-efficiency micro-cogeneration plants and micro-cogeneration plants fuelled by renewables, in order to minimise the burden on producers and to streamline the exchange of information between municipalities, network operators and GSE as part of activities involving the construction, connection and operation of this particular type of plant.

Article 14 of Directive 2012/27/EU introduces an important general principle for energy efficiency, establishing that 'Member States shall ensure that any available support for cogeneration is subject to the electricity produced originating from high-efficiency cogeneration and the waste heat being effectively used to achieve primary energy savings'.

11.1.2 District heating

In Italy, the need to achieve national and EU environmental and energy efficiency targets has galvanised the development of district heating. Against this background, local authorities have supported the construction and development of most of the existing networks, including through municipal companies. Various tools have been put in place over the years to promote district heating: obligations and operating, capital and interest rate incentives.

As regards obligations, Legislative Decree No 311/2006 stipulated that all newly built buildings located no more than 1 km from a district heating network must be set up to allow connection to that network. This rule has been reinforced by Article 22, paragraph 1, of Legislative Decree No 28/2011, according to which infrastructure intended for the installation of networks for distributing renewable energy for heating and cooling are categorised, for all intents and purposes, as primary urban works. Article 11 of Legislative Decree No 28/2011 lays down an obligation to integrate renewables into heat and cold production in new buildings and in existing buildings undergoing major renovation works, with the issuing of the building permit being made subject to compliance with that obligation. This obligation does not apply if the building is connected to a district heating network covering its entire primary energy demand for winter heating, space heating and domestic hot water supply.

As regards capital incentives, the construction of district heating plants and networks benefited from a number of investment incentives laid down by national laws in the 1980s and 1990s, which aimed to pursue the strategic objectives of saving energy and using renewables. These laws have exhausted their effects, but it is useful to recall them briefly for the role they played in supporting development in the sector.

Law No 308/82 considered the use of renewables to be 'in the public interest and to the public's benefit', which also included 'the processing of organic and inorganic waste or plant products [and] heat recoverable in power plants, in exhaust fumes and from heating systems and industrial processes, and other forms of energy recoverable in processes or plants'. Against this background, Article 4 of Law No 308/82 stopped ENEL's monopoly on the production of electricity using cogeneration and, more generally, the production of electricity using renewables in plants with a capacity of less than 3 MWe. This law also set out an important exemption for municipal companies: 'If the plants are operated by municipalities, provinces and their consortia or individual or associated companies, as well as consortia set up between public and private companies, the power limits are determined by heat production demand'. The surplus electricity produced by these plants was purchased by ENEL at prices regulated by the Interministerial Price Committee. In order to encourage the development of production using renewables or cogeneration, non-repayable grants were awarded for feasibility studies and project plans and a fund of ITL 415 billion was set up for capital grants to those subjects who had built or developed renewables or cogeneration plants, up to 30% of the total planned expenditure. These contributions were used to develop certain historical networks, such as those of Brescia, Turin, Bruneck, Rovereto and Verona, and in particular to purchase heat generation plants.

Although Law No 10/91 repealed Law No 308/82, it upheld the incentives and even extended them to include district heating. In particular, Article 11 established that the same beneficiaries as those set out under Article 10 of Law No 308/82 could be awarded capital grants for the same purposes as set out under that Article up to a maximum of 50% of the planned eligible expenditure, namely up to a maximum of ITL 50 million for technical and economic feasibility studies and ITL 300 million for project plans. That same Article also provided for a capital contribution of 40% of the documented expenditure for district heating networks. Paragraph 7 of Article 11 of Law No 10/91 also contained a specific rule in favour of district heating, according to which the 'construction of district heating plants by municipal companies, public bodies, consortia between public bodies, between public bodies and private companies, or between private companies that use heat from the energy production cycles of thermoelectric power plants as well as heat recoverable from industrial processes, can benefit from capital contributions up to 50% of the associated cost'. Article 6 obliged the regions and autonomous provinces of Trento and Bolzano to identify areas suitable for the construction of district heating plants and networks and imposed an obligation on public bodies and administrations to prioritise connections to district heating networks if their buildings are located in these areas. Article 8 also provided for capital grants of between 20% and 40% of documented expenditure if energy efficiency measures are implemented in buildings to support their connection to district heating networks. Law No 10/91 was not refinanced in 1995 and has therefore exhausted its effects. Some regions (Lombardy, Piedmont, Emilia-Romagna, the autonomous provinces of Trento and Bolzano) have, however, continued to support the construction of district heating networks by awarding capital grants, which are mainly used to build heat distribution networks.

The district heating tax credit was first established by Article 8(10)(f) of Law No 448 of 23 December 1998. The incentive in question consists of the granting of a tax credit equal to EUR 0.02194 for each kWh of heat supplied (a measure thus reduced by Prime Ministerial Decree of 21 March 2014), which is passed on to the end user, who is the actual recipient of the tax benefit, in the sale price.

Article 22, paragraph 4, of Legislative Decree No 28/2011 established a guarantee fund to support the construction of district heating networks, which is topped up by a fee of 0.05 EUR/Sm^3 for methane gas consumption that is charged to end customers. Article 5, paragraph 12, of Legislative Decree No 102/2014 replaced the above fund, establishing that the resources set aside must be paid to the State treasury in the amount of EUR 5 million in 2014 and EUR 25 million in 2015 in order to be reallocated to the implementation of an intervention programme to improve the energy performance of buildings belonging to the central public administration.

Article 15 of Legislative Decree No 102/2014 established the Italian national energy efficiency fund (il fondo nazionale per l'efficienza energetica), a revolving fund designed to support the financing of measures to help achieve national energy efficiency targets, by encouraging involvement from national and EU financial institutions and private investors on an appropriate risk-sharing basis, in particular for the following purposes:

- implementing measures to improve energy efficiency in buildings owned by the public administration;
- building district heating and district cooling networks;
- ensuring energy efficiency of public services and infrastructure, including public lighting;
- ensuring energy efficiency in entire buildings intended for residential use, including social housing;
- ensuring energy efficiency and reducing energy consumption in industry and the service sector.

As regards interest rate incentives, subsidised loans granted by the European Investment Bank play an important role in development in the sector.

District heating networks were also made eligible for the white certificates incentive scheme. The securities due to district heating networks fuelled by high-efficiency cogeneration plants are calculated using the methodology set out in Ministerial Decree of 5 September 2011, which defines the support scheme for high-efficiency cogeneration.

Ministerial Decree of 24 October 2005 also made cogeneration plants that feed a district heating network eligible for the green certificates (GC-DH) incentive scheme, proportionate to the quantity of heat fed into the district heating network and the generation technology used and even if they are not fuelled by renewables. Subsequently, Ministerial Decree of 6 July 2012 established that a premium of EUR 40/MWh should be added to the incentive tariff for biomass plants if the cogenerated heat is used for district heating.

District heating has also been able to enjoy some tax benefits with respect to heat production at civil end users. Fuel consumption by cogeneration units and integration boilers that are connected to the same district heating network benefits from the reduced rate of excise duty for industrial uses (and the relevant share of the reduced rate for electrical uses), provided that certain conditions are met (high-efficiency cogeneration and power-to-heat ratio > 10%). If this requirement is not met, this consumption is subject to the rate of excise duty for civil uses.

Law No 77 of 17 July 2020 lists measures that are entitled to this reduced rate, including connections to efficient district heating systems, as defined by Article 2, paragraph 2, letter t), of Legislative Decree No 102/2014, for mountain municipalities excluded from the European infringement procedures initiated following Italy's failure to comply with the obligations under Directive 2008/50/EC.

11.2 Main targets and measures identified in the INECP

The integrated national energy and climate plan sent to the European Commission in accordance with Regulation (EU) 2018/1999 outlines the targets and measures that define Italy's contribution to achieving European energy transition and climate targets. The plan will be updated to reflect the greater decarbonisation ambition agreed at European level but, at the time of writing this report, there are no official updated versions of the INECP.

There are five dimensions to the INECP:
- decarbonisation, the main elements of which are greenhouse gas emissions and absorption and the development of renewables;
- energy efficiency, with a reduction in final energy consumption compared to the year-on-year scenario and thanks to active policies acting as a pillar;
- energy security, structured around the dynamics of energy supply composition and origin;
- the internal energy market, including analyses of energy infrastructure, market integration and energy poverty;
- research, innovation and competitiveness, which cut across the initiatives underpinning the other four dimensions.

In particular, those concepts that concern the dimensions of decarbonisation, energy efficiency and research, innovation and competitiveness, the content of which is most relevant to areas such as heat supply and demand and, in general, to targets, policies and measures aimed at increasing efficiency and reducing the environmental externalities of heating and cooling, are mentioned below.

As regards heat consumption, the key European concept of putting energy efficiency first should be kept in mind, a concept expressed by the European Commission back in 2016 as part of the winter package and according to which it is recognised that the cheapest, cleanest and safest energy is energy that is not used. Energy efficiency is thus regarded as an energy source, the first and most effective vector for reducing consumption and lowering its environmental impact, thus promoting energy transition towards a more competitive, low-carbon economy.

11.2.1 The main targets of the INECP in relation to heat consumption

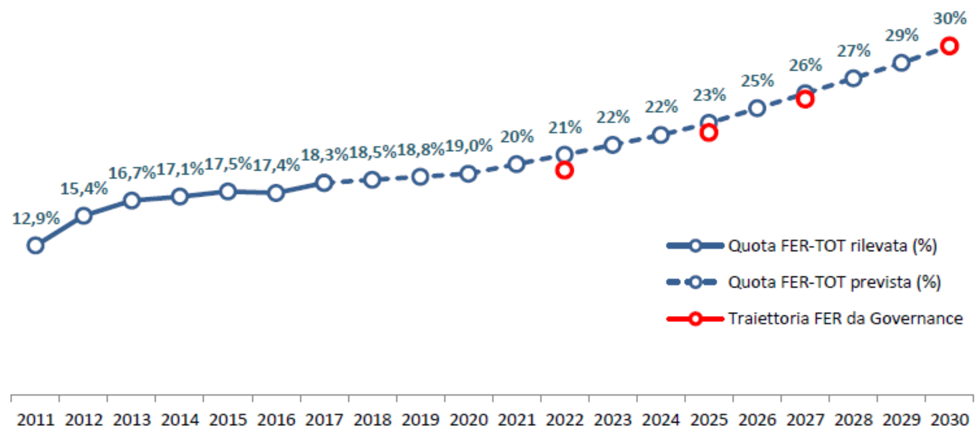
Decarbonisation and renewables

The target of reducing greenhouse gas emissions at European level by at least 40% by 2030 compared to 1990 is split between ETS (energy industries, energy-intensive industries and aviation) and non-ETS (transport, residential, services, non-ETS industry, agriculture and waste) sectors, which will have to record a reduction of 43% and 30%, respectively, compared to 2005.

Greenhouse gas (GHG) emissions from energy use account for 81% of the national total, which, in 2016, was around 428 million tonnes of CO_2 equivalent. The remaining share of emissions comes from non-energy sources, which are mainly linked to industrial processes, fluorinated gases, agriculture and waste.

In the INECP, Italy sets a target of covering 30% of gross final energy consumption from renewables by 2030, outlining a pathway of sustainable growth that includes fully integrating renewables into the system. In particular, the 2030 target is for a gross final energy consumption of 111 Mtoe, with about 33 Mtoe coming from renewables. The trend in the share of renewables follows the indicative minimum trajectory outlined in Article 4 of the Governance Regulation.

Figure 167: Trajectory of the overall renewables share [source: INECP]



Quota FER-TOT rilevata (%)	Total share of renewables recorded (%)
Quota FER-TOT prevista (%)	Total share of renewables expected (%)
Traiettoria FER da Governance	Renewables trajectory from Governance

Table 99: Overall renewables target for 2030 (ktoe) [source: INECP]

	2016	2017	2025	2030
Numeratore	**21.081**	**22.000**	**27.168**	**33.428**
Produzione lorda di energia elettrica da FER	9.504	9.729	12.281	16.060
Consumi finali FER per riscaldamento e raffrescamento	10.538	11.211	12.907	15.031
Consumi finali di FER nei trasporti	1.039	1.060	1.980	2.337
Denominatore - Consumi finali lordi complessivi	**121.153**	**120.435**	**116.064**	**111.359**
Quota FER complessiva (%)	**17,4%**	**18,3%**	**23,4%**	**30,0%**

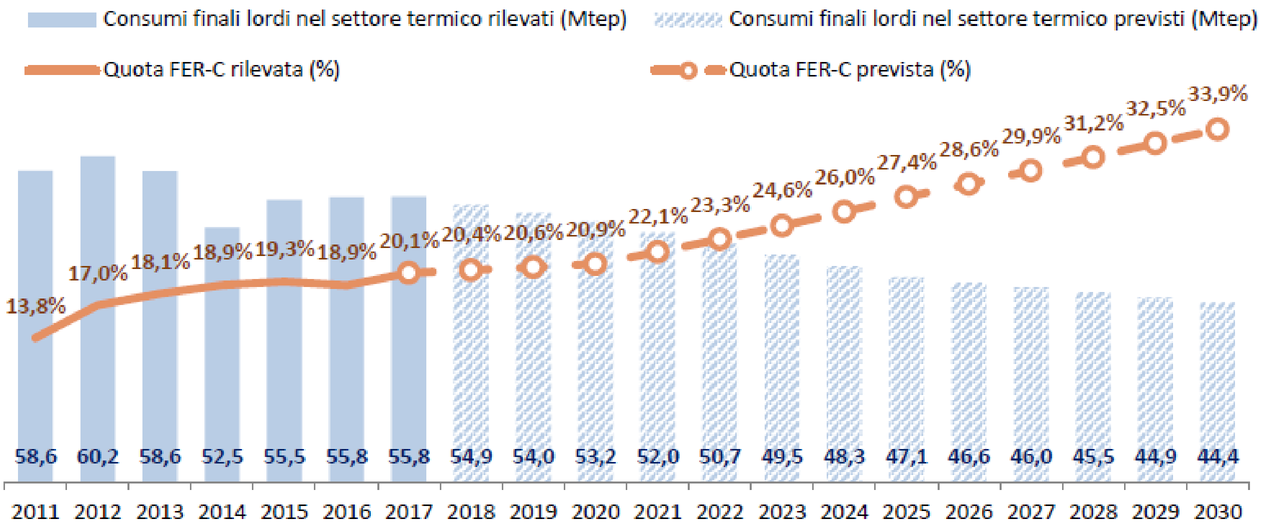
Numeratore	**Numerator**
Produzione lorda di energia elettrica da FER	Gross electricity production from renewables
Consumi finali FER per riscaldamento e raffrescamento	Final consumption of renewables for heating and cooling
Consumi finali di FER nei trasporti	Final consumption of renewables for transport

Denominatore - Consumi finali lordi complessivi	**Denominator** – Total gross final consumption
Quota FER complessiva (%)	**Total share of renewables (%)**
21.081	21 081
9.504	9 504
17,4%	17.4%

The contribution of renewables to meeting total gross final consumption by 2030 (30%) is expected to be different for each sector:

- 55.0% share of renewables in the electricity sector;
- **33.9% share of renewables in the thermal sector (heating and cooling uses);**
- 22.0% as regards the share of renewables in transport (calculated using the obligation accounting criteria set out by RED II).

Figure 168: Trajectory of the renewables share in the thermal sector [source: INECP]



Consumi finali lordi nel settore termico rilevati (Mtep)	Gross final consumption recorded in the thermal sector (Mtoe)
Consumi finali lordi nel settore termico previsti (Mtep)	Gross final consumption expected in the thermal sector (Mtoe)
Quota FER-C rilevata (%)	Share of renewables recorded (%)
Quota FER-C prevista (%)	Share of renewables expected (%)

Increase in the share of thermal renewables

An increase in the share of renewables in heat consumption is highly dependent on widespread retrofitting of the existing building stock, which may lead to a significant reduction in consumption. In absolute terms, consumption from thermal renewables is expected to exceed 15 Mtoe in the heating and cooling sector by 2030, which is mainly related to the increase in renewable energy supplied by heat pumps. The installation of new biomass heating plants should be guided towards high-efficiency, environmentally friendly plants, with consideration also being given to the possibility of introducing restrictions on new installations in areas where air quality is critical. The introduction of stricter performance requirements for accessing incentives for biomass heat generators provides a short-term stimulus for replacing old plants with efficient, low-emission technologies. Given their high efficiency, heat pumps will gain increasing weight in the renewable thermal mix, further supported by technological progress in the sector. Thermal solar power will be able to increase its contribution through integrated systems for efficient and renewable heat production, such as hybrid systems and integration in district heating systems. A margin for development of district heating is expected; in order to exploit this potential, it will be important to leverage the synergies between the use of renewables and high-efficiency cogeneration, taking into account the specific climate and technical and economic conditions.

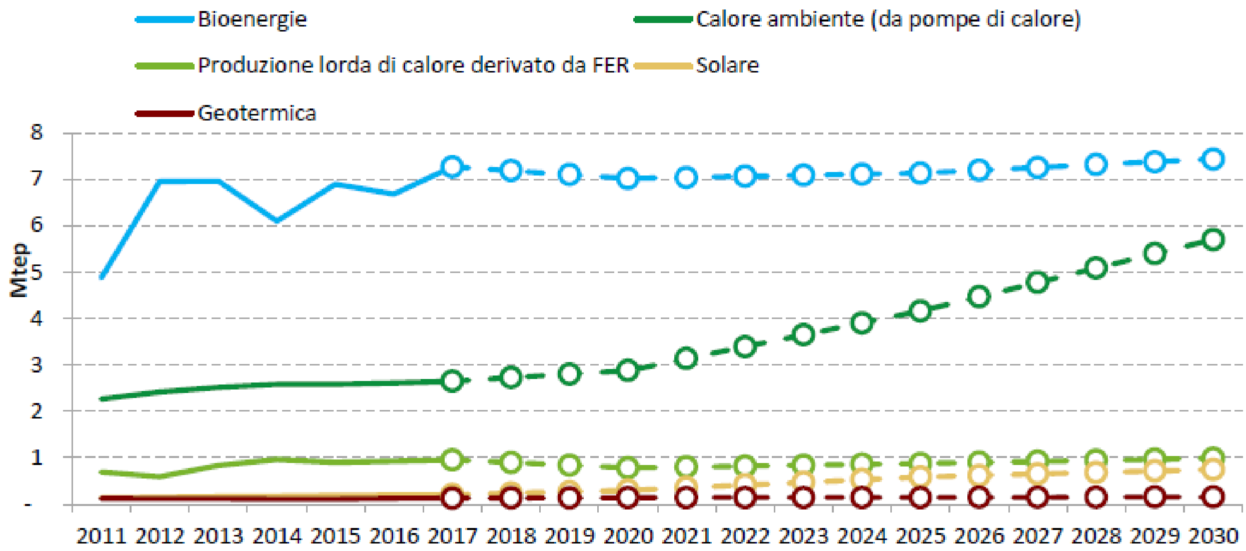
Table 100: Renewables targets in the thermal sector (ktoe) [source: INECP]

	2016	2017	2025	2030
Numeratore	**10.538**	**11.211**	**12.907**	**15.031**
Produzione lorda di calore derivato da FER*	928	957	881	993
Consumi finali FER per riscaldamento	9.611	10.254	12.026	14.038
di cui bioenergie*	6.677	7.265	7.128	7.430
di cui solare	200	209	590	751
di cui geotermico	125	131	148	158
di cui energia ambiente da pdc	2.609	2.650	4.160	5.699
Denominatore - Consumi finali lordi nel settore termico	**55.796**	**55.823**	**47.126**	**44.350**
Quota FER-C (%)	**18,9%**	**20,1%**	**27,4%**	**33,9%**

*Per i bioliquidi (inclusi nelle bioenergie insieme alle biomasse solide e al biogas) si riporta solo il contributo dei bioliqui sostenibili.

Numeratore	**Numerator**
Produzione lorda di calore derivato da FER*	Gross heat production from renewables*
Consumi finali FER per riscaldamento	Final consumption from renewables for heating
di cui bioenergie*	of which from bioenergy*
di cui solare	of which from solar power
di cui geotermico	of which from geothermal power
di cui energia ambiente da pdc	of which from ambient energy from heat pumps
Denominatore - Consumi finali lordi nel settore termico	**Denominator** – Gross final consumption in the thermal sector
Quota FER-C (%)	**Share of renewables (%)**
*Per i bioliquidi (inclusi nelle bioenergie insieme alle biomasse solide e al biogas) si riporta solo il contributo dei bioliqui sostenibili.	*For bioliquids (included in bioenergy together with solid biomass and biogas), only the contribution from sustainable bioliquids is reported.
10.538	10 538
9 611	9 611
18.9%	18.9%

Figure 169: Growth trajectories for renewables in the thermal sector by 2030 [source: INECP]



Bioenergie	Bioenergy
Calore ambiente (da pompe di calore)	Ambient heat (from heat pumps)
Produzione lorda di calore derivato da FER	Gross production of heat derived from renewables
Solare	Solar power
Geotermica	Geothermal power
Mtep	Mtoe

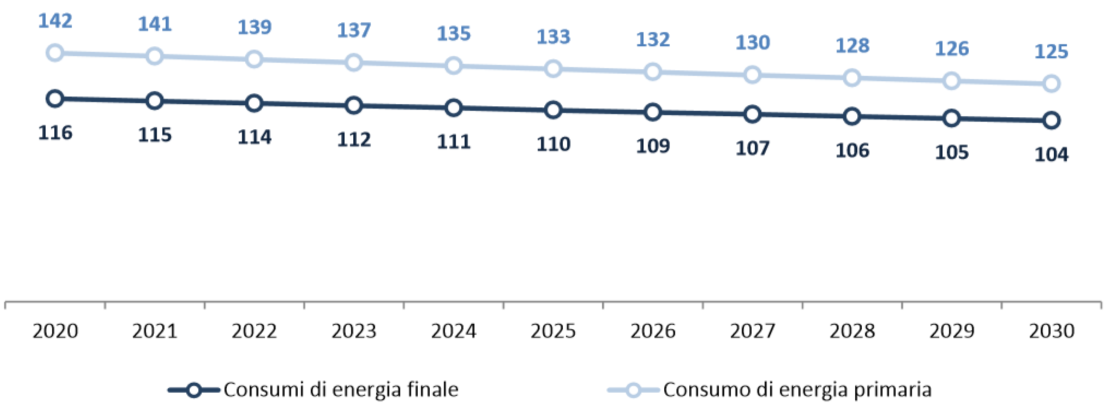
The analyses carried out in order to assess the potential for efficient heating lead to the conclusion that the forecasts set out in the INECP for heat consumption to 2030 can be revised slightly (cf. comparison between Table 96 and Table 100 and between Figure 158 and Figure 169). These assessments will be taken into consideration as part of the INECP update, in the broader context of its partial revision to take into account the more ambitious European decarbonisation targets for 2030.

As regards the research, innovation and competitiveness dimension, the aim is to create the necessary system conditions to ensure that research programmes are broadly participated in by Italian industry and public and private research centres. In particular, looking at the development of technologies to allow efficient penetration of the electric vector through to end uses, research activities will focus on complex heat pump systems or those combined with non-conventional storage systems; the use of high-temperature heat pumps in industrial processes to recover waste heat will also be studied. The evolution and development of the above-mentioned technologies would allow the accumulation of excess energy production from non-programmable renewables using renewable energy vectors (biomethane, hydrogen, heat), increasing the overall efficiency of the energy system and starting a synergistic path between the two systems towards a possible merger of the gas and electricity sectors into a single energy sector.

Increase in energy efficiency

As indicated in the INECP, Italy intends to pursue the indicative target of a 43% reduction in primary energy consumption and a 39.7% reduction in final energy consumption by 2030 compared to the PRIMES 2007 reference scenario – 125.1 Mtoe of primary energy and 103.8 Mtoe of final energy in absolute terms – following a trajectory that must provide for a minimum target of overall cumulative reduction of final energy of 50.98 Mtoe in the period 2021-2030.

Figure 170: Trajectory of primary and final energy consumption (Mtoe) in the period 2020-2030 [source: INECP]

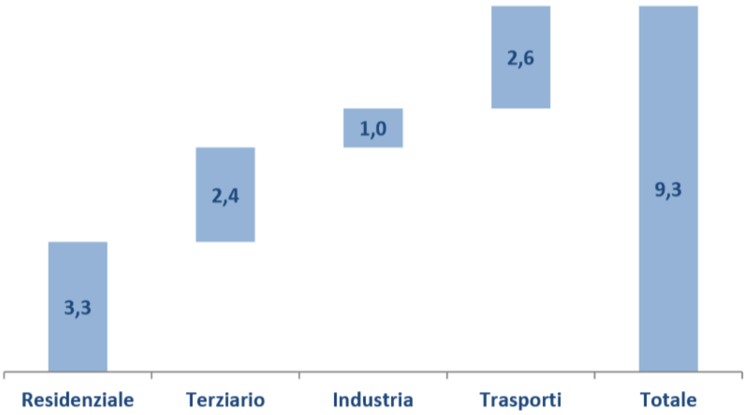


Consumi di energia finale	Final energy consumption
Consumo di energia primaria	Primary energy consumption

In the INECP, Italy states that it intends to pursue a cumulative savings target of approximately 51.4 Mtoe, corresponding to more than 9.3 Mtoe of annual savings by 2030, to be achieved through active policies primarily aimed at the civil and transport sectors, in conjunction with achieving renewables and decarbonisation targets.

The reduction in final energy consumption by 2030, to be achieved through active policies in predominantly non-ETS sectors, has been allocated to the different sectors following a modelling approach to minimise system costs, with the sectors with the greatest potential for efficiency and the most cost-effective measures being identified to ensure that the target set in the EED Directive is met. The sectoral breakdown is influenced by trends in the performance and cost of energy technologies, sectoral potential and the renewables target, which encourages options, such as heat pumps, that support the attainment of renewables targets.

Figure 171: Breakdown by economic sector of savings falling under the 2030 target (Mtoe) [source: INECP]



Residenziale	Residential
Terziario	Services
Industria	Industry
Trasporti	Transport
Totale	Total

The civil sector (residential and services) is identified as the main area for efficiency improvements, with a reduction in energy consumption of around 5.7 Mtoe compared to the baseline scenario for 2030. In particular, reductions of 3.3 Mtoe in the residential sector and 2.4 Mtoe in the service sector are expected to be achieved through building renovation works and the installation of renewables technologies, as well as a strong increase in the efficiency of end-use devices while simultaneously committing to phase out heating oil.

The lower contribution expected from the industrial sector, with a reduction in consumption of around 1.0 Mtoe, should not be taken to imply that this is a sector with few opportunities for intervention, in fact the opposite is true. Industry has already wisely embarked on the road to increasing efficiency, and this can continue beyond the minimum target set by the scenario models. A snowballing technological evolution offers ever greater opportunities to optimise industrial processes; the possibility of recovering waste heat and using innovative technologies such as HE CHP are key aspects on which efforts to modernise and improve the efficiency of industrial activities should be focused.

The attainment of energy targets is strategically linked to the renewal of building stock belonging to both the public administration (PA) and the private sector, with priority being given to energy efficiency and the use of renewable energies. With regard to PA building stock, an obligation to retrofit 3% of the useful floor area of central government buildings each year has been set.

In order to attain the targets for reducing consumption in the civil sector (5.7 Mtoe), preliminary estimates show that, for the residential sector, an acceleration of the rate of major renovations to values of around 0.7% per year is necessary, following a strong uptake of technologies such as air-to-water heat pumps for use as DHW and air conditioning systems in both stand-alone and centralised contexts. For the non-residential sector, the rate of major renovations should reach 2.9% by 2030 (hospitals excluded). To give some idea of the kind of stimulus that is needed to reach the percentages given above, the virtual annual rate of major renovations of the national building stock achieved in the period 2014-2018 was around 0.26%.

To attain these targets, it is necessary to use technologies that are able to ensure a low energy demand of the building envelope for winter and summer climate control and systems with a higher performance able to cover primary energy demand, including for DHW, which will be met by ensuring a high level of energy efficiency and by using renewables. Increased comfort demands in dwellings must also be taken into account, particularly in relation to the – relatively new – cooling demand. When it comes to available solutions, electric and gas heat pumps, which allow heating, air conditioning and DHW to be provided using one single device, are of strategic importance.

With a view to ensuring the best-possible system optimisation, it will be necessary to make use of the most appropriate technological mix from the possibilities currently on the market, in consideration of Italy's substantial geoclimatic complexity (including environmental constraints) and consequently the many opportunities to meet summer/winter climate control demand – biomass generators (low emission and high performance), solar systems, heat recovery systems, hybrid systems, HE CHP cogeneration – that can be exploited on-site and/or off-site, including making use of efficient district heating/cooling systems, with hot/cold generation plants, which are increasingly served by renewables technologies, being provided for the latter.

11.2.2 The main measures linked to heat consumption set out in the INECP and those already launched

Table 101: Non-exhaustive list of the main measures* set out in the INECP in relation to issues of heat consumption and meeting heating and cooling demand

Scope	Type of instrument	Short name for the measure
Emissions	Regulatory	Measures to improve air quality in the Po Basin
	Regulatory	Action plan for improving air quality
	Regulatory	Reduction of atmospheric pollutants – Directive (EU) 2016/2284
	Regulatory	Certification of biomass heat generators
	Regulatory	Law No 141 of 12 December 2019
	Regulatory	Improved waste management
	Regulatory	Energy transition fund for the industrial sector
Electric and thermal renewables	Regulatory	Extension of the obligation to integrate renewables into existing buildings
	Regulatory	Enhanced obligation to integrate renewables into new buildings
	Tax	Tax deduction for energy requalification and building renovations
	Economic	Incentives for electric and thermal renewables on the smaller islands
Thermal renewables and efficiency	Economic	White certificates
	Economic	Heating account
	Economic	Grants to municipalities for investments in energy efficiency and sustainable regional development
Efficiency	Regulatory	Energy audits in undertakings

	Economic	Italian national energy efficiency fund
	Tax	National enterprise plan 4.0
	Programme	Measures to change consumer behaviour
	Training	Consumer information and training programme – PIF
	Economic	The energy requalification programme of the central public administration – PREPAC

* Measures on research, innovation and competitiveness enabling novel solutions can also have a positive effect on issues relating to heat consumption

Table 102: Non-exhaustive list of the main regulatory changes – relevant to this study – following submission of the INECP to the European Commission

Regulatory references	Brief description of relevant content
Law No 77 of 17 July 2020 **Converted into law, with amendments, by Decree Law No 34/2020 (known as the 'Relaunch' Decree) on urgent measures in the field of health, support for work and the economy, and social policies related to the Covid-19 epidemic**	Provisions on technological innovation in the energy sector. Incentives for energy efficiency, earthquake bonus, photovoltaics and electric vehicle charging stations. 110% tax deduction. For cogeneration units in operation since 1 January 2019, HE CHP white certificates are recognised from the date on which they entered into operation.
Decree Law No 76 of 16 July 2020 **Urgent measures for simplification and digital innovation ('Simplification Decree') – Excerpt – Measures on procurement, construction, administrative simplification, environmental impact assessment (EIA), reclamation of polluted sites**	Simplification provisions relating to works on projects or plants fuelled by renewables and certain new plants and concerning the dissemination of incentives. Simplification of authorisation procedures for plants and transmission and distribution networks. Simplifications for issuing funding guarantees for projects under the green new deal.
Decree Law No 73 of 14 July 2020 **Implementing Directive 2018/2002/EU, amending Directive 2012/27/EU on energy efficiency**	Amendments to Legislative Decree No 102 of 4 July 2014, primarily in terms of promoting energy efficiency in buildings, the national energy savings target, information and training, and the national energy efficiency fund.
Decree of the Minister for Economic Development of 9 July 2020 **Guarantee fund for SMEs. Approval of broader eligibility conditions and general provisions**	In addition to setting out the eligibility conditions and general provisions of the guarantee fund for small and medium-sized enterprises, the Decree also approves the operating procedures of the special section referred to in Article 56, paragraph 11, of Decree Law No 18 of 17 March 2020 (the 'Cure Italy' Decree), adopted by the fund's management board at its meeting on 14 April 2020.
Decree of the Minister for Economic Development of 2 July 2020 **Grants to municipalities with fewer than 1 000 residents for projects relating to investments in energy efficiency and sustainable regional development – 2020 breakdown**	Allocation of grants to municipalities for implementing projects relating to energy efficiency and sustainable regional development works.

Decree of the Minister for Economic Development of 1 July 2020 **Energy efficiency – white certificates – extension to the catalogue of eligible projects**	Update to the table listing the eligible project types, as referred to in Decree of the Minister for Economic Development of 11 January 2017, amended by Decree of the Minister for Economic Development of 10 May 2018 on white certificates
Legislative Decree No 48 of 10 June 2020 **Energy performance of buildings – Implementation of Directive 2018/844/EU – Amendments to Legislative Decree No 192/2005**	Amendments to Legislative Decree No 192 of 19 August 2005: long-term renovation strategies, adoption of general criteria, a calculation methodology and energy performance requirements, national portal on the energy performance of buildings, APE and monitoring, analysis, evaluation and adaptation of national and regional energy legislation
Decree of the Minister of the Interior of 14 January 2020 **Grants to municipalities for projects relating to investments in energy efficiency and sustainable regional development – 2020 allocation – implementation of Article 1, paragraph 29, of the 2020 Budget Law**	Allocation of grants to municipalities for investments intended for public works relating to energy efficiency and sustainable regional development in 2020.

Decarbonisation and air quality

In order to achieve the target for the period 2021-2030 of reducing greenhouse gas emissions by 33% compared to 2005, as set out in Regulation (EU) 2018/842, Italy intends to make use of various measures that are already in place, as well as new policies that will be subsequently introduced.

As part of attempts to reduce emissions under the decarbonisation dimension, one important measure to consider, along with others that focus on improving air quality with obvious repercussions on current and future investment choices as regards heating, is the 'action plan for improving air quality' signed by the Prime Minister's Office, six ministries, regions and autonomous provinces. This plan contains measures relating to transport, agriculture and domestic heating using biomass, which are the most heavily polluting sectors. Among the five areas in question, it is worth mentioning the thermal sector, specifically civil heating, which has implemented measures to reduce polluting emissions from biomass stoves and biomass heating systems, but also restrictions on the use of oil-fired heating systems and the qualification of installers of plants fuelled by renewables.

With particular regard to measures aimed at reducing pollution from biomass combustion, provision is made for the following: the updating of sectoral legislation to incentivise the replacement of heating systems fuelled by firewood, briquettes and wood chips but subject to certification of these solid biofuels by certification bodies in compliance with the relevant technical standards (ISO UNI EN 17225, parts 3, 4 and 5) and to the observance of suitable forms of traceability and environmental sustainability criteria aimed at ensuring reduced polluting and carbon dioxide emissions for the same amount of energy produced; analysis of possible restrictions on the use of biomass to produce heat for district heating in areas particularly affected by air pollution.

Another measure to consolidate the national strategic policy for combating climate change and improving air quality is Law No 141 of 12 December 2019, converting Decree Law No 111 of 14 October 2019, what is known as the 'Climate Decree'. The Decree takes urgent measures in all sectors deemed vulnerable to climate change: water, agriculture, biodiversity, construction and infrastructure, energy, prevention of major industrial risks, human health, soil and related uses, and transport. The rationale is to incentivise virtuous behaviour and actions by planning a series of actions at various levels that are capable of involving all stakeholders, i.e. administrations but also citizens.

Thermal renewables and energy efficiency

The contribution from the thermal sector is crucial to achieving the binding national target for renewables, as more than 40% of total final energy consumption is used for these purposes.

The main tools that the INECP intends to use to promote thermal renewables are often combined with tools for energy efficiency, which are already operational. These are:

- tax deductions for energy efficiency measures and renovation of the existing building stock, both of which are also intended for thermal renewables;
- heating account;
- the white certificates scheme, including the promotion of high-efficiency cogeneration;
- obligation to integrate renewables into buildings;
- grants to municipalities for investments in energy efficiency and sustainable regional development.

The obligation to integrate renewables into buildings is a measure that has been undergoing a process of extension and refinement for several years, as already mentioned in Annex 3 to Legislative Decree No 28/2011, transposing the RED Directive, including the identification of obligations to integrate renewables into new buildings or buildings undergoing major renovation works, which has been in force since 31 May 2012. These obligations are currently set in terms of the percentage share (increasing over the years) of a building's energy demand for the provision of summer/winter climate control and domestic hot water services that is covered by renewables. In particular, it is provided that, in the case of new buildings or buildings undergoing major renovation works, systems for producing thermal energy must be designed and built such as to ensure simultaneous coverage, using energy produced by plants fuelled by renewables, of 50% of the expected consumption for domestic hot water and certain percentages (20%, 35% and 50%, depending on the period in which the request for the building permit in question falls) of the total consumption expected for domestic hot water, heating and cooling. Systems fuelled by renewables must also be installed to cover a share of the electricity demand, which is dependent on the floor area of the building. The obligation to integrate renewables into buildings, which has brought many benefits in terms of improving their energy performance and making thermal renewables more widely used, needs to be made more effective in order to broaden its scope and ensure that it is applied in all the cases identified. In particular, provision is made to update the system of obligations by making it simpler and more directly applicable, by, for example, introducing a list of renewable technologies from which the designer will be able to choose according to the individual case and the characteristics of the building, thus encouraging – as previously mentioned – the integration of traditional technologies with renewable ones, including through the use of hybrid systems. When broadening the scope of the obligation, provision can be made for synergies with existing promotional tools in order to optimise the cost-benefit ratio of investments for installing systems for producing thermal energy. This issue is being defined as part of the transposition of the RED2 Directive.

As regards grants awarded to municipalities for investments in energy efficiency and sustainable regional development, it emerges that, over the past decade, various forms and channels of financing, including cumulative ones, have contributed to activating important lines of investment in the public building stock of Italian municipalities. One example is Decree Law No 34 of 30 April 2019, which established a grant for municipalities dependent on their resident population of up to a maximum of EUR 500 million in 2019 from the Development and Cohesion Fund (FSC), for measures relating to investments in the field of energy efficiency and sustainable regional development.

Schemes to promote thermal renewables will favour high-efficiency installations that are environmentally friendly. In order to stimulate the replacement of old plants with efficient, low-emission technologies, the existing schemes will be updated, with the introduction of more stringent performance and environmental requirements for biomass heat generators. Following the public consultation, consideration will be given to introducing constraints on the replacement of obsolete heating appliances and to obligations for the periodic inspection and maintenance of biomass plants (computerised cadastre).

The tools specifically dedicated to the promotion of energy efficiency, which intersect with those on thermal renewables, are summarised in the following table according to those sectors most affected by these tools.

Table 103: Summary of measures to achieve the Article 7 EED targets and the main sectors addressed [source: INECP]

Tipologia Misura	Denominazione misura	Settori				Povertà energetica
		Residenziale	Terziario	Industria	Trasporti	
Schema d'obbligo	Certificati Bianchi					
Misure alternative	Detrazioni fiscali (bonus casa + Ecobonus)					
	Conto Termico					
	Fondo Nazionale Efficienza Energetica					
	Piano Impresa 4.0					
	PREPAC					
	Politiche di coesione					
	Piano informazione e formazione					
	Rinnovo parco mezzi TPL					
	Shift modale delle merci					

Tipologia Misura	**Type of measure**

Denominazione misura	Name of measure
Settori	**Sectors**
Residenziale	**Residential**
Terziario	**Services**
Industria	**Industry**
Trasporti	**Transport**
Povertà energetica	**Energy poverty**
Schema d'obbligo	Compulsory scheme
Misure alternative	Alternative measures
Certificati Bianchi	White certificates
Detrazioni fiscali (bonus casa + Ecobonus)	Tax deductions (Casa bonus + Ecobonus)
Conto Termico	Heating account
Fondo Nazionale Efficienza Energetica	National energy efficiency fund
Piano Impresa 4.0	Enterprise plan 4.0
PREPAC	PREPAC
Politiche di coesione	Cohesion policies
Piano informazione e formazione	Information and training plan
Rinnovo parco mezzi TPL	Renewal of the LPT vehicle fleet
Shift modale delle merci	Modal shift of goods

The aforementioned schemes are estimated to help reduce annual final consumption in the civil sector (residential and services) by 5.7 Mtoe by 2030, by increasing the efficiency of thermal heating/cooling demand and often simultaneously promoting the use of thermal renewables.

The schemes are summarised below. **For further details and a detailed discussion of the individual measures included in the INECP, please refer to the INECP (targets and measures on renewables and energy efficiency) and the report, submitted together with the INECP, as per Annex III to Regulation (EU) 2018/1999 on the Governance of the Energy Union (notifying the measures and methods adopted by the Member States to implement Article 7 of Directive 2012/27/EU).**

Tax deductions for energy requalification and renovation of the building stock

Tax deductions consist of reductions in personal income tax (IRPEF) and corporate income tax (IRES) (for the latter only with reference to energy requalification of buildings) granted for measures that contribute to improving the energy performance of existing buildings. In particular, there are three main types of measure to date:

- measures for energy requalification of buildings (known as the 'Ecobonus') – 2007 Finance Law;
- measures to 'renovate' the building stock (known as the 'Casa' bonus) – Law No 449 of 27 December 1997;
- measures with the combined aim of reducing seismic risk and energy requalification (known as the 'Sisma' bonus) – Law No 205 of 27 December 2017;

Law No 77 of 17 July 2020, converting, with amendments, Decree Law No 34 of 19 May 2020 (known as the 'Relaunch Decree') introduced significant amendments to the tax deduction scheme in terms of deductible percentages, bringing the threshold to 110% (known as the 'Superbonus') for certain measures for energy efficiency (the 'Ecobonus'), reducing seismic risk (the 'Sisma Bonus'), and installing photovoltaic plants and electric vehicle charging stations.

The tax deduction scheme – which has been extended until 31 December 2021[68], plus a further 6 months for social housing – has undergone significant change over the years with a view to strengthening it, but also in order to combat energy poverty (increase in the number of people who are eligible for social housing and the possibility of accessing what is known as the 'credit transfer' or 'invoice discount' scheme).

The scheme is targeted towards the civil sector – both residential and private services – for measures to increase the energy efficiency of the opaque and transparent envelope (possibly together with measures for seismic consolidation/reinforcement) and related systems, including the installation of renewable technologies.

With particular regard to the thermal renewables sector, subsidies are granted to install solar thermal systems, heat pumps and geothermal plants in buildings as replacements for existing winter heating systems and biomass-fuelled systems.

The following are certain tax incentives that should be taken into account in the financial model when performing calculations to help define the district heating potential:
- 50% deductions for the installation of condensing gas boilers by private individuals and a 65% reduction for the installation of a class A condensing boiler with simultaneous installation of advanced thermoregulation systems (2021 Budget Law);
- 65% deductions for a district heating substation/exchanger;
- for biomass and geothermal district heating networks, a tax credit equal to 0.02194 EUR/kWh for each kWh of heat supplied (to be passed on to the end user in the sale price).

In its various forms, this measure is now the tool most widely used in the non-public civil sector to retrofit existing buildings, improving the performance of the system and thus reducing the primary energy demand for winter and summer climate control.

Heating account

The heating account is an incentive scheme for measures to increase the energy efficiency of existing buildings (reserved for public administrations only) and for producing thermal energy from renewables (aimed at both public administrations and private individuals). The measure has a budget of EUR 900 million per year, EUR 200 million of which is allocated for the public administration alone.

Elements aimed at taking effective and efficient action on final consumption in the thermal sector (specifically heating/cooling) include the following:
- energy efficiency (only public administrations are eligible for incentives), relating to the opaque and transparent envelope, the replacement of condensation heat generators for winter heating, the installation of 'building automation' technologies and the transformation of buildings into nZEB;
- incentivisation to replace winter heating systems with generators fuelled by renewables, such as biomass generators, electric or gas heat pumps,

[68] Under the national recovery and resilience plan (PNRR), the recently introduced 110% 'Superbonus' measure (Article 119 of the Relaunch Decree) will be extended from 2021 to 2023 (to 30 June 2023 for measures carried out by IACPs, provided that at least 60% of the works have been carried out by the end of 2022).

hybrid systems, heat pump water heaters and solar thermal systems (including permanent ones) for DHW and winter heating and, if combined with solar cooling, also for the production of thermal energy for production processes or for feeding into district heating and cooling networks.

White certificates

White certificates (WC) are negotiable securities certifying the achievement of final energy savings through measures and projects to increase energy efficiency; introduced by Ministerial Decrees of 24 April 2001, they are a compulsory primary energy savings scheme for electricity and natural gas distributors with more than 50 000 customers. Entities subject to this obligation can fulfil the mandatory quota by directly implementing energy efficiency projects for which WC are recognised by GSE or, alternatively, by purchasing securities through negotiations on the WC market managed by Gestore dei Mercati Energetici (GME) or through bilateral transactions with entities that are not subject to this obligation but meet the requirements.

White certificates are also issued for energy savings generated by high-efficiency cogeneration plants, including plants fuelled by renewables and plants connected to district heating networks. As regards HE CHP plants, the volume of useful heat recovered varies between 31 and 38 TWh per year on average, with an average increase of approximately 1.2 TWh per year compared to the previous year. Of this annual increase, between 40 and 140 GWh is made up of renewable energy.

The sectors affected by the scheme are industry, civil, transport, networks and services. With particular reference to measures for the public administration, the following is found to be very effective:
- for very energy-intensive services (lighting, public transport, heat management) with energy distribution companies or ESCO;
- to meet electrical and thermal demand (heating and cooling) in schools and universities, municipal sports centres, hospitals, municipal offices, etc. after HE CHP installations, including in combination with district heating.

The scheme is evolving, allowing for a natural process of updating and enhancement with a view to streamlining, optimising the methods for quantifying and recognising energy savings, and reducing the time needed to approve, issue and offer securities on the market. Greater attention is being paid to training and educating operators through the dissemination of guides, databases with predefined baselines, and approved best practices for the different sectors and measures.

Energy requalification programme for buildings belonging to the central public administration

The PREPAC, established by Legislative Decree No 102/2014 implementing Directive 2012/27/EU, is a scheme for promoting energy efficiency measures on central public administration buildings, aiming to ensure the energy requalification of at least 3% of the air-conditioned useful floor area of these buildings each year.

The implementation of measures for which projects are submitted annually by the central administrations (including by entering into EPC contracts) is managed by the operational structures of the Interregional Public Works departments of the Ministry of Infrastructure and Transport.

Eligible interventions include all those aimed at increasing the energy efficiency of the building and producing thermal energy from renewables for winter heating and DHW production. In addition, the installation of cogeneration or trigeneration plants and other plants for producing electricity or heat that are not detailed in the application (which are eligible only in order to contribute to meeting the primary energy demand of the building) is allowed. Measures on buildings and plants that are not included in the areas described above are also permitted, provided that they lead to a reduction in energy consumption.

This measure has been extended to cover the period 2021-2030 and there will also be upgrades and enhancements aimed at streamlining administrative activities, exploiting synergies between the public administrations involved in management, and providing for the development of appropriate IT management support.

National energy efficiency fund (FNEE)

Established pursuant to Article 15 of Legislative Decree No 102 of 2014 and operational as of May 2019, the fund is designed to facilitate the financing of measures needed to achieve national energy efficiency targets. The fund is a revolving one and provides for 70% of the annual resources to be earmarked for the provision of low-interest loans (20% of which are reserved for public administrations), while the remaining 30% are earmarked for providing guarantees on loans; of the guarantees section, 30% are earmarked for measures relating to district heating networks or plants.

The fund, whose endowment has been increased for the period 2021-2030 using some of the resources from the ‘fund for financing investments and infrastructural development of the country’, finances measures aimed at reducing energy consumption in industrial processes, the construction and/or expansion of networks and plants for district heating and/or cooling, the energy requalification of buildings – including standard energy efficiency measures in apartment blocks – and measures for improving the efficiency of public services and infrastructures, including public lighting.

Businesses and public administrations can access the fund through projects involving energy-saving measures in buildings, plants and production processes. In addition, one section is set aside for the granting of guarantees to credit institutions providing loans to private citizens or apartment blocks for energy efficiency measures in their building unit or the whole building, working in synergy with tax deduction schemes. This measure will contribute to overcoming one of the main barriers to implementing energy requalification measures, namely the initial investment.

In order to increase the fund’s capacity to promote energy efficiency measures, the currently available budget will be increased, favouring the disbursement of resources for energy efficiency managed by central and local administrations (European Structural and Investment Funds – ESIF) and directing the scheme towards promoting measures in the civil (both residential and services) and transport sectors. It will also be important to provide for dissemination activities to ensure that this tool is more widely known about and used. Finally, an increase in the types of financial and economic support offered by the fund will be evaluated in order to maximise the effectiveness of available resources.

11.2.3 INECP guidelines on HE CHP and district heating

The INECP repeatedly highlights the importance of evaluating the need for new infrastructure for district heating and cooling from renewables. The plan also recalls the usefulness of this report for analysing future trends in this sector.

The INECP highlights the potential of exploiting synergies between the use of renewables and high-efficiency cogeneration and district heating, taking into account the specific climate and technical and economic conditions. The aim should be to expand the use of efficient district heating and cooling by exploiting the remaining economic potential in a manner consistent with other energy and environmental policy objectives, such as reducing the need for waste-to-energy and limiting the use of biomass in order to reduce emissions.

The INECP also makes reference to the benefits of analysing the possibility of integrating certain technologies with district heating networks, which are currently marginal in the area of district heating but show potential in high-density urban contexts, such as thermal solar power, centralised heat pumps or the recovery of waste thermal energy from plants located throughout the territory. Thermal solar power will be able to play an increasingly key role in integrated systems for efficient and renewable heat production, such as hybrid systems and, most notably, integration in district heating systems.

In order to exploit the potential of district heating, existing tools will be strengthened to encourage the new construction and expansion of urban heat distribution infrastructure, particularly where heat production hubs are close to consumption sites. Priority will be given in this respect to the development of efficient district heating, i.e. district heating based on the distribution of heat generated to a large extent from renewables, waste heat or cogenerated heat (and, in the future, from biomethane as well). To this end, the economic reserve for providing guarantees in favour of measures for building district heating and cooling networks, included in the national energy efficiency fund, will be confirmed, with provision being made for the implementing decree already announced by Law No 172/2017 to be issued, which will identify subsidies for measures on plants involving an increase in thermal production capacity aimed at maintaining or achieving an efficient district heating system set-up and that are combined with an extension of the network in terms of increased transport capacity.

With an eye to the future, the provisions on air conditioning systems in the heating and cooling sector will be updated with the specific aim of gradually replacing systems with high emissions (such as oil boilers and inefficient biomass plants) with low-emission, high-efficiency technologies.

Among the many targets set, consideration can be given to the potential contribution to decarbonisation of the existing building stock and buildings that have not undergone major renovation, which make up the bulk of the total built environment. Careful consideration could be given in this context to thermal solar power, electric and gas heat pumps, and high-efficiency micro and mini cogeneration technologies, particularly if fuelled by renewable gases.

Measures to ensure compliance with regulations and standards will also be strengthened, by increasing monitoring of the operating hours of heating systems, in order to verify that there are no anomalies with respect to usage limits.

The introduction of new limits on the use of cooling systems will be evaluated, be defining restrictions (for example days of use, hours, minimum temperatures) to be set in relation to the climate zone of reference.

11.3 The potential for efficient heating and the evolution of the INECP

The integrated national energy and climate plan (INECP), in its final version drafted in 2019, outlines the targets and measures that define Italy's contribution to achieving European energy transition and climate targets, as defined by Regulation (EU) 2018/1999 on the Governance of the Energy Union.

The previous version of the report assessing the national potential for applying high-efficiency cogeneration and efficient district heating provided for in Article 14 of the EED Directive, drafted in 2015, formed an integral part of the development scenarios envisaged in the INECP.

In particular, the INECP incorporated the results of the assessment of the financial economic potential for district heating and HE CHP and estimated an economic potential for district heating of 13.5 TWh in terms of thermal energy delivered (growth of 4 TWh), while for HE CHP in the industrial, service and utilities sectors, it foresaw an economic potential of 49 TWh in terms of cogenerated heat (growth of 18 TWh).

This study, drawn up in 2020, proposes more ambitious development potentials for district heating and HE CHP than the previous one, as a result of a broader and more detailed survey of the technologies and sectors involved, and provides not just the financial economic potentials but also the system economic potentials that enable the targets set out in the INECP to be met.

In the thermal sector, the system's economic scenario includes a potential for district heating of 19.8 TWh in terms of thermal energy delivered (growth of 10 TWh) and 63.3 TWh of cogenerated useful heat (growth of 28 TWh), of which 47 TWh comes from individual HE CHP plants in industry and services and 16 TWh from HE CHP district heating plants, accompanied by an additional increase in individual thermal renewables of 159 TWh (growth of 49 TWh).

Including with regard to thermal renewables, as highlighted above, the analyses carried out in order to assess the potential for efficient heating lead to the conclusion that the forecasts set out in the INECP for heat consumption to 2030 can be slightly revised (cf. comparison between Table 96 and Table 100 and between Figure 158 and Figure 169).

At the time the INECP was drafted, the European body of law still contained a target to reduce greenhouse gas emissions by 40% by 2030 compared to 1990. On 11 December 2020, at the instigation of the European Commission, an agreement was reached to increase the European interim emissions reduction target for 2030 from 40% to 55% compared to 1990 levels, in order to achieve climate neutrality by 2050 and to meet the obligations of the Paris Agreement.

In light of the new strategic framework, the Italian INECP will be updated to adjust the targets and measures to reflect the new level of ambition defined at European level. Operational activities to revise the plan in this respect have just commenced.

As with the previous version, this report will be integrated into the analyses and development scenarios for the energy system that will be developed in the new INECP, and will also, where necessary, be fine-tuned to meet the more challenging decarbonisation and energy efficiency targets.

With the updating of the modelling chain and the quantitative drivers and variables that will have to be implemented for the new scenario cycle, it is not certain that the results of this study will be reproduced as such at output level in the updated INECP, but they will certainly constitute at least a new point of reference as input to the development of new scenarios.

11.4 The PNRR and the district heating investment programme

The recovery and resilience plan presented by Italy in April 2021 details investments and a package of reforms to which resources amounting to EUR 191.5 billion are allocated, financed through the recovery and resilience facility with EUR 30.6 billion from the supplementary fund established by Decree Law No 59 of 6 May 2021, based on the multi-year budgetary slippage approved by the Council of Ministers on 15 April. The total expected funds amount to EUR 222.1 billion. In addition, a further EUR 26 billion has been earmarked by 2032 for the implementation of specific works and to replenish resources from the Development and Cohesion Fund. Some EUR 248 billion in total will thus be available. In addition to these resources, the REACT-EU programme will also make available funds totalling a further EUR 13 billion to be spent in the period 2021-2023, in accordance with EU regulations.

The plan is developed around three strategic axes shared at European level: digitisation and innovation, ecological transition, and social inclusion. This measure aims to repair the economic and social damage caused by the pandemic, contribute to solving the structural weaknesses of the Italian economy, and lead the country on a path of ecological and environmental transition. The PNRR will make a substantial contribution to reducing regional, generational and gender gaps.

In the PNRR, the resources earmarked for the green revolution and ecological transition play a major role (allocating 59.3 billion from the RRF and 9.3 from the fund) and aim to provide support for measures to increase the energy efficiency of buildings and for renewable energies, sustainable mobility, the hydrogen chain, sustainable agriculture, the circular economy, and regional protection and development.

Among the four lines of investment of Mission 2 'Green revolution and ecological transition', M2C3 of the national recovery and resilience plan aims to significantly improve the energy efficiency of both public and private buildings. Investments will be concentrated in the following three areas of action:

- implementation of a programme to improve the efficiency and safety of the public building stock, with measures relating to schools and judicial citadels in particular;
- use of a temporary incentive for energy requalification and anti-seismic renovation of the private building stock and for social housing, through tax deductions in respect of the costs incurred for the measures (the 'Superbonus');
- development of efficient district heating systems.

The target is to save at least 0.32 Mtoe and 0.98 MtCO_2 by 2026.

Table 104: PNRR, breakdown of resources for Mission 2 'Green Revolution and ecological transition' (billion EUR)

M2. RIVOLUZIONE VERDE E TRANSIZIONE ECOLOGICA	PNRR (a)	React EU (b)	Fondo complementare (c)	Totale (d)=(a)+(b)+(c)
M2C1 - AGRICOLTURA SOSTENIBILE ED ECONOMIA CIRCOLARE	5,27	0,50	1,20	6,97
M2C2 - TRANSIZIONE ENERGETICA E MOBILITA' SOSTENIBILE	23,78	0,18	1,40	25,36
M2C3 - EFFICIENZA ENERGETICA E RIQUALIFICAZIONE DEGLI EDIFICI	15,22	0,32	6,72	22,26
M2C4 - TUTELA DEL TERRITORIO E DELLA RISORSA IDRICA	15,06	0,31	0,00	15,37
Totale Missione 2	**59,33**	**1,31**	**9,32**	**69,96**

M2. RIVOLUZIONE VERDE E TRANSIZIONE ECOLOGICA	M2. GREEN REVOLUTION AND ECOLOGICAL TRANSITION
PNRR (a)	PNRR (a)
React EU (b)	REACT-EU (b)
Fondo complementare (c)	Supplementary fund (c)
Totale (d)=(a)+(b)+(c)	Total (d)=(a)+(b)+(c)
M2C1 - AGRICOLTURA SOSTENIBILE ED ECONOMIA CIRCOLARE	M2C1 – SUSTAINABLE AGRICULTURE AND CIRCULAR ECONOMY
M2C2 - TRANSIZIONE ENERGETICA E MOBILITA' SOSTENIBILE	M2C2 – ENERGY TRANSITION AND SUSTAINABLE MOBILITY
M2C3 - EFFICIENZA ENERGETICA E RIQUALIFICAZIONE DEGLI EDIFICI	M2C3 – ENERGY EFFICIENCY AND REQUALIFICATION OF BUILDINGS
M2C4 - TUTELA DEL TERRITORIO E DELLA RISORSA IDRICA	M2C4 – PROTECTION OF LAND AND WATER RESOURCES
Totale Missione 2	Total for Mission 2

Among the areas of action and measures for energy efficiency and requalification of buildings, the plan includes the development of district heating systems, for which EUR 0.2 billion has been allocated. It is recalled in this respect that, due to its ability to integrate efficiency with the use of renewables, as well as the relocation and reduction of polluting emissions, particularly in large urban areas where the problem is even more acute, district heating plays an important role in the technological mix needed to guarantee the achievement of the environmental targets for the next decade in the heating and cooling sector.

In order to exploit this potential, the resources of the PNRR will be used to finance projects relating to the construction of new networks or the extension of existing district heating networks to increase the number of customers supplied, including the facilities for supplying them. Priority will be given in this respect to the development of efficient district heating, i.e. district heating based on the distribution of heat generated from renewables, waste heat or cogenerated heat in high-efficiency plants.

The target set by the investment measure is the development of 330 km of efficient district heating networks and the construction of plants or connections for waste heat recovery for 360 MW, assuming that 65% of the resources are allocated to the networks (cost EUR 1.3 million per km) and about 35% to the development of new plants (cost EUR 0.65 million per MW).

Achieving this target would be expected to deliver energy-related and environmental benefits equalling 20.0 ktoe per year of primary fossil energy saved and 0.04 $MtCO_2$ per year of greenhouse gas emissions prevented in non-ETS sectors.

Table 105: PNRR, breakdown of resources within the framework of the M2C3 measure (billion EUR)

Ambiti di intervento/Misure	Totale
1. Efficientamento energetico edifici pubblici	1,21
Investimento 1.1: Piano di sostituzione di edifici scolastici e di riqualificazione energetica	0,80
Investimento 1.2: Efficientamento degli edifici giudiziari	0,41
Riforma 1.1: Semplificazione e accelerazione delle procedure per la realizzazione di interventi per l'efficientamento energetico	-
2. Efficientamento energetico e sismico edilizia residenziale privata e pubblica	13,81
Investimento 2.1: Ecobonus e Sismabonus fino al 110% per l'efficienza energetica e la sicurezza degli edifici	13,81
3. Sistemi di teleriscaldamento	0,20
Investimento 3.1: Sviluppo di sistemi di teleriscaldamento	0,20

Ambiti di intervento/Misure	**Areas of action/measures**
Totale	Total
1. Efficientamento energetico edifici pubblici	1. Energy efficiency of public buildings
Investimento 1.1: Piano di sostituzione di edifici scolastici e di riqualificazione energetica	Investment 1.1: School building replacement and energy requalification plan
Investimento 1.2: Efficientamento degli edifici giudiziari	Investment 1.2: Efficiency of judicial sites
Riforma 1.1: Semplificazione e accelerazione delle procedure per la realizzazione di interventi per l'efficientamento energetico	Reform 1.1: Simplification and acceleration of procedures for implementing energy efficiency measures
2. Efficientamento energetico e sismico edilizia residenziale privata e pubblica	2. Energy efficiency and seismic improvement of private and public residential buildings
Investimento 2.1: Ecobonus e Sismabonus fino al 110% per	Investment 2.1: Raising the 'Ecobonus' and 'Sisma' bonus to

l'efficienza energetica e la sicurezza degli edifici	110% for energy efficiency and building safety
3. Sistemi di teleriscaldamento	3. District heating systems
Investimento 3.1: Sviluppo di sistemi di teleriscaldamento	Investment 3.1: Development of district heating systems

Annex 1

HE CHP and district heating in regional environmental and energy plans (PEAR) and other regional acts

By analysing individual regional measures - first and foremost the regional environmental and energy plans (PEAR) definitively approved by the regional councils or, in many cases, approved by regional governments that are now in the public consultation phase - it is possible to distinguish between regions that have substantially addressed the issues of cogeneration and district heating in recent years and regions that have considered more marginal development scenarios for these technologies or have not issued specific measures and guidelines on the subject.

Figure 172: Regions whose official documents contain assessments of the potential of HE CHP

Figure 173: Regions whose official documents contain assessments of the potential of district heating

In particular, the propensity of the northern regions to view HE CHP and, in particular, district heating as valid forms of energy diversification supporting, above all, the residential and industrial sectors becomes clear once the main regional data from this benchmark is mapped. Naturally, this is the result of specific and distinctive climate and socio-economic factors, such as heating demand or the existence of certain energy districts and poles with favourable supply conditions for the raw materials used.

The following table summarises the regions that provide assessments of **cogeneration** development potentials in their PEARs (and other documents), followed by brief descriptions by region of the main findings from legislative acts as regards the assessment of cogeneration potentials.

Table 106: HE CHP: Regions whose PEARs (and other documents) contain assessments of potentials[69]

Region	Source year	Source consulted
Piedmont	2019	Regional Government Decision No 18-478 of 8 November 2019 Draft PEAR
Valle d'Aosta	2014	Regional Council Decision No 727 of 25 September 2014 PEAR
Lombardy	2015	Regional Government Decision No 3706 of 12 June 2015 PEAR
Autonomous province of Bolzano	2016	2050 energy and climate plan for South Tyrol PCEAA
Autonomous province of Trento	2021	Provincial Government Decision No 339 of 5 March 2020 PEAP
Veneto	2017	Regional Council Decision No 6 of 9 February 2017 PEAR
Friuli-Venezia Giulia	2015	Decree of the Regional President No 260 of 23 December 2015 PER
Emilia-Romagna	2017	Regional Council Decision No 111 of 1 March 2017 PER 2030 and PTA 2017-2019
Liguria	2017	Regional Council Decision No 19 of 14 November 2017 PEAR 2014-2020
Tuscany	2015	Regional Council Decision No 10 of 11 February 2015 PAER
Umbria	2017	Regional Council Decision No 205 of 7 November 2017 SEAR
Marche	2016	Regional Council Decision No 42 of 20 December 2016 PEAR
Lazio	2020	Regional Government Decision No 98 of 10 March 2020 PER
Abruzzo	2009	Regional Council Decision No 27/6 of 15 December 2009 PER
Molise	2017	Regional Council Decision No 133 of 11 July 2017 PEAR 2017
Campania	2020	Observations of 18 February 2020

[69] The regions underlined in the first column of the table are those whose PEARs were approved, either as proposed by the regional governments or definitively by the regional councils, following the first edition of this study.

		Draft PEAR and initiation of SEA
Apulia	2015	Regional Government Decision No 1181 of 27 May 2015 PEAR
Basilicata	2010	Regional Law No 1 of 19 January 2010 PIEAR
Calabria	2005	Regional Council Decision No 315 of 14 February 2005 PEAR
Sicily	2019	Summary document of 5 June 2019 PEARS 2019-2030
Sardinia	2015	Regional Council Decision No 48/13 of 2 October 2015 PEAR

Among the regions that have provided information on the potential for growth and development of HE CHP in their territory is the **Autonomous Province of Bolzano**, which, in its 2050 energy and climate plan for South Tyrol, approved in 2011, states that the number of cogeneration plants in the province’s industrial and artisan sectors will be further expanded, in consideration of heating demand in residential areas. In addition, in order to increase the number of cogeneration plants in the province’s industrial and commercial sector, the existing potential would have been reached by 2013, in cooperation with representative organisations.

The **Autonomous Province of Trento**, in the heat demand scenarios of the PEAP 2020-2030, which is currently in the consultation stage, reports that the deployment of heat pumps in individual heating represents the main technological change in the decarbonisation pathway, increasing from 4% in the baseline 2016 scenario to 11/27% in LC/LC+ 2030 and 43/64% in LC/LC+ 2050. Biogas cogeneration is also expected to grow markedly, while biomass boilers are expected to remain stable. In the electricity sector, however, biogas cogeneration shows a smaller increase due to the limited availability of the renewables required. In addition, cogeneration associated with district heating is stable, as chosen by the PEAP working group, while industrial gas cogeneration increases slightly by 2030 before dropping again by 2050.

The PEAR of the **Valle d’Aosta Region** approved in 2014 presents a plan scenario in which it is assumed that cogeneration plants fuelled by natural gas, diesel and biomass with respective capacities of 2 MWt, 4 MWt and 4 MWt will be installed by 2020. These capacities also include mini and micro cogeneration plants.

With regard to the **Veneto Region**, the section ‘Potential for energy saving in the industrial sector’ of the plan approved by the regional council by way of Regional Council Decision No 6 of 9 February 2017 predicts that energy efficiency improvement measures using HE CHP in the industrial sector will amount to 6 280 GWh/year in 2016, with 2 493 GWh/year achieved in 2010 through energy saving measures. If the actual and feasible electric and thermal savings (it being assumed that the thermal energy produced by cogeneration is used in the production process or in trigeneration applications) achieved from adopting these technologies were added together, this would result, in the baseline 2020 scenario, in energy savings of 266 ktoe at regional level (calculated using the lower technology penetration rate), with 134 ktoe attributed to electric savings and 132 ktoe to thermal savings.

In its regional energy plan adopted at the end of 2015, the **Region of Friuli-Venezia Giulia** also surveys the existing regional cogeneration stock and focuses on the growth of HE CHP, including through specific regional measures such as the establishment of rotary and/or guarantee funds to help SMEs invest in this technology to ensure a more efficient use of energy outputs (thermal, electrical and cooling). A further aim is to encourage the development of small cogeneration plants, including through subsidised forms of credit, with a view to fully exploiting local resources (biomass) and maximising plant efficiency by recovering process heat.

In its draft PEAR for 2015, the **Lombardy Region** provides important information on the role of HE CHP in the various sectors (residential, industry) and on future developments that may be relevant to bioenergy in particular, and specifically solid biomasses derived from wood and residues in civil sectors for individual heating and in plants serving district heating networks, including thermal and electric cogeneration; biogas in electric generation, including thermal and electric cogeneration; liquid biofuels in transport and electric generation.

The **Piedmont Region**, in the plan scenario for developing district heating systems in urban areas contained in its new draft PEAR approved by Regional Government Decision No 18-478 of 8 November 2019, considers maximising the use of heat produced through cogeneration in existing plants (in particular as regards district heating in the Turin metropolitan area). It is also held that the integration of high-efficiency cogeneration and thermal renewables should be implemented more strictly in Piedmont in the future, by anticipating the definition of the requisite boundary conditions when urban planning decisions are made in relation to new neighbourhoods and residential areas with suitable infrastructure in terms of building climate control with low-temperature systems aimed at exploiting both the synergies that can be achieved with low-enthalpy geothermal power assisted by heat pumps, and the exploitation of thermal solar power and, only in built-up areas not affected by air quality issues, by using biomass from the management of the surrounding area and, in any case, from a short supply chain. Priority support measures include, where possible and technically appropriate:

- the use of cogenerated heat storage techniques for urban heating in order to manage existing and/or planned systems efficiently, allowing peak heat demand to be covered while minimising the need to operate supplementary and reserve heating plants;
- the development of distributed generation by deploying high-efficiency biomass-fuelled cogeneration plants serving local district heating networks in mountain municipalities not affected by critical air quality issues, encouraging the development of local biomass supply and the forestry supply chain.

In the **Liguria Region**, according to the PEAR approved by Regional Council Decision No 19 of 14 November 2017, it is pointed out that, despite the high regional potential in terms of users that can possibly be served (large apartment blocks, office buildings and shopping centres, hotels and hospitals), the potential of these technologies (HE CHP and district heating) is only being minimally exploited at present. In order to develop suitable districts, the plan is to access the funding provided by the 'Horizon 2020' programme, dedicated to 'smart cities and communities'.

The **Region of Emilia-Romagna** cites continuity as the reasoning behind the facilitation policies it has implemented as part of the 2007-2013 ROP ERDF, aimed at supporting the implementation of the APEA, which had already been financed using the 2007-2013 Structural Funds, through a series of measures designed, for example, to facilitate the construction of cogeneration and trigeneration plants, primarily integrated into the company's production cycles, and district heating networks, provided that these are competitive in terms of energy efficiency compared to targeted measures that serve all users in the production areas. With regard to building, urban and regional requalification in particular, the energy savings, which are estimated to be around 20-25% on average, are attributed to the entire cogeneration plant/district heating network system. The aim is to strengthen the cogeneration sector ('electricity from cogeneration'), as Emilia-Romagna is one of the regions with the highest potential for consumption growth in the civil and service sectors. Although cogeneration cannot, in and of itself, be defined as a 'renewable', the current economic and tariff scenario is such that the use of cogeneration is indispensable in order to disseminate technologies with a high specific cost, such as those that use bioenergy. In addition, further consideration needs to be given to the development potential of heat pumps in the 2030 scenario, also taking into account the fact that the promotion of heat pumps in industrial and commercial buildings is especially valuable in the energy sector if these are combined with distributed cogeneration systems, rather than thinking of widespread use of heat pumps fuelled by electricity that is produced in large-scale power plants located a considerable distance away. Another measure involves the provision of support for the exploitation and recovery of thermal waste present within existing industrial processes and areas and for the dissemination of high-efficiency cogeneration.

With regard to the industrial users mentioned in the PEAR approved by Regional Council Decision No 42 of 20 December 2016, the **Marche Region** identifies a number of areas with energy characteristics suitable for the introduction of cogeneration plants, even though the application of cogeneration plants to locations such as large shopping centres or other users related in some way to the service sector was still very infrequent. Focusing on the specific topic of 'district power stations', it should be noted that the untapped potential referred to situations where the energy advantage was more obvious than the economic one. In this sense, a widespread dissemination of HE CHP (coupled with district heating in cases where this is the only way to use the heat produced) could only become feasible with the introduction of new, adequate incentive schemes.

In the SEAR approved by Regional Council Decision No 205 of 7 November 2017, the **Umbria Region** identifies measures for incentivising cogeneration plants (fuelled by renewables or methane gas) and district heating/cooling in the service sector, which can be financed through ERDF and EAFRD funds and have the overall aim of reducing consumption. Therefore, the development of small combustion plants for producing electricity from renewables is an important option for developing small networks at local level capable of exploiting the thermal waste that is often lost.

In the preliminary document for the new 2015 PEAR, the **Molise Region** mentions the possibility of focusing on HE CHP for regional hospital users for a primary energy saving of around 13 600 MWh/year, which is about 10% of the original level of consumption. There would also be a strong focus on micro cogeneration for smaller users with a lower level of consumption.

By way of Regional Government Decision No 1220 of 26 November 2018 approving the public notice for the presentation and selection of projects for building and managing biomass-fuelled cogeneration or trigeneration plants, the **Basilicata Region** planned to promote cogeneration by drawing on the resources of Axis 4 ‘Energy and urban mobility’ of the 2014-2020 OP ERDF Basilicata.

In the baseline scenario of the 2015 PEAR, the **Sardinia Region** intends to focus on energy districts with biomass-fuelled cogeneration plants with a capacity of less than 1 MW that are used to supply heat/cold to households and users in the service sector, where those households and users are located in energy districts with district heating networks.

The cumulative installed capacity is expected to be 3 MW by 2020; the development scenario raises the cumulative capacity to be installed by 2020 to 6 MW; the industrial development scenario raises the cumulative installed capacity to 10 MW by 2020. As regards biomass in particular, the PEAR aims to promote the cogenerative use of biomass in energy districts and Sardinian municipalities, and sets the target of building a number of high-efficiency biomass-fuelled cogeneration systems for a cumulative nominal electrical capacity of 10 MWe by 2020.

When promoting measures to develop cogeneration and the efficient use of biomass, the Sardinia Region also promotes and incentivises the construction of district heating networks, intended to maximise the use of cogenerative heat. To this end, what is proposed is to use residual biomasses, as indicated in the ‘Study on the energy potential of biomasses in Sardinia’, to fuel small-to-medium-sized cogeneration/trigeneration plants (with a capacity of less than 1 MW) supplying district or sector micro networks placed in locations that are suitable from both a geographical and climatological point of view and in terms of the availability of indigenous biomasses. The Sardinia Region has set itself the target of building 10 plants by 2020, which may possibly be located in energy districts. The Region promotes the use and implementation of hybrid plants, which combine different energy sources to optimise their conversion. Preferential locations for the installation of such plants are then identified in centres with greater heat consumption, such as public offices, hospitals, schools, universities, student accommodation and retirement homes.

On the other hand, in the PEAR submitted to the SEA procedure, for which the public consultation ended in October 2019, the **Campania Region** set itself the minimum target of increasing the installed electrical capacity of natural gas plants by 50 MWe by 2013 and by 100 MWe by 2020, with additional savings in terms of non-renewable primary energy demand, estimated to be 25 ktoe/year by 2013 and 50 ktoe/year by 2020.

The **PEARS 2019-2030 of the Region of Sicily** contains numerous information sheets describing actions and measures involving cogeneration (for self-production or otherwise), starting with the hypothetical construction of small-scale fixed production plants fuelled by both biomass and natural gas.

The following table summarises the regions whose PEARs (and other documents), as already mentioned above for cogeneration, contain assessments of **district heating** development potentials, followed by brief descriptions by region of the main findings from legislative acts as regards the assessment of district heating potentials.

Table 107: District heating: Regions whose PEARs (and other documents) contain assessments of potentials[70]

Region	Source year	Source consulted
Piedmont	2019	Regional Government Decision No 18-478 of 8 November 2019 Draft PEAR
Valle d'Aosta	2014	Regional Council Decision No 727 of 25 September 2014 PEAR
Lombardy	2015	Regional Government Decision No 3706 of 12 June 2015 PEAR
Autonomous province of Bolzano	2016	2050 energy and climate plan for South Tyrol PCEAA
Autonomous province of Trento	2021	Provincial Government Decision No 339 of 5 March 2020 PEAP
Veneto	2017	Regional Council Decision No 6 of 9 February 2017 PEAR
Friuli-Venezia Giulia	2015	Decree of the Regional President No 260 of 23 December 2015 PER
Emilia-Romagna	2017	Regional Council Decision No 111 of 1 March 2017 PER 2030 and PTA 2017-2019
Liguria	2017	Regional Council Decision No 19 of 14 November 2017 PEAR 2014-2020
Tuscany	2015	Regional Council Decision No 10 of 11 February 2015 PAER
Umbria	2017	Regional Council Decision No 205 of 7 November 2017 SEAR
Marche	2016	Regional Council Decision No 42 of 20 December 2016 PEAR
Lazio	2020	Regional Government Decision No 98 of 10 March 2020 PER
Abruzzo	2009	Regional Council Decision No 27/6 of 15 December 2009 PER
Molise	2017	Regional Council Decision No 133 of 11 July 2017 PEAR 2017
Campania	2020	Observations of 18 February 2020 Draft PEAR and initiation of SEA
Apulia	2015	Regional Government Decision No 1181 of 27 May 2015 PEAR

[70] The regions underlined in the first column of the table are those whose PEARs were approved, either as proposed by the regional governments or definitively by the regional councils, following the first edition of this study.

Basilicata	2010	Regional Law No 1 of 19 January 2010 PIEAR
Calabria	2005	Regional Council Decision No 315 of 14 February 2005 PEAR
Sicily	2019	Summary document of 5 June 2019 PEARS
Sardinia	2015	Regional Council Decision No 48/13 of 2 October 2015 PEAR

In its 2014 PEAR, the **Valle d'Aosta Region** identified a number of energy efficiency and energy conversion efficiency measures for 2020, including the Aosta district heating project (production of 95 GWht of heat per year at the plant entrance, resulting in about 85 GWht/year useful energy for users, if network losses are taken into account, and production of around 30.5 GWhe of electricity to 2020) and the Breuil Cervinia district heating project (production of around 82.7 GWht of heat to 2020 and around 8.3 GWhe of electricity). An increase of 19 MW from thermal plants and a further 8.5 MW from cogeneration plants in the form of medium-sized plants or mini district heating networks has been estimated to 2020, leading to a total thermal energy production from biomass of around 354 GWh/year by 2020.

The **Lombardy Region** participated in the European 'BioEnerGIS' project (concluded at the end of 2011), which aimed to help public and private stakeholders identify the best location for new biomass district heating networks, by matching heat demand with local availability of biomass. The input data for the residential sector relate to annual energy consumption at municipal level, broken down by fuel type and disaggregated into census areas, number of apartments and buildings, the dimensions of an average apartment, and heating rate for energy carriers at municipal level as a proxy. The census area is georeferenced, meaning that the volume of energy demand per census area can be converted into the volume per cell. The census area level has a good spatial resolution: in Lombardy, there are about 49 000 census areas across 1 546 municipalities, with an average population of 200 residents per census area and an average area of 0.488 km^2. The results of the residential sector data analysis show kWh/year per municipality, per census area (estimated) and per fuel (estimated) during the period 2000-2008. The optimum size for maintaining a local supply chain within the Lombardy region is generally between 1 and 10 MW; considering thermal production alone, this results in a potential of almost 130 new biomass plants each with 10 MW of capacity.

According to the estimates provided, if all of the 'sustainable' wood biomass in Lombardy were used, it would be possible to install 1 283 MW (about 10 times the volume of thermal power recorded by district heating plants in Lombardy to 2012) and produce about 320 ktoe, a 6-fold increase in the total amount of energy produced by biomass district heating in 2012 (about 50 ktoe). The PEAR 2020 high- and medium-level scenarios envisage an increase in the efficiency of district heating networks of 120 and 80 ktoe respectively (in the residential and service sectors), while the scenarios relating to renewables penetration and development and biomass for domestic use, district heating and industrial and agricultural uses reach 1 140 ktoe in the high-level 2020 scenario and 806 ktoe in the medium-level one; geothermal power (direct use, district heating) reaches 30 ktoe in the high-level scenario and 13 ktoe in the medium one; renewable waste with district heating use reaches 130 ktoe in the high-level renewables scenario and 110 ktoe in the medium-level one.

In Chapter 11 of its 2020-2030 PEAP, the preliminary document for which was approved by Regional Government Decision No 339 of 5 March 2021, the **Autonomous Province of Trento** evaluated the energy potential of Trento's wood biomass. The analysis considers the availability of wood biomass to 2017, which has been updated to 2020 following the post-vaia action plan and on the basis of forecasts for the next 3 years, the use of existing district heating systems, industry forecasts, and air quality targets. This scenario assumes that the total production of renewable energy from local biomass remains more or less constant, while the distribution of this kind of production, namely between large district heating systems, centralised plants with high nominal capacity and domestic production, is regarded as changeable. The scenario envisages an increase in the use of local forest material for energy conversion in centralised plants with a capacity of more than 500 kW located in areas not served by methane pipelines, optimisation of the use of material in areas served by methane pipelines and those soon to be served by methane pipelines, and the replacement of domestic systems. The Autonomous Province of Trento estimates the current level of district heating biomass consumption (2017) to be 300 000 msr. The PEAP itself reports district heating consumption of 10 ktoe in 2016. Based on actual data collected from production companies, the Autonomous Province of Trento estimates that there will be a surplus of forest chips (net of 2017 district heating demand), including by-products from the wood industry, of about 422 000 msr in 2017. It is noted that the proposed scenario does not foresee a significant increase in the production of – predominantly thermal – energy, and instead focuses on a strategy of, on the one hand, improving air quality and, on the other, enhancing and thus increasing the use of local raw materials, in close conjunction with the plan to extend the methane gas network.

As part of the 2050 energy and climate plan for South Tyrol, approved in 2011 and subject to revision every 5 years, the **Autonomous Province of Bolzano** has planned a further extension of the existing district heating network for the city of Bolzano, with the use of residual heat from the new waste incineration plant. When completed, the district heating network in the South Tyrolean capital will cover more than 20% of the city's heat demand, replacing the equivalent of 22 500 000 litres of diesel. In addition, the heat produced by burning waste will be used in absorption cooling systems for large-scale users, such as the entire Bolzano hospital structure. It is noted that the provincial regulation governing the promotion of district heating is Regional Government Decision No 1382 of 18 December 2018, which approved the criteria for granting contributions to incentivise existing district heating systems. On the other hand, Regional Government Decision No 1176 of 30 December 2019 suspended contributions for extending existing district heating production systems, as referred to in Article 9 of Regional Government Decision No 1382 of 18 December 2018, as amended by Regional Government Decision No 253 of 9 April 2019, and amended the criteria for granting contributions to incentivise existing district heating systems.

Furthermore, several locations have already been identified where geothermal energy can be used from great depths: geothermal energy drawn from the subsoil can be used both to produce electricity and to supply the district heating network. According to the project data, the thermal power would amount to 17 054 kW, while the electrical power produced would be 2 000 kW. Own energy consumption corresponds to 10/12% of electrical power.

In the section 'Potential for energy generation from geothermal sources' of the PEAR approved in 2017, the **Veneto Region**, which has already used 2007-2013 ROP funds to finance a series of measures aimed at extending district heating networks, has, in light of the availability of geothermal sources for direct supply to district heating networks, requested pilot projects; it may be assumed that some district heating networks serving civil users may be installed in the region by 2020 with a capacity of 20 MW, which would involve 1.1 ktoe of renewables. As well as the geothermal source, the supply of wood fuel, and in particular wood chips, should also be taken into account. The production sectors for these fuels have been the subject of a detailed survey regarding potential supply in the PEAR (more than 1 200 000 t/year available according to that survey).

As regards methods for consuming heat from renewables to 2020, the **Tuscany Region**, through the PAER approved by the Regional Council at the beginning of 2015, identifies 29 ktoe for biomass from district heating, 2.2 ktoe for heat pumps combined with district heating and 48.9 ktoe for direct geothermal and/or district heating.

In 2019, the **Piedmont Region** announced that, based on trends in recent years, district heating would contribute approximately 100 Mm^3 to the regional targets set by the Burden Sharing Agreement by 2020, it being understood that these forecasts assume the implementation of specific support measures for developing district heating, related to HE CHP and/or heat generation from renewables.

In the SEAR approved by Regional Council Decision No 205 of 7 November 2017, the **Umbria Region** identifies measures for incentivising cogeneration plants (powered by renewables or methane gas) and district heating/cooling in the service sector, which can be financed through ERDF and EAFRD funds and have the overall aim of reducing consumption.

In order to ensure that 29% of heating and cooling consumption is covered by renewables, the **Region of Emilia-Romagna** intends to support the development of high-efficiency renewable technologies capable of meeting the energy demand for heating and cooling buildings and producing heat for manufacturing. It will be vital to promote high-efficiency cogeneration and the propagation and expansion of renewable and efficient district heating networks that include heat storage systems and are fuelled by bioenergy (with particular reference to hill and mountain areas), especially if these networks are 'active'. i.e. where there are multiple heat production sources spread throughout the region. With regard to housing stock, there were an estimated 2.2 million dwellings occupied by residents in Emilia-Romagna in 2014, 1.7 million of which had independent heating systems. In the vast majority of dwellings (about 1.7 million, or more than 78%), the heating system is fuelled by natural gas, followed by biomass (10%), heat pumps (4.2%), LPG (3.6%), district heating (2.0%) and diesel (1.8%).

In the plan scenario for the **Liguria Region**, district heating plants contribute to attaining the energy efficiency target set in the 2014-2020 PEAR, with a share of 332 ktoe. The PEAR itself (which provides a useful SWOT analysis for each type of renewable, including district heating) lists essential lines of development, including the installation of advanced technological systems such as cogeneration and trigeneration plants and district heating and cooling with the aim of reducing consumption, including using resources available in the 2014-2020 ERDF Structural Funds programme.

In the PER 2015, the **Region of Friuli-Venezia Giulia** sets out regional measures to support district heating networks (establishment of revolving and/or guarantee funds), in line with the 2007-2013 ROP ERDF funds already allocated in previous years. Studies are currently ongoing as to the possibility of building an urban district heating network fuelled by heat recovered from off-gas for the industrial sector, for example in one of the region's steel plants; the company currently recovers heat for a kind of internal district heating and plans to use absorption machines to cool the electrical and control cabins. Furthermore, the main energy sources able to supply district heating networks, such as solar thermal power, heat pumps, biomass, incinerators, industrial heat recovery, etc., are analysed for possible applications in the region. The expected measures also include a target for transforming traditional energy production plants into more sustainable ones (upgrading of distribution networks, smart grids, district heating, storage systems). It is conurbations that are most affected in the civil sector when it comes to converting traditional energy production plants into more sustainable ones (upgrading of distribution networks, smart grids, district heating, storage systems).

Annex 2

Public consultation

When preparing the assessment of the potential for efficient heating, in addition to fruitful dialogue with the **Ministry of Ecological Transition** and discussion and collaboration with **RSE (Ricerca sul Sistema Energetico) S.p.A.**, there were two main opportunities for discussion between GSE, the author of the study, and various stakeholders.

Table 108: Trade associations that took part in the public consultation between September and October 2020

Association	
AICARR	Italian Association for Air Conditioning, Heating and Refrigeration
AIRU	Italian Association for Urban Heating
Anigas	National Association of Gas Industries
ANIGhp ANIPA	National Association for Hydrogeology and Water Wells – Geothermal and Geoexchange Division
ARSE	Association for Emission-Free Heating
Ascomac	National Federation for Machines Trading
Assistal	National Association of Plant Builders, Energy Efficiency Services
Assocarta	Trade association that brings together, represents and protects companies producing paper, cardboard and paper pulp in Italy
Assoclima	Association of Air Conditioning Manufacturers federated to ANIMA Confindustria Meccanica Varia
Assoege	Association of Energy Management Experts
AssoESCO	Italian Association of Energy Service Companies and Energy Efficiency Operators
A2A	A multi-utility operating in the environmental, energy, heat, networks and smart city technologies sectors
Egea Spa	A multi-utility operating in the sectors of electricity production and distribution, district heating services, water systems and other public utilities

Elettricità Futura	An Italian electricity association created as a result of the integration of Assoelettrica and AssoRinnovabili
FIPER	Italian Federation of Renewable Energy Producers
Italcogen-ANIMA Confindustria	An association of manufacturers and distributors of cogeneration plants
Utilitalia	An association of water, energy and environmental companies

Legislative Decree No 73 of 14 July 2020, which entered into force on 29 July 2020, stipulated that, when preparing the report containing the assessment of the national potential for application of HE CHP and of efficient district heating and cooling, GSE should consult the relevant trade associations, including for the purpose of identifying the current obstacles limiting distribution of the efficient technologies in question and collecting proposals on the most effective solutions. GSE has therefore launched a public consultation on its website, inviting trade associations in particular to comment on:

- possible areas, types and conditions for developing high-efficiency cogeneration and other efficient heating and cooling technologies;
- barriers limiting greater propagation of these technologies;
- solutions to overcome these obstacles.

As a result of this, 17 contributions were received from various stakeholders between September and October 2020.

The contributions received focused mainly on the topic of incentive schemes. The main issues raised during the consultation are presented below, split up into HE CHP and district heating.

HE CHP:

- Energy communities: supports the inclusion of HE CHP as a technology eligible for benefits under legislation on energy communities.
- TEE – refurbishments: the minimum limit of 12 years for carrying out refurbishments was deemed detrimental, and several solutions were proposed, such as reducing the limit to 10 years or introducing k coefficients.
- TEE – timing of incentives: the time between a measure being initiated/financed and a WC first being recognised is excessively long, in some cases up to 3-4 years; various possibilities have been proposed, including for example schemes for advance payment/adjustment.
- TEE – value uncertainty: the uncertainty as to the value of TEE, and thus the associated revenue, was criticised, it being proposed that this value should be fixed in advance.
- Cumulation with other incentives: it is argued that it would be useful to have a single regulatory reference as regards the cumulation of the various possible incentives/subsidies, with solutions such as a tax amnesty in the event of errors also being proposed.
- Treating HE CHP in the same manner as renewables or, in any case, a review of ARERA’s approach to allow greater development of private networks.

District heating:

- Issuing of the implementing decree provided for by Law of 4 December 2017 on a special support scheme for efficient district heating systems.
- Efficient district heating: it is proposed that efficient district heating be applied, definitively and unequivocally, as a necessary and sufficient condition for accessing incentives.

- Make provision for support mechanisms/tax credits, including for cold district heating systems where the network operates at a low temperature with a circuit offset by waste heat, geothermal power, solar thermal power or the like to which individual users connect using their own heat pump, by establishing support mechanisms such as access to tax credits.
- 110% 'Superbonus': broaden access to deductions for efficient district heating, including in non-mountainous municipalities with poorer air quality.
- TEE: include efficient district heating fuelled by thermal renewables and waste heat in the scheme. An operating account incentive is proposed, linked to the issuing of WCs as a function of energy savings.
- District heating energy account: it is suggested that a scheme be established for incentivising the construction of plants and networks that allow the transition from an inefficient district heating system configuration to an efficient one.
- Subsidised VAT system for efficient district heating with an optimum target rate of 4%. As a first step, it is considered appropriate to extend the current 10% VAT system to all supplies fed by an efficient district heating network.
- Extension of the tax credit to include efficient district heating in general, whereas it is currently limited to geothermal power and biomass.

These comments have been evaluated and taken into account by the Ministry of Ecological Transition as part of the process to update these schemes.

Subsequently, as the results of the assessment of potential unfolded, a second, more informal discussion was held. As part of this discussion, a summary report and a detailed presentation of the analyses carried out and the emerging results (114 pages long) was sent to the same stakeholders who had taken part in the public consultation and to other – mainly institutional – parties, containing a polite request for comments, even informal ones. The list of these additional stakeholders is provided in the following table.

Table 109: Stakeholders informally asked by GSE for their opinion on the results of the study

Party	
Trade association that took part in the public consultation (previous table)	
Regions	Officials from those regions involved in energy coordination
ARERA	Regulatory Authority for Energy, Networks and Environment
ENEA	National Agency for New Technologies, Energy and Sustainable Economic Development – Energy Efficiency Unit
ISPRA	Higher Institute for Environmental Protection and Research
PoliMi	Polytechnic University of Milan – Energy Department
UGI	Italian Geothermal Union
FIRE	Italian Federation for Rational Energy Use
AIEL	Italian Agro-Forestry Energy Association
FREE	Coordination of Renewables and Energy Efficiency
GIGA	Informal Group for Geothermal Power and the Environment

As part of this second, more informal consultation, which showed a general appreciation of the complex work carried out, careful consideration was given to the comments of those who were willing and able to graciously accept the invitation to provide their opinion.

Some of these comments have already been implemented in the final version of the study. Other comments were also deemed to be valid for other areas of work (for example comments provided by ISPRA, which were useful for establishing additional links between the exploitable potential of biomass and air quality). As regards the other comments (for example those received from some trade associations suggesting further analysis to check whether the technical potential of district heating or geothermal resources — including those with low enthalpy – or other renewable sources or technically conveyable waste heat can be extended even further), in light of the fact that the results obtained after a long and complex cross-analysis are, at present, also supported by the optimisation models used to draft the INECP, any further verifications will be carried out during the upcoming update of the INECP, in consideration of the new drivers and the more challenging targets to be achieved in terms of decarbonisation, which verifications could perhaps reveal, for example, a lower contribution from natural gas for HE CHP supplying district heating and therefore an even greater contribution from thermal renewables for HE CHP and district heating than the one that currently emerges from both the economic-financial analysis and the system modelling analysis.